# Tick size, market quality, and market structure

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February, 2024

**Abstract**

The tick size is the minimum price increment by which securities can be quoted. As such, it determines the granularity of the grid over which securities prices take values and is thus an important driver of trading costs. The magnitude of the tick size affects not only the distribution of trading surplus between liquidity demanders and suppliers, but also market quality, the structure of the trading industry and important aspects of a firm's life such as managerial learning from stock prices, fundamentals information acquisition, and shareholders' monitoring.

*Keywords:* Liquidity provision, tick size.
*JEL Classification Numbers: G10, G12, G14*

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# 1 Executive summary

The tick size is the minimum price increment by which securities can be quoted. As such, it determines the granularity of the grid over which a security's prices take values.[1]

While it may seem a minor aspect of market design, the tick size constitutes an important driver of trading costs. Hence, it affects not only the distribution of trading surplus between liquidity demanders and suppliers (the "buy" and "sell" side), but also traders' willingness to post limit and market orders, the interaction among different market participants, market quality, the structure of the trading industry, and important aspects of corporate activity such as managerial learning from stock prices, investors' fundamental information acquisition decisions, and shareholders' monitoring.

Interestingly, the effect of a change in tick size seems related to the *scope* of its impact. Specifically, regulatory interventions to decrease the tick size at a market wide level have mixed effects on market quality. On the one hand, they have been associated with a consistent reduction in spreads, lowering transactions costs for retail investors. On the other hand, they have also occurred together with a decline in the depth available at the quotes, which instead tends to amplify institutional traders' trading costs, since these traders typically post larger orders. This suggests that a mandated lower tick size creates a tension between the advantages of lower trading costs at the touch, and the disadvantages of potentially higher costs for institutional investors and smaller rewards for liquidity providers.

However, tick size reductions that result from exchanges' competitive decisions, seem to have an overall positive impact on market quality. Indeed in 2007, in the wake of MiFID, a flurry of new venues entered the EU financial industry. The competition for volume that ensued led to a tick size "war" which prompted an improvement in informational efficiency and market quality, increasing market wide depth and volume. This suggests that in the absence of a regulated minimum price variation, the tick size becomes an important strategic variable for trading venues willing to

[1] For instance, if the current best ask for security XYZ is £10 and the corresponding tick size for the secutity is 1p, then a liquidity provider can post a competing sell order with a £9.99 ask, but not one with an ask of £9.999.

compete trading volume away from incumbents, with an overall positive impact on market quality.

Additionally, price discreteness affects the structure of the trading industry. Indeed, it is arguably responsible for the development and thriving of alternative trading venues that subsidise or tax liquidity creation (make/take or take/make venues) or "dark venues" in which orders are crossed at the midquote (which thus allows price improvements that can contravene tick size restrictions). Several authors argue that for a fixed total fee, any change in make or take fees is washed out by an adjustment in the raw spread, implying that changes in fees do not work as an exchange's strategic variable to attract volume. However, such a result hinges on the assumption that prices are continuous variables and does not hold when the tick size is non-null. In this case, exchanges compete for order flow by using make/take fees to vertically differentiate their (otherwise identical) product offering and screen customers. High quality exchanges lower their take fee, which attracts liquidity demanders. In turn liquidity providers with large gains from execution choose such exchanges to lower non-execution risk. Additionally, evidence based on the 2016 US Tick Size Pilot suggests that exchange fee models (and dark venues) attract volume because they permit subpenny price improvements within the spread, and that such effect is strengthened by a tick size widening, especially for tick-constrained stocks.

Finally, a change in tick size is known to have an impact on aspects of a firm's corporate life that are farther removed from the efficiency or liquidity of the secondary market, such as managerial learning from stock prices, shareholder monitoring, and information acquisition.

This helps explaining why the debate around the tick size is invariably very lively among market participants. For instance, in 2016 the SEC launched a Tick Size Pilot to address some of the concerns about how "sweeping changes to US equity market structure since the late 1990s had affected market quality for small-capitalization stocks." The view of many market participants at the time was that the advent of decimalization of price quotations in 2000-2001, in an environment that had already seen the tick size go down from \$1/8 to \$1/16, reduced liquidity providers' incentives to make markets in small stocks, which in turn discouraged small firms from going public. From a practical point of view, the Pilot called for an increase in the tick size to $0.05 for a randomly selected sample of 1,200 small cap stocks, for a 2-year period. The Pilot was largely regarded as a failure, but spurred further debate around how to reform the current two-tiered tick size regime in the US. This eventually led to a new proposal to amend Rule 612, presented in December 2022, to introduce a tick size regime that varies depending on the value of the time weighted average quoted spread of a security.

In the European Union, instead, it is precisely the lack of a regulatory imposed uniform tick size that contributed to create turmoil among different trading venues. Indeed, the absence of such a standard allowed the players that entered the financial industry in the wake of MiFID in 2009, to wage a tick size war against incumbent exchanges to gain market share. The conflict lasted until January 2010 when all the involved parties agreed to harmonise their tick size granularities, accepting a proposal drafted by FESE (Federation of European Stock Exchanges). However, this did not prevent Euronext to eventually announce a further, unilateral revision of the tick size it applied for trading in Dutch and French blue chips shares, in January 2011.[2] The current regulatory framework for stocks traded in the EU is laid out under Article 49 of MiFID II (2018) as implemented by Regulatory Technical Standard 11 (RTS11), which introduces 19 price bands and 6 liquidity classes with tick sizes ranging from 5 to 500 basis points, in a way that the tick size is positively (inversely) related to a stock price (liquidity). The empirical evidence on the impact of MiFID II on market quality aligns with the findings based on the US experience: tick size reductions (increases) lower (augment) quoted and effective spreads and reduce (increase) depth at the quotes. This should benefit retail traders, but has a mixed impact on institutions' trading costs.

[2]See *Euronext sparks outrage with tick size reduction*, Financial Times, January 28, 2011

# Introduction

The tick size is the minimum price increment by which securities can be quoted. As such, it determines the granularity of the grid over which a security's prices take values.[3]

While it may seem a minor aspect of market design, the tick size constitutes an important driver of trading costs. Hence, it affects not only the distribution of trading surplus between liquidity demanders and suppliers (the "buy" and "sell" side), but also traders' willingness to post limit and market orders (Harris (1996), Goettler et al. (2005, 2009)), the interaction among different market participants, market quality (Goldstein and Kavajecz (2000), O'Hara et al. (2018)), the structure of the trading industry (Angel et al. (2010), O'Hara et al. (2018), and Comerton-Forde et al. (2019)), and important aspects of corporate activity such as managerial learning from stock prices (Ye et al. (2023)), investors' fundamental information acquisition decisions (Lee and Watts (2021)), and shareholders' monitoring (Ahmed et al. (2020)).

Interestingly, the effect of a change in tick size seems related to the *scope* of its impact. Specifically, regulatory interventions to decrease the tick size at a market wide level have mixed effects on market quality. On the one hand, they have been associated with a consistent reduction in spreads, lowering transactions costs for retail investors (see, e.g., Chakravarty et al. (2001), Bacidore et al. (2003), and Bessembinder (2003)). On the other hand, they have also occurred together with a decline in the depth available at the quotes, which instead tends to amplify institutional traders' trading costs, since these traders typically post larger orders (Goldstein and Kavajecz (2000) and Jones and Lipson (2001)). This suggests that a mandated lower tick size creates a tension between the advantages of

[3]For instance, if the current best ask for security XYZ is £10 and the corresponding tick size for the secutity is 1p, then a liquidity provider can post a competing sell order with a £9.99 ask, but not one with an ask of £9.999. The unit of reference for the tick size is associated with the financial instrument it refers to. For instance, for stocks it is currency dependent, with ticks expressed as fractions of \$, £, or €. For rates, ticks are typically expressed in basis points and for currencies in "pips," that is 1/10000 of the base currency. Futures markets implement a tick size that changes with the traded instrument. For the E-mini S&P 500 Futures contract, for instance, the tick is set to 1/4 of an index point. Since an index point corresponds to \$50 for the E-mini, this means that a one-tick movement is worth $\$0.25 \times \$50 = \$12.5$ (see CME).

lower trading costs, and the disadvantages of smaller rewards for liquidity providers (Harris (1991, 1996), Cordella and Foucault (1999)).

However, tick size reductions that result from exchanges' competitive decisions, seem to have an overall positive impact on market quality. Indeed in 2007, in the wake of MiFID, a flurry of new venues entered the EU financial industry. The competition for volume that ensued led to a tick size "war" which, according to Foley et al. (2022), prompted an improvement in informational efficiency and market quality, increasing market wide depth and volume (see Section 4.2).

Additionally, price discreteness affects the structure of the trading industry. Indeed, it is arguably responsible for the development and thriving of alternative trading venues that subsidise or tax liquidity creation (make/take or take/make venues) or "dark venues" in which orders are crossed at the midquote (which thus allows price improvements that can contravene tick size restrictions).[4] Angel et al. (2010) and Colliard and Foucault (2012) argue that for a fixed total fee, any change in make or take fees is washed out by an adjustment in the raw spread, implying that changes in fees do not work as an exchange's strategic variable to attract volume. However, such a result hinges on the assumption that prices are continuous variables and does not hold when the tick size is non-null (Fou-

[4]For the US, trading currently takes place in 4 major types of venues, besides lit exchanges. These are exchanges with a maker/taker (or a taker/maker) model, which subsidize liquidity provision and tax liquidity consumption (tax liquidity provision and subsidize liquidity consumption). Off-exchange venues (Alternative Trading Systems–ATSs, Single Dealer Platforms–SDPs) that offer features not available on regulated exchanges, such as counterparty selection or pre-trade opacity. Finally, Principal Dealers, which are intermediaries that execute retail orders at quotes that match or improve the NBBO (see CBOE, *A Deep Dive Into U.S. Equities Trading Venues*). With the advent of competition among trading venues and the fragmentation that ensued, exchanges started competing to attract order flow. They thus adopted a model according to which liquidity provision is subsidised and liquidity consumption is taxed. Such a model is called "make-take," because it supports the "making" of liquidity via standing limit orders, while charging liquidity "taking" via market orders. In recent years, a different market model has arisen in which, instead, liquidity provision is taxed while liquidity consumption is subsidised (see, e.g., BATS-Y, NASDAQ BX and EDGA). Such a model is called "inverted market" or take-make and is likely to attract liquidity provision in tick constrained stocks. Indeed, the subsidisation of liquidity consumption offered by inverted markets increases the chances that a non-marketable limit order receives a fill, speeding up its execution compared to a traditional market. ATSs offer execution without advertising quotes or depth at the quotes, typically at prices that improve upon the NBBO. Differently from ATSs that delegate to a matching engine the execution of orders, SPDs may execute orders upon receipt.

cault et al. (2013)). In this case, exchanges compete for order flow by using make/take fees to vertically differentiate their (otherwise identical) product offering and screen customers. High quality exchanges lower their take fee, which attracts liquidity demanders. In turn liquidity providers with large gains from execution choose such exchanges to lower non-execution risk (Chao et al. (2018)). Additionally, evidence based on the 2016 US Tick Size Pilot (Comerton-Forde et al. (2019), Bartlett and McCrary (2020)) suggests that exchange fee models (and dark venues) attract volume because they permit subpenny price improvements within the spread, and that such effect is strengthened by a tick size widening, especially for tick-constrained stocks.[5]

Finally, a change in tick size is known to have an impact on aspects of a firm's corporate life that are farther removed from the efficiency or liquidity of the secondary market, such as managerial learning from stock prices, shareholder monitoring, and information acquisition. Analyzing the effects of the 2016 Tick Size Pilot (TSP), Ye et al. (2023) find that the sensitivity to stock prices increases for the treated firms, an evidence that is consistent with managers inferring more novel information from companies' stock price movements. Ahmed et al. (2020), look instead at the impact of TSP on firms' financial reporting quality, finding that it overall improves for treated firms. Finally, Lee and Watts (2021) find that fundamentals information acquisition prior to earnings announcements improves for treated stocks.

This helps explaining why the debate around the tick size is invariably very lively among market participants. For instance, in 2016 the SEC launched a Tick Size Pilot to address some of the concerns about how "sweeping changes to US equity market structure since the late 1990s had affected market quality for small-capitalization stocks" (see Section 4.1).[6] The view of many market participants at the time was that the advent of decimalization of price quotations in 2000-2001, in an environment that had already seen the tick size go down from \$1/8 to \$1/16, reduced liq-

[5] Lin et al. (2018) show that trading on dark and inverted venues increases following the 2016 Tick Size Pilot.

[6] Assessment of the Plan to Implement a Tick Size Pilot Program. Originally Submitted to the NMS Plan Participants July 3, 2018. Available at https://www.sec.gov/files/TICK%20PILOT%20ASSESSMENT%20FINAL%20Aug%202.pdf.

uidity providers' incentives to make markets in small stocks, which in turn discouraged small firms from going public.[7] From a practical point of view, the Pilot called for an increase in the tick size to $0.05 for a randomly selected sample of 1,200 small cap stocks, for a 2-year period (IPO Task Force (2011), see Section 4.1).[8] The Pilot was largely regarded as a failure, but spurred further debate around how to reform the current two-tiered tick size regime in the US. This eventually led to a new proposal to amend Rule 612, presented in December 2022, to introduce a tick size regime that varies depending on the value of the time weighted average quoted spread of a security.[9]

In the European Union, instead, it is precisely the lack of a regulatory imposed uniform tick size that contributed to create turmoil among different trading venues. Indeed, the absence of such a standard allowed the players that entered the financial industry in the wake of MiFID in 2009, to wage a tick size war against incumbent exchanges to gain market share (see Section 4.2 and Foley et al. (2022)).[10] The conflict lasted until January 2010 when all the involved parties agreed to harmonise their tick size granularities, accepting a proposal drafted by FESE (Federation of European Stock Exchanges). However, this did not prevent Euronext to eventually announce a further, unilateral revision of the tick size it applied for trading in Dutch and French blue chips shares, in January 2011.[11] The current regulatory framework for stocks traded in the EU is laid out under Article 49 of MiFID II (2018) as implemented by Regulatory Technical Standard 11 (RTS11), which introduces 19 price bands and 6 liquidity classes with tick sizes ranging from 5 to 500 basis points, in a way that the tick size is positively (inversely) related to a stock price (liquidity)–see Section 4.2.

The rest of the paper is organized as follows. The next section reviews the theoretical contributions to the subject, while Section 3 focuses on the

[7]For stocks priced below $0.25 the tick size was set to $1/32.

[8]According to Rule 612, the tick size stands at $0.01 for all stocks priced above of $1 and $0.0001 for stocks priced at less than $1.

[9]See https://www.sec.gov/files/rules/proposed/2022/34-96494.pdf.

[10]"Multilateral trading facilities (MTFs) and exchanges are on the verge of igniting a tick size war that could decrease market efficiency and prove detrimental to investors searching for liquidity in European stocks." *European trading venues risk war over tick sizes*, The trade, June 17, 2009.

[11]See *Euronext sparks outrage with tick size reduction*, Financial Times, January 28, 2011

empirical evidence, zooming in on the impact of tick size variations on market quality, execution speed and trade size, profitability of liquidity supply, order exposure and measure of firms' performance, like managerial learning from stock prices. In Section 4, I review the impact of the debate on tick sizes on regulation both in the US and EU/UK. The final section contains concluding remarks.

# 2 Theoretical contributions

The tick size affects the marginal profit financial intermediaries earn from liquidity supply, because it *limits the extent to which they compete with their quotes*. To see this, consider a liquidity provider acting in a competitive limit order book market. Suppose that it has just absorbed a sell market order at a bid $B_n$ and subsequently posts a sell limit order at a certain higher ask $A_n = B_n + \Delta$, where $\Delta \equiv$ '1 tick' $= B_n - B_{n-1} > 0$, to rebalance its position. Suppose further that $A_n$ is one tick above the current best ask $A_{n-1}$: $A_n = A_{n-1} + \Delta$. The expected profit he nets depends positively (1) on the chance that an incoming buy market order consumes all the liquidity available at $A_{n-1}$ and, provided this occurs, (2) on the magnitude of the tick size $\Delta$. All else equal, a smaller tick size (say a halving of the tick from $\Delta$ to $\Delta/2$), erodes the liquidity provider's expected profits. This is because provided all the liquidity at $A_{n-1}$ is consumed, when the order hits the new best quote $A_n$, the liquidity provider obtains half the profit per share it sells, since $A_n - B_n = \Delta$. Thus, all else equal, a lower tick size reduces the round-trip profits for a liquidity provider, and, correspondingly, reduces the trading costs for liquidity demanders. This discourages (encourages) limit (market) order submission. Conversely, *other things equal*, a larger tick size incentivizes liquidity providers to make a market in a security, while augmenting the cost of trading for investors (Angel (1997)).

Goettler et al. (2005) study the equilibrium of a pure dynamic limit order book market (i.e., in a setup in which liquidity is solely supplied via limit orders, without the intervention of intermediaries). In their setup, traders endogenously decide whether to buy or sell a risky security and whether to supply or consume liquidity (submit a limit order or a market order). That is, decisions to supply or consume liquidity must be consistent with the equilibrium restriction. An important finding of their analysis is that a reduction in tick size benefits (penalizes) market order (limit order) submitters. For a stock with average liquidity, the positive effect on the former tends to offset the negative one of the latter, boosting volume and enhancing overall welfare. Buti et al. (2019) analyze the case where stocks have different liquidity. They show that the market quality impact of a tick size reduction depends on whether a stock is or not "tick-constrained."[12] If that is the case, this yields a decrease in spread and depth at the best quotes. The ultimate effect on volume is negligible, since the reduction in spread encourages traders to consume liquidity, and weakens traders' incentives to submit limit orders at the new best quotes. However, for stocks that are *not* tick-constrained, the decrease in the cost of undercutting further weakens liquidity providers' willingness to submit limit orders, which has a negative impact on volume.

However, a narrower tick size doesn't always lower trading costs for liquidity demanders. Indeed, another effect of a coarser price grid is that of facilitating and speeding up negotiations between interested parties. Harris (1991) argues that stock prices tend to cluster on round fractions and that clustering arises when traders use discrete sets of prices to simplify negotiations. A restricted set of prices reduces the number of possible bid and offer prices that traders can propose, which in turn speeds up convergence of the bargaining process between buyers and sellers. In this respect, a larger tick size reduces the time to trade. Conversely, a smaller tick size lengthens the time needed for the best price to be reached which, if the arrival time of a liquidity consuming order is random, implies that transactions can occur at non-competitive prices and that a zero-tick size never minimizes expected trading costs (Cordella and Foucault (1999)).

If time precedence is enforced in the LOB, the tick size determines how costly it is for a "quote matcher" to gain priority over the existing liquidity offered by extant limit orders in the book (Harris (1994)).[13] Thus, Harris (1994) and Huang and Stoll (1994) point out that besides facilitating orderly trading, a larger tick size gives meaning to the time priority rule

[12] A stock is said to be "tick constrained" when it consistently trades with a spread equal to one tick.

[13] Harris (1994) defines "quote matchers" as traders who "may quote on the same side of the market when they" know that a large size will be displayed.

in the limit order book. Indeed, such rule has little effect in a regime where the tick size is so small (relative to the security price) that liquidity providers can jump the queue with inexpensive price improvements. In this sense a larger tick size affords protection to liquidity suppliers and should therefore favor larger displayed depth (Seppi (1997) and Anshuman and Kalay (1998)).

A finite price grid has also an impact on the industrial organization of trading venues. Foucault and Menkveld (2008) argue that, as time precedence is *not* enforced across different venues, the existence of a finite price grid highlights the positive effect of competition on market quality. Intuitively, if liquidity providers cannot shade their bids to offer infinitesimal price improvements, due to time priority, posting a competitive quote at the top of the book exposes them to the risk of non-execution. In this situation, the possibility to trade in a different venue, avoids the problem of creating "long queues" at the top of the book and offers a viable alternative to channel valuable liquidity supply. Suppose, for instance, that for a liquidity provider in a certain security, two LOBs are available: X and Y. Suppose that currently, the best bid and ask on X are 90 and 90.5, while on Y these are respectively 90 and 91. Posting a limit order to sell with limit price 90.5, in venue X, means that the order will only be executed once the pre-existing best quote has been hit by a (liquidity consuming) market buy order. Conversely, posting the same order in venue Y allows the liquidity provider to "jump the queue" (it faces in venue X), improve the prevailing spread (in venue Y) and increase its chances of getting it executed.[14] The opportunity to jump a queue and speed up execution can, however, have a detrimental effect on liquidity providers' willingness to post limit orders. This is what Buti et al. (2015) find in a model where a lit order book competes with a dark venue that allows queue-jumping and offers the

[14] Based on this insight, Foucault and Menkveld (2008) analyze the 2004 entry of London Stock Exchange's EuroSETs (an electronic limit order book) in the Dutch security market where, at the time, most of the trading activity was concentrated on Euronext. Empirically, entry of EuroSETs is associated with two contrasting effects on market quality. On the positive side, entry leads to an improvement in consolidated depth and a reduction in effective spreads. On the negative side, it leads to a reduction in Euronext's depth, which is consistent with the possibility that those investors who could not connect to the new entrant's book did not share in the benefits of competition.

possibility to trade on a finer price grid.[15]

Since the introduction of RegNMS and MiFID (see further, Section 4), the financial intermediation industry has seen the entry of a considerable number of new players in both the US and the EU. Chao et al. (2018) argue that stock price granularity transforms make/take fees into a strategic variable with which exchanges control liquidity provision. That is, with a finite price grid, exchange operators use the fee structure to compete for order flow, which fosters market fragmentation and the proliferation of different trading venues. This is because when the price is a continuous variable, liquidity providers adjust their quotes to neutralize the total fee (Colliard and Foucault (2012)).[16] In such a context, the fee breakdown has no impact on industry structure, operators only compete for order flow on total fees and a Bertrand equilibrium obtains.[17] However, when prices are chosen over a finite grid, liquidity providers can no longer adjust their quotes to neutralize the effect these have on liquidity takers' choice of venue (Foucault et al. (2013)).[18] Exchanges use make/take fees to vertically differentiate their (otherwise identical) product offering to screen customers. High quality exchanges lower their take fee, which attracts liquidity demanders. In turn liquidity providers with large gains from execution choose them to lower non-execution risk (Chao et al. (2018)).

# 3 Empirical evidence

The empirical evidence has concentrated on two types of analysis. The first has considered the effects of a tick size change on observable measures of

[15] Kwan et al. (2015) document that US dark venues direct order flow away from exchanges by offering the possibility of minimal price improvements.

[16] That is the sum of the fee paid to liquidity providers–the "make" fee–and the one paid by liquidity consumers–the "take" fee.

[17] Suppose for instance that the ask and the bid for a security are given respectively by $A = \$100$, and $B = \$99$, and that the exchange charges a fee $f$ allocating a proportion $\gamma \in (0, 1)$ to liquidity makers. The ask that accounts for the fee (that is, the ask "adjusted" to reflect the make fee) is then $A = \$100 - \gamma f$, while the corresponding bid is $B = \$99 + \gamma f$, yielding a "raw" bid-ask spread of $A - B = \$(1 - 2\gamma f)$. However, the cum-fee bid-ask spread is $A - B + 2\gamma f = \$1$, which makes the fee breakdown irrelevant.

[18] Using the previous example, suppose that $f = \$0.07$, and $\gamma = 0.3$. This yields the following cum-fee ask and bid: $A = \$100 - 0.3 \times 0.07 = \$99.979$ and $B = \$99 + 0.3 \times 0.07 = \$99.021$, implying a raw spread of \$0.958. However, such a spread could not be posted in a regime with a tick size equal to 1¢.

market quality (spreads, depth, institutional trading costs, market volatility, price efficiency), trade size, liquidity providers' profitability, incentives for brokerage analysts to support trading operations, and traders' order exposure decisions, for a *given* structure of the trading industry. The second has provided evidence that the granularity of the price grid as well as changes to it *impact* the development of the trading industry.

Additionally, the bulk of the analysis is focused on the US experience, concentrating on three sets of events: (1) the tick size reduction from \$1/8 to \$1/16 that occurred on the NYSE in 1997; (2) the "decimalization" (that is, the reduction from fractional to decimal pricing–\$1/16 to \$1/100) that was implemented via rule 612 by the SEC in 2005; (3) the 2016 SEC Tick Size Pilot and proposals for a new tick size regime that originated from the debate spurred by the Pilot. Some papers also look at the effect of changes in the tick size in different jurisdictions: the introduction of decimalization in the Toronto Stock Exchange in 1996 (Ahn et al. (1998), Bacidore (1997), and Porter and Weaver (1997)); the impact of the tick size on order exposure decisions using data from the Paris Bourse (Harris (1996)); the tick size reduction implemented by the Australian Stock Exchange for stocks price above (below) \$A10 (\$A0.50) in 1995 (Aitken and Comerton-Forde (2005)); the tick size reduction implemented by the Singapore Stock Exchange for stocks priced above \$25 in 1994 (Lau and McInish (1995)); the effects of the tick size war that erupted among EU venues in the wake of MiFID in 2009 (Foley et al. (2022)) as well as the effects of the new tick size regime introduced in the EU by MiFID II in 2018 (Boyde et al. (2018) and Favaretto et al. (2023)).

## 3.1 Liquidity and trading costs

Liquidity is a multidimensional concept that captures the extent to which an order can be executed within a short time frame without causing large price deviations from consensus.

A number of studies based on US data document that a mandated, market-wide *smaller tick size reduces quoted and effective spreads.*[19] Specif-

[19] In 2005, faced with a proliferation of trading venues where the same stock could be exchanged, the SEC promulgated the so-called RegNMS (Regulation National Market System). One of the objectives of such regulation was to ensure that investors received

ically, analyzing the tick size change from \$1/8 to \$1/16 implemented by the NYSE in 1997, Goldstein and Kavajecz (2000) find that that this leads to a decline in quoted spreads of 14.3% on average. Similarly, looking at the effect of decimalization, Chakravarty et al. (2001), Bacidore et al. (2003), and Bessembinder (2003) all find that it lowers both quoted and effective spreads, documenting a stronger effect for smaller transactions.

These effects, however, do not hold across the entire market capitalization spectrum. Bessembinder (2003) breaks down the effect of decimalization for large, mid and small market cap stocks, using a matched sample of 300 NYSE and 300 NASDAQ stocks. Equally weighted average quoted and effective spreads decline for both large and mid cap NYSE and NASDAQ stocks, but the decline for the small cap tranche on NASDAQ is not statistically significant.

A number of authors find that a smaller tick size has a negative impact on depth. This effect is documented for the NYSE tick size reduction from \$1/8 to \$1/16 by Goldstein and Kavajecz (2000), relying on proprietary data provided by the exchange. Indeed, these authors find that the tick size reduction is responsible for a decline in cumulative depth on the limit order book for limit order prices up to half a dollar away from the best quotes. Additionally, Chakravarty et al. (2001) and Bessembinder (2003) also find that decimalization resulted in a lower quoted depth. However Bacidore et al. (2003), document that the cumulative depth available within 15¢ of the best quote midpoint was not affected by decimalization. Additionally, while displayed depth deteriorated for orders standing more than 15¢ away from the best midquote, Bacidore et al. (2003) find that overall execution

the "best price" available anywhere in the US market for their orders. This led to the introduction of the NBBO, that is the National Best Bid and Offer price.

The quoted spread is the difference between the national best offer and the national best bid quoted for a certain stock. While this measures the cost of a round trip transaction at the touch, few transaction occur at the top of the book and only a fraction of the overall trading volume executes against the limit order book (in 1999, only 1/4 of total NYSE volume according to Jones and Lipson (2001)). Thus, a more realistic definition of the cost of trading for orders that exceed the liquidity available at the top of the book is that of the "effective spread," which measures twice the difference between the midpoint of the quoted spread and the price effectively paid in a transaction at a certain point in time. Since such price and the corresponding midquote are likely to differ, the effective spread measures the "price impact" or "slippage" induced by a transaction. The depth available at a certain quote corresponds to the total number of shares available a those quotes.

quality did not change.

Using spreads as a measure of trading costs to assess the execution performance of a large order is typically unsatisfactory.[20] This is because an institution's order is larger by nature and as a consequence takes time to fill. Alternatively, the order could be broken down into a sequence of child orders to ease its impact on the market. In any case, this means that information about a large order is likely to leak to the market during the order execution, which in turn can lead quotes to move during the time needed to complete the order (e.g., with bids increasing as a long position is established), impacting the order's trading cost. To bypass this shortcoming, Jones and Lipson (2001) and Eaton et al. (2021) assess the effect of tick size reductions relying on proprietary data of institutional investors' transactions that relate to two different tick size reduction episodes. Specifically, Jones and Lipson (2001) look at the NYSE tick size reduction from \$1/8 to \$1/16, while Eaton et al. (2021) zoom in on decimalization.

Jones and Lipson (2001) gauge institutional trading costs for trades occurring within 100 days of the NYSE implemented switch to sixteenths. With this data, they measure the volume-weighted average execution price reported by a broker. They then define the "implementation cost" as the difference between the volume-weighted average execution price of trades executed as part of the order, and the price prevailing at the time the institution released the order to its trading desk. Their findings paint a mixed picture of the impact of tick size reduction. Indeed, for institutional orders of less than 1,000 shares (that is, small ones), trading costs decline; and for medium sized orders of 1,000 to 9,999 shares they're essentially unaffected by the tick size reduction. However, for all other types of orders, Jones and Lipson (2001) find that liquidity demanders pay more under sixteenths.[21]

[20] Eaton et al. (2021), for instance, show that typical measures of liquidity (such as quoted and effective spread, the Roll measure, Amihud illiquidity) display very low correlation with a measure of institutional trades' price impact akin to Perold (1988) "implementation shortfall."

[21] More specifically, institutional orders that are at least 100,000 shares cost one-third more to execute after the change. Furthermore, execution costs are larger the more impatient traders are. They are over 50% higher under sixteenths for orders executed in a single day by a single broker. Such orders typically demand more liquidity, since the institution in this case is not willing to execute the order over multiple days or engage multiple brokers.

Eaton et al. (2021) use a proprietary data sample of institutional orders straddling the advent of decimalization in the US to obtain a measure of institutional trading cost which reflects the price impact of institutions' large orders. They then show that such measure is poorly correlated with traditional measures of liquidity (quoted and effective spread, Amihud illiquidity ratio, ...they report that such correlations range from $-0.013$ to 0.068). This suggests that any analysis using trade-level data to evaluate the impact of tick size changes on the performance of institutional trades is unlikely to produce reliable results. Indeed, they find that decimalization had little impact on institutions' trading costs, which questions the results of research that identifies tick size reductions with an increase in institutional liquidity.

Aitken and Comerton-Forde (2005) and Lau and McInish (1995) provide evidence of the impact of a tick size reduction in jurisdictions different from the US. Aitken and Comerton-Forde (2005), analyze the liquidity impact of the 1995 tick size reduction that took place for stocks priced below $A0.50 and above $A10 in the Australian Stock Exchange. Their results confirm the findings obtained by the empirical analysis based on US data for low priced stocks. Indeed, the tick size reduction leads to a decrease in bid-ask spreads and depths at the quotes for stocks priced below $A0.50. However, the finding for stocks priced above $A10 is more puzzling. In this group, low volume stocks exhibited increased spreads and decreased depths. Conversely, high volume stocks reacted with an increase in liquidity to the tick size reduction. Lau and McInish (1995) analyze the effects of the tick size reduction introduced by the Stock Exchange of Singapore in 1994, and find that this has led to a reduction in spreads, with a stronger effect for stocks displaying "tick-constrained" spreads, accompanied by a reduction in depth at the quotes.

Other authors study the effect of a change in the *relative tick size*, that is the value of the tick divided by the price of the stock. The interest for this measure derives from the fact that transactions costs for institutions are often measured as the product between the value of the transaction and the relative effective spread, which is driven by the relative tick size. O'Hara et al. (2018) using data from the NYSE that allows to observe the order flow of different categories of market participants, find that the impact of a larger relative tick size depends on whether a stock's bid-ask spread is or not tick-constrained. Such environment is particularly interesting, since in the presence of a single tick spread, liquidity providers can no longer compete by undercutting quotes and a larger relative tick size leads to larger depth being supplied at the best quotes.[22] Conversely, in an environment where the spread contains multiple ticks, undercutting is possible, and the effect of a larger relative tick size depends on the nature of the trader performing the undercutting. When undercutting proceeds from uninformed traders, spreads narrow and liquidity improves. When, however undercutting is done by informed traders, since it imposes adverse selection on other liquidity suppliers, it may lower the willingness to provide liquidity.

## 3.2 Execution speed and trade size

The findings that depth at the quotes declines when the tick size is reduced (Goldstein and Kavajecz (2000), Chakravarty et al. (2001), Bessembinder (2003), and Bacidore et al. (2003)) suggests that institutional orders (that are on average larger) may take longer to fill and/or that institutions may reduce the size of their trades to cater to the reduced liquidity available in the book. Chakravarty et al. (2005) find that after decimalization institutional orders do take longer to fill, while Werner (2003) finds that institutional orders take longer to work after decimalization. Related to trade size, Bacidore et al. (2003) find that investors tend to submit smaller sized limit orders after decimalization, thereby limiting the liquidity supplied at any given quote. Chakravarty et al. (2001) and Chakravarty et al. (2005), respectively find that with decimalization, overall transaction sizes fall and the order size of institutions declines.

## 3.3 Profitability of liquidity supply

A central concern behind the SEC's decision to launch the TSP in 2016 was that decimalization reduced the profitability of liquidity supply in secondary markets, thereby creating an environment that discouraged the go-

[22] This evidence is also found for tick constrained stocks trading on Nasdaq (see Nasdaq (2019)).

ing public decision of small firms (IPO Task Force (2011)). However, a tick size reduction has two contrasting effects on the profitability of liquidity supply. On the one hand, as we explained above, insofar as it reduces the cost of a turnaround trade, it lowers the profit liquidity providers obtain from offering trading services, and thus discourages liquidity provision. On the other hand, as a smaller minimum price increment allows liquidity providers to gain precedence at a lower cost, it may encourage market makers' participation and boost their profit.

Indeed, Edwards and Harris (2003) find that decimalization has encouraged the practice of stepping ahead of the book with minimal price improvements. Coughenour and Harris (2004) also find that decimalization has encouraged market makers' participation in the NYSE for stocks of all sizes. However these authors find that decimalization did not substantially affect liquidity providers' profits. However, looking at the evidence arising from the TSP, Bartlett and McCrary (2020) find that realized spreads decline very fast within the initial microsecond of a trade for the treated stocks in the sample. They attribute this evidence to the action of strategic High Frequency liquidity providers, casting doubt on the ability of a regulatory imposed larger tick to spur liquidity provision in secondary markets via a profitability increase.[23]

## 3.4 Order exposure

The public exposure of limit orders is crucial for the success of a market. Indeed, in the absence of standing limit orders a market becomes illiquid. However, order exposure subjects a trader to the risk of front-running. This is because by posting a limit order to buy at a bid $B_n$ in a stock, a trader is exposed to the risk that a quote matcher with knowledge of this impending order, can try and acquire shares in the stock and (1) either take advantage of the stock price increase that may occur once the initial order is displayed to the market or (2) if the stock price falls, sell them at $B_n$ to the trader who initially submitted the order. Either way, as a result of front-running, the party who initially submitted the order is likely to

[23]See Section 4.1. The realized spread is a measure of the marginal profit earned by a liquidity supplier.

pay *more* for execution. Exchanges have different ways to contain this risk and encourage order display. First, assuming that a time-precedence rule is enforced in the LOB, an exchange can reduce the risk of front running by implementing a *larger* tick size. This is because to gain execution priority, the quote matcher may need to step ahead of the initial order, and a wider tick makes this more expensive. Additionally, to limit the potential losses due to front running, exchanges can allow traders to partially display the size of the orders they submit to the market.

Harris (1996) analyzes data from the Toronto Stock Exchange (TSE) and the Paris Bourse, to investigate the effect of the tick size on the decision of market participants to display their limit orders. In 1995, both the Paris Bourse and the TSE implemented a tick size schedule that depended on a stock's price, with smaller (larger) ticks associated to cheaper (more expensive) stocks. He then goes on to establish that for both the Paris Bourse and the TSE, the percentage of orders that did not fully disclose the remaining size was inversely related to the relative tick size (that is, the ratio of the tick to the stock price) and that traders allowed their limit order to stand for longer and cancelled them less often with a larger relative tick size. In a similar spirit, Bacidore et al. (2003) provide evidence that limit order traders in the NYSE reduce the size of their orders and cancel their orders more frequently with decimalization. Finally, O'Hara et al. (2018), looking at the effect of the 2016 Tick Size Pilot, document a similar effect for stocks trading on the NYSE, where a larger relative tick size is associated with High Frequency Market Makers leaving limit orders in the book for longer.

## 3.5 Informational efficiency

The Efficient Market Hypothesis (EMH) posits that price changes are due to the arrival of new information and should follow a random walk (Fama (1970)), thus ruling out the systematic predictability of returns. Chordia et al. (2008) relate informational efficiency to the horizon over which the estimation is conducted and show that (midquote) intraday return predictability from order flows has declined in the period 1993-2002. Specifically, Chordia et al. (2008) find that price efficiency improves when the tick size in the US market is lowered from \$1/8 to \$1/16 and from \$1/16 to \$1/100, and suggest that this result may be due to the fact that the higher liquidity facilitated by the tick size reduction spurs the activity of arbitrageurs, as it allows "agents to trade on smaller pieces of information." Albuquerque et al. (2020) provide similar evidence analyzing the effects of the 2016 Tick Size Pilot. These authors find that the treated stocks in the Pilot experience a larger pricing error and a slower market response speed to company-related news, both of which are consistent with a decrease in price efficiency.

### 3.6 Corporate finance

While the bulk of the literature has concentrated its attention on the quality of secondary markets implications of tick size changes, the previous section suggests that a change in tick size could also impact the learning ability from stock prices, or the quality of a firm's financial reporting.

Indeed, analyzing the effects of the 2016 Tick Size Pilot (TSP), Ye et al. (2023) find that the sensitivity to stock prices increases for the treated firms, an evidence that is consistent with managers inferring more novel information from companies' stock price movements. Ahmed et al. (2020), look instead at the impact of TSP on firms' financial reporting quality, finding that it overall improves for treated firms. Finally, Lee and Watts (2021) document that the pre-earnings announcements' stock returns of treated firms are a better signal of the following quarter standardized unexpected earnings, concluding that a wider tick size spurs investors' fundamental information acquisition decisions.

## 4 Implications for regulation

### 4.1 The US experience

Over the past thirty years, the US has experienced two tick size regime changes: from \$1/8 to \$1/16 in July 1997, and from \$1/16 to \$1/100 in January 2001 for all stocks priced at or above \$1 (with a smaller tick of

$0.0001 for stocks priced below $1).[24] In both cases, (average effective) spreads have sensibly declined (see Figure 1).[25]

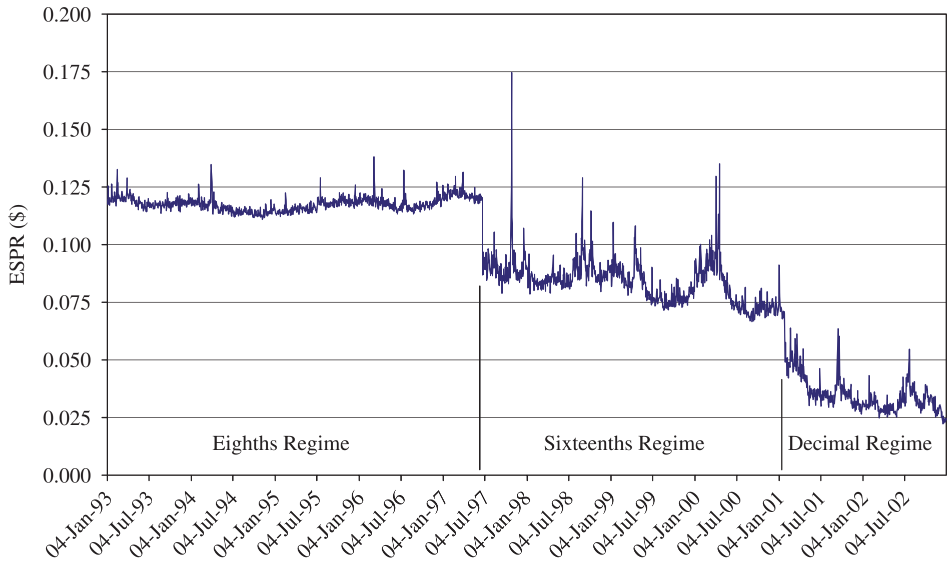


Figure 1: Value-weighted daily average effective spreads for NYSE stocks from January 1993 to July 2002 (see Chordia et al. (2008)).

Prior to the demutualization wave of the late 1990s and 2000s (see, e.g. Hart and Moore (1996)), exchanges were member-owned companies, and implemented rules that maximized the welfare of their owners. A case in point is the choice of the $1/8 tick size which benefited NYSE's specialists and NASDAQ's dealers.[26] Through regulatory pressures and political intervention, the tick size was thus lowered to $1/16 and eventually

[24] SEC Rule 612, which disciplines the tick size in the US, prohibits brokers from accepting and displaying orders that do not conform with the prescribed tick size provision. However, sub-penny execution can take place. This is for instance the case of orders routed to a dark venue that execute at the midquote, or orders matched at make/take or take/make venues (Harris (2013)). Also, trades where prices are set according to a formula such as VWAP can result in sub-penny execution.

[25] The "sixteenth" regime allowed for a larger tick of $1/8 for thinly traded stocks and a smaller one of $1/32 for more liquid ones.

[26] "The Division believes that the current pricing system for stocks needs revision. The markets set the minimum variation permissible for bids and offers at one-eighth ($0.125). The minimum variation can cause artificially wide spreads and hinder quote competition by preventing offers to buy or sell at prices inside the prevailing quote." (see SEC (1994)). Additionally, a 1996 SEC investigation found that NASDAQ dealers colluded over the posted bid and ask quotes to the detriment of the exchange's customers (see https://www.sec.gov/litigation/investreport/nasdaq21a.htm).

to \$1/100. In the wake of the GFC, this eventually opened the door to a debate on the potential impact of decimalization on US firms' incentives to go public (IPO Task Force (2011)). The idea was that the lower profitability of liquidity supply had weakened the incentives to make markets for small cap stocks. This led to an investigation around the benefits of instituting a wider tick size. The study that followed, however, advised against raising the tick size, based on the consideration that the extent to which markets had evolved since the transition to decimal pricing made it hard to pin the IPO decline to a specific aspect of market organization (SEC (2012)).[27] It instead suggested the SEC to take "additional steps" to better understand whether an increase in the tick size would possibly achieve the desired result of enhancing liquidity for small cap companies in the new market environment. This eventually led to the implementation of the 2016 SEC Tick Size Pilot, which tested the market quality impact of two changes to market organization on about 1,200 randomly selected small cap stocks (with market cap of \$3 billion or less): (1) a tick size increase to \$0.05 and (2) the implementation of a "trade-at" prohibition at a national level.[28]

Rindi and Werner (2019) analyze the results of the Pilot, and conclude that for treated stocks the larger tick size considerably increased the cost for retail-sized liquidity demanding orders (by almost fifty percent), while raising the profits of liquidity providers.[29] Most of the effect occurred for tick-constrained stocks, whereas trading costs for unconstrained stocks declined by more than ten percent. Chung et al. (2020) also find that small orders face higher costs, but that liquidity for large orders (cumulative depth and price impact of multiple trades) and price efficiency improve after the pilot. In contrast to one of the Pilot's main objectives (that is, that of increasing the profitability of liquidity provision), Bartlett and McCrary (2020) document that realized spreads decline very fast within

[27] Arguably, decimalization is only one of four major changes that have reshaped the structure of the intermediation industry, the remaining three being: the move of trading from floors to screens; the introduction of RegATS and RegNMS; the growing share of volume intermediated by HFT and Dark Pools.

[28] The experiment lasted for a period of two years. The expression "trade-at" refers to the possibility offered by a venue to trade at the NBBO without having a displayed quote or order at that price.

[29] Rindi and Werner (2019) note that dealers' daily profits increase by approximately 40%.

the initial microsecond of a trade. They attribute this evidence to HFT market makers' ability to quickly adjust their quotes, reacting to changes in market conditions (as in Aït-Sahalia and Sağlam (2023)). Suppose that the best quote for a security is $B_n = \$10.00$, and $A_n = \$10.10$. A dealer receiving an incoming buy could fill the order at the ask, selling the security short, and then attempt to capture the spread by hitting the market bid, to pocket the \$0.10 difference. However, a strategic HFT that monitors the market may adjust the bid up, forcing the dealer to correspondingly revise upwards the price it pays to cover the short. Such effect is arguably more severe when the tick size is widened. For example, the five fold increase to \$0.05 implemented by the Tick Size Pilot compromises even more the dealer's ability to capture the spread, as the revised quote would now be $B_{n+1} = \$10.05$.[30] Nasdaq (2019) concludes that "the Tick Size Pilot is widely considered a failure," based on the estimate that it could cost investors more than \$300 million.[31]

The Tick Size Pilot however spurred a debate centered on ways to improve the functioning of the US stock market. In a recent report, Nasdaq (2019) provides evidence that the two-tiered tick structure implemented by Rule 612 leads many low priced stocks to be tick constrained (which implies that long quotation queues form at the best quotes–a similar evidence for NYSE stocks is presented by O'Hara et al. (2018)).[32] Conversely, high priced stocks tend to trade at large multiple of the tick size, which widens the spread.

Both effects may have a negative impact on market quality. When stocks trade at single tick spreads, ticks are "too wide" compared to stock prices and there's no room for price improvement. As we have seen above, in this case the evidence suggests that the existence of a tick constraint leads investors to direct their orders to exchanges implementing a fee-structure which enable sub-tick trading and allow them to gain price priority (see also Angel et al. (2010)). When ticks are "too narrow" compared to stock

[30] This could be further complicated by price-time priority rules that can favour the creation of long queues at the new best bid $B_{n+1} = \$10.05$, inducing a migration of liquidity provision towards inverted or dark venues.

[31] See https://www.pragmatrading.com/2018/secs-tick-size-pilot-will-cost-investors-300-million/.

[32] On the effect of the tick constraint on quotation sizes, see also Harris (2013).

prices, outbidding becomes relatively inexpensive, which discourages passive liquidity provision, and ultimately reduces quote competition. However, Comerton-Forde et al. (2019), exploiting the results of the Tick Size Pilot, find that order flow migration to inverted markets improves price efficiency for tick-constrained stocks.[33] Specifically, they suggest that this happens because such venues allow trades to occur with sub-tick price improvements, which enables prices to reflect additional information.

## 4.2 The EU and UK experience

The evolution of market structure in the EU (and the UK, which has left the EU since the 2016 Referendum), differs in some aspects from the one of the US. Importantly, competition among trading venues was introduced by the first EU directive that regulated financial services only in 2007. Thus, compared to the US, the EU has only recently come to implement free market concepts that are naturally conducive to the idea of competition in the supply of financial services.[34] In this spirit, the Market in Financial Instruments Directive (MiFID), scrapped the "concentration rule," a provision according to which investment firms were required to route their orders to Regulated Markets (RMs–the *national* incumbents in each European country) only, and allowed the entry of two new type of trading venue: "Multilateral Trading Facilities" (MTFs), and "Systematic Internalizers" (SIs).[35] The former are akin to Alternative Trading Systems in the US. According to Article 4(15) of MiFID an MTF is a venue that is "[...] operated by an investment firm or a market operator [...]" and "[...] which brings together multiple third-party buying and selling interests in financial instruments – in the system and in accordance with non-discretionary rules – in a way that results in a contract."[36] The latter, are "investment firms which, on an organized, frequent and systematic basis, deal(s) on own account by executing client orders outside a RM or an MTF" (Article

[33]See also Chart 5 in Nasdaq (2019).

[34]In the US, execution away from primary exchanges starts happening in the late 1960s, fuelled by institutional traders' need to lower transactions costs (Harman (1978)).

[35]See Fioravanti and Gentile (2011).

[36]The first MTF to enter the European market was Chi-X in 2007, followed by BATS Europe and Turquoise in 2008. In February 2011, BATS agreed to acquire Chi-X. In 2017 BATS was acquired by Cboe Global Markets.

4(7) of the directive). Additionally, in the US since the creation of the National Market System, a "consolidated tape" reports latest price and volume data on sales of exchange-listed stocks taking place on the different trading venues part of the National Market System (Harman (1978)). Such a vehicle of information aggregation and information transmission is currently not available in the EU or the UK.[37]

After the enactment of MiFID, the new entrants initially offered the opportunity to trade the blue-chip index stocks that were available at RMs, adopting the same price grid. However, in the summer of 2009, thanks to the absence of a regulatory imposed uniform tick size, an all out price war broke out to steer volume away from RMs. Indeed, the three largest MTFs (BATS, Chi-X and Turquoise) lowered their tick sizes, compared to the ones implemented by their primary exchanges direct competitors.[38] This so-called "tick size war" (Foley et al. (2022)), led some MTFs to considerably increase the granularity of their price grids. For instance, the Oslo Stock Exchange at the time implemented a price grid with three tick sizes ranging from NOK 0.01 to NOK 1, with a classification criterion that encompassed a stock liquidity and its index inclusion. On 1 June 2009, Chi-X aggressively lowered its tick size to NOK 0.001 for all shares priced less than NOK 10 and NOK 0.005 for all the others. BATS and Turquoise followed suit, with similar, albeit less aggressive, reductions. Incumbent exchanges quickly retaliated, adjusting their price grids. By the end of January 2010, the market eventually reached a new equilibrium brokered by FESE (Federation of European Securities Exchanges), which introduced a uniform tick size regime based on share prices. The thrust of FESE's argument at the time was that the price war was not in the interest of the venues nor of the investors.

Foley et al. (2022) analyze the impact of the tick size war of 2009 and find that the venues that lowered their tick size (i) gained market share from rivals that kept a coarser price schedule and (ii) attracted liquidity supply from dealers that were particularly enticed by the low tick size which induced competition to quote best prices. Additionally, Foley et al.

[37]In 2023, European and UK exchanges have pledged to set up a similar system (see *European bourses want to offer pan-EU share price feed to investors*).

[38]That is, the London Stock Exchange, Copenhagen Stock Exchange, Oslo Stock Exchange, and Stockholm Stock Exchange.

(2022) find that the market wide effect of the war is a reduction in transactions costs and an increase in total quoted order book depth, total traded volume, and informational efficiency. This improved market quality, with the strongest effects occurring for stocks that prior to the price war were tick-constrained.

Since 1 January 2018, the regulatory regime in the EU harmonizes the tick size tables adopted by different venues for equities and certain equity-like instruments (that is, depositary receipts and exchange-traded funds). Specifically, article 49 of MiFID II assigns a certain tick size to a security based on two criteria: (1) the security's price band and (2) the security's liquidity band (measured in terms of the Average Daily Number of Transactions (ADNT) for the stock in the most liquid lit EU market), in a way that the tick size is positively (inversely) related to a security price (liquidity)–see Table 1.[39]

Boyde et al. (2018) and Favaretto et al. (2023) analyze the market quality impact of the tick size regime introduced by MiFID II. Due to the nature of the introduced regulation, post MiFID II stocks fall into one of three distinct buckets: stocks that experience a tick size *decrease*, stocks that experience a tick size *increase* and stocks experiencing *no change* in tick size. Boyde et al. (2018) present evidence of market quality indicators impact for stocks in major indices (FTSE100, DAX30, STOXX50) traded in lit markets, comparing results in the last quarter of 2017 with those in the first month of 2018. Spreads and depth at the touch decline (increase) for stocks experiencing a tick size reduction (increase). However, for stocks belonging to the last bucket, the picture is mixed. No material change happens for stocks in the DAX30 and STOXX50, whereas for the 50 stocks in the FTSE100 that experienced no tick size change, spreads and depth still decline. The distribution of depth at the quotes is also affected by the regulatory change: depth moves away from the touch towards price levels deeper in the book for stocks in the first bucket, while it concentrates closer to the touch for those in the second bucket. Favaretto et al. (2023) use London Stock Exchange data from 9 October 2017 to 26 March 2018 to investigate the impact of MiFID II on liquidity. Their evidence is consistent

[39] Thus, the transactions that occur OTC or in dark venues do not contribute to the calculation of a stock's ADNT.

with Boyde et al. (2018) for the spreads of stocks in the first two buckets. They also find that the cost of trading for stocks in the first (second) bucket declines (increases) post MiFID II. Overall, these results align with the evidence on the effects of decimalization and those of the Tick Size Pilot (see Section 4.1).

For the UK, the Onshored Regulatory Standard 11 establishes the provision for tick size requirements implemented by trading venues for financial instruments (shares, depositary receipts and ETFs), implementing the prescriptions of MiFID II Article 49. Consistently with the approach outlined above, the tick size depends (i) positively on the instrument price and (ii) negatively on its liquidity, as measured by the instrument's average daily number of transactions on the venue exhibiting the highest turnover within the UK.[40]

| | **Liquidity bands** | | | | | |
|---|---|---|---|---|---|---|
| **Price ranges** | **0 ≤ Average daily number of transactions < 10** | **10 ≤ Average daily number of transactions < 80** | **80 ≤ Average daily number of transactions < 600** | **600 ≤ Average daily number of transactions < 2000** | **2000 ≤ Average daily number of transactions < 9000** | **9000 ≤ Average daily number of transactions** |
| **0 ≤ price < 0.1** | 0.0005 | 0.0002 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| **0.1 ≤ price < 0.2** | 0.001 | 0.0005 | 0.0002 | 0.0001 | 0.0001 | 0.0001 |
| **0.2 ≤ price < 0.5** | 0.002 | 0.001 | 0.0005 | 0.0002 | 0.0001 | 0.0001 |
| **0.5 ≤ price < 1** | 0.005 | 0.002 | 0.001 | 0.0005 | 0.0002 | 0.0001 |
| **1 ≤ price < 2** | 0.01 | 0.005 | 0.002 | 0.001 | 0.0005 | 0.0002 |
| **2 ≤ price < 5** | 0.02 | 0.01 | 0.005 | 0.002 | 0.001 | 0.0005 |
| **5 ≤ price < 10** | 0.05 | 0.02 | 0.01 | 0.005 | 0.002 | 0.001 |
| **10 ≤ price < 20** | 0.1 | 0.05 | 0.02 | 0.01 | 0.005 | 0.002 |
| **20 ≤ price < 50** | 0.2 | 0.1 | 0.05 | 0.02 | 0.01 | 0.005 |
| **50 ≤ price < 100** | 0.5 | 0.2 | 0.1 | 0.05 | 0.02 | 0.01 |
| **100 ≤ price < 200** | 1 | 0.5 | 0.2 | 0.1 | 0.05 | 0.02 |
| **200 ≤ price < 500** | 2 | 1 | 0.5 | 0.2 | 0.1 | 0.05 |
| **500 ≤ price < 1000** | 5 | 2 | 1 | 0.5 | 0.2 | 0.1 |
| **1000 ≤ price < 2000** | 10 | 5 | 2 | 1 | 0.5 | 0.2 |
| **2000 ≤ price < 5000** | 20 | 10 | 5 | 2 | 1 | 0.5 |
| **5000 ≤ price < 10000** | 50 | 20 | 10 | 5 | 2 | 1 |
| **10000 ≤ price < 20000** | 100 | 50 | 20 | 10 | 5 | 2 |
| **20000 ≤ price < 50000** | 200 | 100 | 50 | 20 | 10 | 5 |
| **50000 ≤ price** | 500 | 200 | 100 | 50 | 20 | 10 |

Table 1: The tick size table implemented by MiFID II, Article 49 (source European Commission.)

[40]To avoid the possibility that a financial instrument trades at a disadvantageous tick due to its most liquid venue being located outside of the UK, the FCA has proposed to allow trading venues to use the "tick size applicable in the relevant primary market located outside the UK," [...] "when that tick size is smaller than the one determined based on calculations using data from UK venues" (see FCA (2022)). Such a regulatory change have been introduced in May 2023 (see FCA (2023)).

## 5 Concluding remarks

The standard approach to asset pricing theory assumes that security prices are continuous variables (see, e.g., Cochrane (2005)). However, far from being frictionless, actual trading takes place in a setup where prices are defined over a grid. In this survey, we have seen that such a market friction has important implications not only for the quality of the market but also for the industrial organization of the trading industry and for corners of the financial industry that are further removed from trading.

The evidence surveyed suggests that a smaller tick size intensifies competition among liquidity providers, which lowers the spread at the touch, thereby reducing transactions costs for (small) marketable orders. Additionally, a more granular price schedule improves arbitrageurs' ability to take advantage of mispricings, transferring liquidity across securities, and improving price efficiency. Smaller ticks, however, increase the number of available price points, which makes liquidity spread among a larger number of price quotes. This may lower the depth available at each price point and, possibly, increase the number of order revisions needed to realize a trade, augmenting the volume of market data, potentially inflating information processing costs. A larger tick size, on the other hand, favors the consolidation of liquidity over a smaller number of price points, enhancing price stability and strengthening the time dimension of the price-time order precedence rule in a limit order book. However, it lowers the ability of market participants to improve prices, which can lead to wider spreads. This, in turn, increases transactions costs for (especially small) marketable orders, discourages liquidity provision from traders that cannot afford to cross the spread, and favors the diversion of order flow towards venues that allow sub-tick price improvement (dark venues, venues offering/imposing rebates/taxes to liquidity providers/consumers). Larger ticks are favored by market makers, because, other things equal they increase the marginal profit they earn on each trade.[41] Also, smaller brokers that do not have access to the technological infrastructure to navigate complex markets (e.g., smart order routers) tend to favor larger ticks. Conversely, smaller ticks

[41] But the controversial results of the 2016 US Tick Size Pilot in this respect represent a powerful warning against dismissing the importance of the forces that contribute to shape the industry–see Section 4.1.

favor retail traders (and brokers), since these tend to consume liquidity at the touch. Statistical arbitrageurs and electronic market makers are also typically in favor of smaller ticks, because they allow them to compete more effectively for liquidity provision in a given security or across different securities.

Importantly, an understanding of the debate around the effects of the tick size goes hand in hand with a better appreciation of the way that (i) technological innovation and (ii) market participants' access to/ability to process market data, play in shaping modern trading. For instance, the evidence presented by Foucault and Menkveld (2008) that price granularity has a positive impact on liquidity, hinges on liquidity providers' ability to access data and exploit technology. Indeed, in their context, the entrant exchange's (i.e., Chi-X) liquidity improvement relies on the fact that pricing is not continuous. However, the queue jumping strategy liquidity providers deploy across Euronext and Chi-X, can only be exploited via the knowledge of the state of the book in the alternative venue and the reliance on smart order routers. A similar argument holds for the evidence that market participants react to the new rules instituted by the 2016 Tick Size Pilot by relying more heavily on inverted venues for tick constrained treated stocks (Comerton-Forde et al. (2019)). Access to technology and market data also plays a central role in the tick size war that takes place among European trading venues across 2009-2010 (Foley et al. (2022)). Finally, the advent of HFT and its high-speed ability to process and exploit data, is central to understanding why a reversion to wider ticks "per-se" fails to boost the profitability of liquidity provision during the 2016 Tick Size Pilot, as pointed out by Bartlett and McCrary (2020).

Based on the results of the TSP surveyed above and Nasdaq (2019), a reasonable tick size regime should strike a balance between two contrasting objectives. On the one hand, that of discouraging frequent outbidding and favoring price stabilization (that is, the tick size cannot be too small). On the other hand, that of avoiding the formation of large quotation sizes that substitute for quote competition and may lead to a migration of liquidity provision towards venues that speed up fulfillment or allow subpenny price improvements (that is, the tick size cannot be too large). Both such undesirable outcomes are bound to augment the complexity of the market place.[42] To achieve such objective, AMF (2018) argues that a regulatory regime should rely on a two-dimensional classification that encompasses a stock price *and* its liquidity. A similar structure is indeed behind the regulatory provision for the tick size in MiFID II.[43] Specifically, as we saw in Section 4.2, article 49 of MiFID II assigns a certain tick size to a stock based on two criteria: (1) the stock's price band and (2) the stock's liquidity band (measured in terms of the average daily number of transactions for the stock), in a way that the tick size is positively (inversely) related to a stock price (liquidity).[44] As argued in Section 4.2, the empirical evidence on the impact of MiFID II on market quality (Boyde et al. (2018) and Favaretto et al. (2023)) aligns with the findings based on the US experience (Goldstein and Kavajecz (2000), Bessembinder (2003) and Comerton-Forde et al. (2019)). However, in view of Eaton et al. (2021), the available results are unlikely to shed light on the effects of the new tick size regime on institutions' trading costs.

In the absence of a universally accepted measure of market quality, however, evaluating the desirability of *any* mandated tick size provision is complicated, and risks favoring some market participants over others, without necessarily achieving a higher welfare for the market as a whole. In this respect, a rigorous analysis should take into account that price granularity has an effect on three classes of market participants: the trading venues that facilitate securities trading, the liquidity demanders/suppliers that interact in such venues, and the firms that issue the securities that are traded in those venues.[45]

[42]For different reasons: frequent outbidding increases the number of manipulative orders with a short lifetime; the proliferation of trading venues that subsidize/tax liquidity provision/consumption, increases the degree of opacity of advertised quotes.

[43]Before MiFID II, in the EU the tick size was chosen by each trading venue, which exploited this as a strategic variable to attract order flow (see AMF (2018)).

[44]Article 49 of MiFID II sets out the current tick size regulatory regime in the EU and introduces 19 price bands and 6 liquidity classes with tick sizes that range from 5 to 500 basis points. AMF (2018) assesses the market quality effects of Article 49, looking at a representative sample of 500 stocks traded on Euronext Paris, around the implementation of the new regime. The findings point at a sharp increase in depth and a significant reduction in the number of messages sent to the market. This, however, comes at the cost of an increase in the spread for the most liquid stocks. Overall the impact for market participants is a slight increase in trading costs compensated by an increase in the depth available at the top of the book.

[45]The market microstructure literature lacks an analysis of models that encompass the actions of the different parties that interact with exchanges. Some notable exceptions

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in this respect are Cespa and Vives (2021) and Pagnotta and Philippon (2018).

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