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Minimum tick size reduction and stock liquidity: lessons from the Warsaw Stock Exchange

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Abstract

On 4 March 2019 the minimum tick size reduction was implemented on the Warsaw Stock Exchange (WSE herein), allowing stock prices to be quoted with an accuracy of up to 0.0001 PLN. Studies carried out based on American stock markets indicate that the minimum tick size reduction results in a change in stock liquidity. We aim to analyse whether the reduction of the minimum tick size on the WSE in March 2019 has resulted in a change of stock liquidity. Our analyses spanned various time perspectives and various subsamples as well. Based on the results of the paired difference test, we conclude that the implemented changes have caused an increase of tightness (cost dimension of liquidity) and a decrease of depth (volume dimension of liquidity). Resiliency (price impact dimension of liquidity) remained unaffected by the changes implemented. Thus, the minimum tick size reduction on the Polish stock market had the same effect on liquidity as on American ones. Our results allow the use of the minimum tick size reduction as a quasi-natural experiment for future studies, e.g. for the difference-in-differences method.

Keywords: stock liquidity, minimum tick size, bid-ask spread, tick size, Warsaw Stock Exchange

JEL: G12 , G14, G18

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1. Introduction

In the capital market companies can raise the long-term funds needed to finance their economic activities. This market performs specific functions, namely allocation, mobilisation and valuation. The realization of these functions is conditioned by market efficiency which, in turn depends, among other things, on its liquidity (Chordia, Roll, Subrahmanyam 2008; Kowalke 2017; Sarr, Lybek 2002; Subrahmanyam 2009). For this reason most theories of finance are based on the assumption of perfect liquidity of securities traded in the market. Stock liquidity is thus of great importance to both academics and investors in the capital market. Stock liquidity in the capital market is determined by many factors, which can be divided into macroeconomic factors, market features and specific stock features. One of the market features, significantly affecting the liquidity of listed stocks is trading rules and technology.

In the world literature on stock liquidity, one can come across studies that analyse the impact of changes in trading technology on the liquidity of market-listed instruments. Amihud, Mendelson and Lauterbach (1997) have pointed out that the introduction of a continuous trading system in place of the call auction mechanism on the Tel Aviv Stock Exchange has improved the liquidity of stocks transferred to the continuous trading session. Amihud, Mendelson and Uno (1999) in turn have noted that the reduction in the minimum trading unit in Japan has also resulted in an improvement in stock liquidity. Tayal and Thomas (2012) have analysed the impact of short sales constraints on the liquidity of shares, indicating that the existence of such constraints causes a decrease in liquidity.

Changes in trading technology that can improve market liquidity also include minimum tick size reduction. Changes in the regulations of the minimum tick size on the New York Stock Exchange from 1/8 USD to 1/16 USD in late 1990s, followed by decimalisation (change of the minimum price movement to 1 cent) in 2001, resulted in a reduction in transaction costs (indicating an increase in liquidity), but at the same time caused a reduction in the size of orders placed (indicating a reduction in liquidity) (Bessembinder 2003; Chordia, Roll, Subrahmanyam 2011; Goldstein, Kavajecz 2000; Jones, Lipson 2001).

Similar studies have also been carried out on the Polish stock market. As an example, Marcinkiewicz (2012) has studied the effect of changes in short selling regulations on stock liquidity, however indicating no significant improvement. In her studies, Będowska-Sójka (2016, 2018) has noted that the introduction in April 2013 of a much more efficient trading system on the WSE (WARSET has been replaced by UTP) has resulted in a general improvement in market liquidity.

By resolutions No. 58/2019 and 61/2019 of 1 February 2019, the WSE Management Board adopted a change in the accuracy of stock price quotations of shares listed on the main market (WSE hereafter) and in the Alternative Trading System (NewConnect, NC or ATS hereafter) as well. According to the resolutions, starting from 4 March 2019, prices of some shares listed on the WSE and in the ATS are quoted with an accuracy of even up to 0.0001 PLN. This constitutes a significant change compared to previous regulations, according to which the minimum price movement could be equal to 0.01 PLN. The minimum tick size for a given stock depends on two components: its price and Average Daily Number of Transactions (ADNT hereafter) in the previous twelve months. Implementation of such a change can significantly influence several aspects of investing in the stock market, including market liquidity.

The implementation of the new listing steps was intended to enable the determination of stock prices to be quoted with greater accuracy, and thus, a more accurate valuation of listed shares, in particular penny stocks. The change in the minimum tick size should also contribute to facilitating transactions

and eliminating excessive percentage changes in prices of penny stocks. The aforementioned effects of the minimum tick size reduction should positively influence the liquidity of shares listed on the WSE and in the ATS as well. The aim of this paper is to investigate whether the stock liquidity has changed in the short- and long-term as a result of the change in the minimum price movement introduced on the Warsaw Stock Exchange in March 2019.

A change in stock liquidity resulting from a change in the minimum tick size may be a quasi--natural experiment. Due to the common reverse causality between liquidity and various phenomena, the presence of such a quasi-natural experiment makes it possible to identify liquidity as a cause, e.g. with the use of the difference-in-difference (DiD) method. This is due to the fact that changes in liquidity being the consequence of tick size constitute an exogenous liquidity shock that is beyond the company's control. This approach has already been used in research; the introduction of decimalisation in American stock market was a quasi-natural experiment. This allowed to confirm that stock liquidity affects, among other things:

– a company's value (Eaton 2015; Fang, Noe, Tice 2009),
– firms' innovations (Fang, Tian, Tice 2014),
– managerial short-termism (Chen et al. 2015),
– earnings management (Huang, Lao, McPhee 2017; Li, Xia 2021),
– firms' investment and production (Amihud, Levi 2018),
– capital structure (Cheung et al. 2019),
– corporate cash holdings (Hu, Li, Zeng 2019),
– corporate tax avoidance (Chen et al. 2019).

The rest of the paper is structured as follows. The following section is devoted to the regulations on the minimum price movement on the Warsaw Stock Exchange, with the emphasis on the changes in these regulations implemented in 2019. Section 3 is devoted to the methodological aspects of the conducted empirical study and the results of the study are presented in Section 4. Section 5 contains a series of robustness tests and Section 6 constitutes a summary. The study was financed from the funds granted within the research project by the National Science Centre, Poland (2017/27/N/HS4/00751).

2. Minimum tick size on the Warsaw Stock Exchange

Minimum tick size on the WSE is defined in §70 of WSE Detailed Exchange Trading Rules in the UTP System. In turn, the minimum tick size for stock listed on the NewConnect is defined in §70 of Rules for Trading in Financial Instruments in the Alternative Trading System (attached as Appendix No. 2 to the Rules of Alternative Trading System). On 1 February 2019 the Management Board of the WSE adopted two resolutions (numbered respectively 59/2019 and 61/2019), pursuant to which, as of 4 March 2019, the minimum tick sizes were changed. On the last trading day before the change, just after the closing of the trading sessions, all orders were cancelled.

The minimum tick size depends on two components: the liquidity band (based on the Average Daily Number of Transactions) to which a share belongs, and the price level of a given stock. According to the regulations in force since 4 March 2019, shares are quoted with accuracy of up to 0.0001; however, the stock price may not be lower than 0.01 PLN. The WSE Management Board has established six liquidity bands, within which it has defined price ranges for which a given tick size applies. The minimum price

movements for stocks listed on the WSE and in the NewConnect, effective as of 4 March 2019, are presented in Table 1. The newly introduced tick sizes are highlighted in grey.

The WSE Management Board, by resolution, determines the liquidity band for a given share which is effective as of 1 April of a given year for the following twelve months. Accordingly, a temporary assignment to the minimum tick size tables was in force in March 2019. As of 1 April 2019 a new assignment was already in force, with 248 companies (out of a total of 850 companies listed on the WSE and in the AST) assigned to a different liquidity band than on 4 March 2019. Thus, the implementation of the changes in the minimum tick size took place in two stages and lasted one month.

3. Methodology of the study on the effects of tick size reduction on stock liquidity

3.1. Liquidity measurement

Despite the crucial significance of liquidity for contemporary finance and constantly increasing interest of academics in its role in capital markets, still no universal definition of liquidity has been agreed. Difficulties in properly defining liquidity may be due to its complexity and latency (Amihud, Mendelson, Pedersen 2005; Salighehdar et al. 2017). The problem in defining liquidity also translates into problems with measuring this phenomenon (Aït-Sahalia, Yu 2009; Gourieroux, Jasiak, Le Fol 1999). The concept of stock liquidity is closely related to transactional efficiency, being one of the dimensions of capital market efficiency. In this context, the lack of perfect liquidity may be perceived as a market friction (Chordia, Shivakumar, Subrahmanyam 2004; Vayanos, Wang 2011, 2013), being the effect of market microstructure.

It can be assumed that perfect securities' liquidity means the ability to trade (sell and buy) any quantity of these securities at any time, without incurring any cost and causing an unfavourable movement in the security's price. Defined as such, perfect liquidity is ungradable, which means that it either is there or it is not, thus causing the necessity to introduce another definition, namely the level of liquidity. The level of liquidity can be defined as the extent to which an investor is able to trade (buy or sell) large quantities of securities at any time, at no cost, and without causing an unfavourable movement in the securities' price (Stereńczak, Zaremba, Umar 2020).

The level of liquidity is thus the size of the deviation from perfect liquidity as defined in the previous paragraph. Such deviation may apply to: 1) the time of execution, 2) the volume of transaction, 3) the cost of transaction, and 4) price impact (unfavourable movement in the security's price). It is therefore necessary to distinguish four dimensions of liquidity:

– immediacy (time dimension),
– depth (quantity dimension),
– tightness (cost dimension),
– resiliency (price impact dimension).

Due to the multidimensionality of liquidity, it is insufficient to measure liquidity with only one metric, as no single measure is able to capture all these dimensions simultaneously (Chou, Ko, Wei 2011, 2013; Jankowski, Olbryś 2015; Jensen, Moorman 2010; Otola, Grabowska 2012; Sarr, Lybek 2002). Thus, in order to encompass the effect of tick size reduction on stock liquidity more accurately, four different measures to represent three dimensions of liquidity have been used.

The most popular measure of transaction costs is the bid-ask spread; however, its calculation requires the use of data on all orders placed into the market in a given period. Apart from the time--consuming calculations, the data needed to compute the bid-ask spread is difficult to access for less developed markets, such as the Polish capital market. Therefore, various spread proxies are often used, and the Percent Quoted Closing Spread (*PQCS*) is indicated as the best performing one (Chung, Zhang 2014; Fong, Holden, Trzcinka 2017). *PQCS* is computed as in Chung and Zhang (2014), based on the bid and ask prices quoted at the end of a trading day:

$$PQCS_{it} = \frac{1}{NoTD_{it}} \sum_{m=1}^{NoTD_{it}} \frac{ask_{imt} - bid_{imt}}{mid_{imt}} \tag{1}$$

where *mid* is the average of the best ask and bid prices on the order book at the end of day *m*, and $NoTD_{it}$ is the number of days with a quote for stock *i* in month *t*. To eliminate errors in the data, days with zero or negative spread values and also days with spread values above 0.25 were omitted.

The bid-ask spread reflects only transaction costs for small orders. While transactions of low volume do not cause the change of the price more than it results from the bid-ask spread, transactions of volume exceeding the volume of best bid or best ask orders already lead to such a change (Brennan, Subrahmanyam 1996; Gourieroux, Jasiak, Le Fol 1999). For high-volume transactions that lead to a larger price change than the best bid and ask prices would imply, effective spread is a more appropriate approximation of transaction costs (Hasbrouck, 2009; Zhao, Wang 2015). The effective spread is calculated as the difference between the last trading price and the average of the ask and bid prices (midquote), divided by the midquote. We calculate the effective spread using the data on the best bid and the best ask prices at the end of a trading session:

$$PECS_{it} = \frac{1}{NoTD_{it}} \sum_{m=1}^{NoTD_{it}} \frac{\left| close_{imt} - mid_{imt} \right|}{mid_{imt}} \tag{2}$$

where *close* is the closing price of share *i* on day *m* of month *t*. In this study, the effective spread is calculated based on the prices of the best bid and ask in the order book at the end of the day and the closing price. To eliminate errors in the data, the days when the spread values were above 0.25 were omitted.

To measure depth, a dimension related to the size of transactions, the turnover ratio, used as the simplest measure of liquidity, was used. Its value reflects what proportion of shares has changed hands in a given period. For the purposes of the study, it is calculated based on the turnover value and capitalization (Datar, Naik, Radcliffe 1998):

$$TURN_{it} = \left(\sum_{m=1}^{NoTD_i} \frac{Val_{imt}}{close_{imt} NoSH_{imt}} \right) \tag{3}$$

where Val_{imt} is the trading value of trading in share *i* on day *m* of month *t* and $NoSH_{imt}$ denotes the number of outstanding shares.

Numerous studies (e.g. Ahn, Cai, Yang 2018; Fong, Holden, Trzcinka 2017; Stereńczak 2019) indicate, that the best measure of the price impact dimension of liquidity is the Amihud (2002) illiquidity ratio. Its computation requires only daily data on stock quotations, freely available even for the least developed markets and calculations are not time-consuming, which is an additional advantage. Moreover, it has a relatively simple construction and interpretation: it reflects the percentage change in stock price resulting from the execution of transactions of a certain volume (Amihud 2002):

$$ILLIQ_{it} = \frac{1}{NoTD_{it}} \sum_{m=1}^{NoTD_{it}} \frac{|r_{imt}|}{Val_{imt}} \tag{4}$$

where r_{imt} denotes the stock return on ith stock on day m of month t. In order to avoid extremely low values of *ILLIQ* trading, the value in the denominator is expressed in millions of PLN.

3.2. Research sample

The study covered all stocks listed on the Warsaw Stock Exchange and in the Alternative Trading System NewConnect over the entire two-year period from 2018 to 2019. All the required data needed to compute liquidity measures come from the S&P CapitalIQ database. In particular, closing prices (both raw and adjusted for corporate actions), best bid and best ask prices quoted at the end of the trading day, volumes and capitalisations have been exploited. Only stocks with a complete dataset, allowing to compute all liquidity measures for all 24 months of the study period, have been included in the research sample. Finally, the research sample covers 502 companies, including 358 companies listed on the WSE and 144 companies listed in the ATS. Descriptive statistics for liquidity measures are presented in Table 2. Panel A presents statistics for the entire sample, while Panel B contains results for stocks listed in the WSE only, and Panel 3 shows the statistics for shares listed in the NewConnect.

Based on the statistics presented in Table 2 we can make some interesting observations. First of all, liquidity measures for stocks listed on the Polish market have their distributions far from normal, which is mainly indicated by the values of skewness and kurtosis. In all the analysed cases distributions are right-skewed and leptokurtic. *PQCS* for shares listed in the ATS has its distribution closest to normal, while the most deviating from it is the turnover for stocks listed on the WSE. Secondly, NewConnect has a lower level of liquidity than WSE, as evidenced by higher values of *PQCS*, *PECS* and *ILLIQ* and lower values of *TURN*. In the case of the last measure, the mean is higher for NewConnect than for the WSE, though the median is lower. As the arithmetic mean is not resistant to extreme observations, more reliable conclusions can be drawn from the median values.

3.3. Research methods

Due to the purpose of the study, it is reasonable to apply a paired difference test to indicate the change in the level of liquidity due to the tick size reduction. We take into account values of liquidity measure prior to and after the reduction of tick size. Various preceding and various succeeding periods have been taken into account, in particular covering one month before and one month after, to study short-

-term effects, and covering the maximum available period (nine months before and nine months after) to study the long-term effects. The paired difference test allows to indicate whether possible differences in liquidity prior to and after the change in tick size are statistically significant. The null hypothesis H_0: $m_d = 0$ is tested against the alternative hypothesis H_1: $m_d \neq 0$, where m_d is the mean difference in liquidity measure prior to and after the change in tick size. The test statistic is given as follows (Sobczyk 2019):

$$t = \frac{\bar{d}}{S(d)}\sqrt{n} \sim t(n-1) \tag{5}$$

where $\bar{d} = \frac{1}{n}\sum_{i=1}^{n}(liq_{i,after} - liq_{i,prior})$, and $S(d) = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(d_i - \bar{d})^2}$ where *liq* denotes one of the four liquidity measures applied in the study.

4. Empirical results

4.1. Preliminary analyses

Figure 1 presents the dynamics of liquidity measures across the entire study period, taking into account the whole sample and two subsamples: stocks listed on the WSE and stocks listed in the ATS. Panel A presents the dynamics of *PQCS*, Panel B is devoted to *PECS*, while *ILLIQ* is presented in Panel C and *TURN* in Panel D. March 2019 is marked with a bold vertical line, as this is the month in which the minimum tick size reduction took place.

After the reduction of the minimum tick size in March 2019, we can observe a reduction in mean of *PQCS* and *PECS*, in particular on the NewConnect market. The reduction in the mean is also observed for *TURN*; however, this reduction was similar for both subsamples. Surprisingly, the decrease of *PQCS* and *PECS* means the opposite of the decrease of *TURN*: while the former suggest an improvement in the stock market liquidity, the latter suggests its deterioration. Based solely on Figure 1, it is hard to indicate whether the values of *ILLIQ* have decreased or increased due to the minimum tick size reduction.

4.2. Changes in stock liquidity – a long-term perspective

It is impossible to indicate statistical significance of the changes in liquidity based solely on the analysis of the figures. Table 3 presents the results of the paired difference test. The period preceding the minimum tick size reduction covers nine months and spans from June 2018 to February 2019, while the period succeeding this change spans from April 2019 to December 2019. We skip March 2019 as, starting from April 2019, stocks were assigned to new liquidity bands, as a result of which 248 out of a total of 502 stocks changed the liquidity band. The differences $\bar{d}$ were calculated as the difference of the average liquidity measures (calculated for monthly periods) for the nine months preceding the changes in the minimum tick size and those succeeding the changes, respectively.

The change in the minimum tick size resulted in an average decrease in *PQCS* by 25 bps. This value accounts for about 5.5% of mean *PQCS* prior to the minimum tick size reduction. It is worth noticing

that this decrease is statistically significant at 0.01 taking into account the whole sample. In terms of value, greater reduction in the PQCS is observed for the stocks listed in the NewConnect, though it turns out to be statistically insignificant. This, in turn, may be a result of a smaller sample of companies listed in the ATS. Moreover, the relative decrease in *PQCS* was higher for stocks listed on the WSE and accounted for about 6.5% of mean *PQCS* prior to the minimum tick size reduction. For companies listed in the ATS, the corresponding value was equal to about 4.5%.

The minimum tick size reduction also resulted in a reduction of *PECS* by about 15 bps, which accounts for about 6.4% of its mean in the period preceding the change. The improvement in stock liquidity is statistically significant for stocks listed on the WSE as well as for stocks from NewConnect. Similarly, as in the case of *PQCS*, the absolute *PECS* values decreased more for stocks listed in the ATS (about 25 bps compared to about 11 bps for stocks listed on the WSE); however, the relative change was lower for those stocks (about 5.8% vs. about 6.9% for stocks listed on the WSE). In relative terms, the decrease in value following the change of the minimum tick size was higher for *PECS* than for *PQCS*.

The average values of *ILLIQ* in the period succeeding the change in the minimum tick size do not differ significantly from the corresponding values in the period preceding the change. It is worth noticing that for stocks listed on the WSE the values of this measure have slightly increased, while for stocks listed in the ATS – have decreased. Not surprisingly, differences in the values of *ILLIQ* before and after the minimum tick size reduction are statistically insignificant.

The changes introduced in March 2019 have also resulted in the reduction of *TURN* by about 15.25% (in absolute terms, this change was equal to -0.00322). This difference is statistically significant at a significance level of 0.05. The deterioration of stock liquidity was more severe for the WSE than for the ATS. In the former market *TURN* decreased by about 16.9% (0.00346 in absolute terms), while in the latter it decreased by 11.6% (0.00263 in absolute terms). Moreover, the difference in the values of *TURN* before and after the change in the minimum tick size proved to be statistically insignificant for stocks listed in the ATS.

Summarizing the above considerations, we can claim that the introduction of new tick sizes has resulted in an improvement of liquidity in terms of transaction costs (market tightness), deterioration of liquidity in terms of market depth, and had no effect on stock liquidity in terms of price impact (market resiliency). This means that our results are consistent with the results of similar research carried out on the US markets. As an example, Goldstein and Kavajecz (2000) proved the decrease in both spreads and order volumes due to the reduction of the minimum tick size. The combined effect of the decrease in transaction costs and market depth makes it more profitable to place low volume orders, as investors that place orders of large volumes did not benefit from the change in the tick size. Similar results were presented by Jones and Lipson (2001). They showed a reduction in spreads due to the reduction in the minimum tick size to 1/16 USD, with a simultaneous increase in total transaction costs for investors placing large volume orders.

4.3. Changes in stock liquidity – a short-term perspective

The adoption of nine-month periods preceding and succeeding the minimum tick size reduction allows us to capture the long-term effects of introducing these changes. We have adopted one-month

periods to capture short-term effects. In this case, the preceding period covered February 2019, while the succeeding period covered April 2019. The results of paired difference tests for one-month periods are presented in Table 4.

The analysis of short-term effects of the minimum tick size reduction on stock liquidity produces different results than the analyses of the long-term effects. The changes introduced in March 2019 did not cause an improvement in stock liquidity in terms of tightness, expressed by the reduction in values of *PQCS* and *PECS*. Indeed, the values of these measures have decreased in the whole sample and both subsamples; however, mostly they turned out to be statistically insignificant (*PECS* for stock listed in the ATS is the exception). Stock liquidity also did not improve in terms of price impact, similarly as it was in the long-term analysis. Only the deterioration of liquidity in market depth (measured by *TURN*) was immediate and long-lasting, being more severe for stocks listed on the WSE rather than for stocks listed in the NewConnect.

4.4. Changes in stock liquidity and liquidity band

Changes in stock liquidity caused by the introduction of new tick sizes could affect various stocks to a different extent. As pointed out by Goldstein and Kavajecz (2000), low volume stocks and penny stocks were affected differently by a minimum tick size reduction than other stocks. It is thus reasonable to carry out the analysis of the effect of tick size reduction on stock liquidity in various subsamples, based on the criteria covering various stock characteristics. Liquidity is one of the most obvious features of shares that can be used to create subsamples. To this end, we have utilised the liquidity band to which a given stock has been assigned by the WSE Management Board. Table 5 presents the results of the analysis of nine-month periods preceding and succeeding, while Table 6 provides analogous values for one-month periods.

Based on the results presented in Tables 5 and 6, we can claim that ADNT has affected the change in stock liquidity due to the minimum tick size reduction. Surprisingly, the values of *PQCS* and *PECS* indicate a deterioration in liquidity of stocks with high ADNT (thus the most liquid ones). For the least liquid stocks with ADNT not exceeding 10, we can observe a significant improvement in liquidity. This applies both to the measures reflecting market tightness (*PQCS* and *PECS*) and market depth (*TURN*). Looking at market resiliency (*ILLIQ*), we can observe no statistically significant changes in stock liquidity.

4.5. Changes in stock liquidity and minimum tick size

Tables 7 and 8 present the changes is stock liquidity due to the minimum tick size reduction in subsamples distinguished based on the minimum tick size of a given stock. In particular, the stocks have been divided into to two groups: those whose tick sizes were below one penny after the changes, and those whose tick sizes equalled or exceeded one penny. Stocks belonging to the former group may be viewed as the ones that benefited from the changes in tick sizes. Thus, the improvement in liquidity for those shares should be more significant than for the other ones. Stocks have also been divided into two different groups: those whose tick sizes decreased, and those whose tick sizes did not change or increased in March 2019.

The results presented in Tables 7 and 8 indicate that paradoxically, stock liquidity improved the most for the stocks with tick sizes in April 2019 not lower than one penny, and for stocks whose tick sizes increased as compared to February 2019. The liquidity of these shares improved in cost dimension (tightness): the reduction in values of *PQCS* and *PECS* was statistically significant. On the other hand, we can observe a deterioration in liquidity in terms of depth for stocks whose minimum tick sizes were lower than 0.01 PLN or decreased as compared to February 2019. This is evidenced by the statistically significant reduction of *TURN*.

Stocks listed on the WSE are the exception to the abovementioned dependencies. The values of *PQCS* and *PECS* for stocks whose tick sizes decreased in April 2019 as compared to February 2019 decreased more than for stocks whose tick sizes did not change or increased. This proves a greater improvement in stock liquidity in terms of tightness. At the same time, stocks from the former group (i.e. experiencing a decrease in tick sizes) experienced a more severe deterioration in stock liquidity in terms of depth, which is evidenced by the differences in *TURN* for those stocks.

Interestingly, stocks listed on the WSE whose tick size was below one penny since April 2019, experienced a deterioration in stock liquidity in the long-term also in terms of resiliency. Taking into account the preceding and succeeding nine-month periods, an increase of *ILLIQ* for those shares (equalling 18.622) is statistically significant at 0.1 level. The above analyses are indirectly coherent with the results of studies carried out on the US markets. It has been proven that the tick size reduction caused a deterioration in stock liquidity in terms of depth (Goldstein, Kavajecz 2000) and an increase in transaction costs for transactions of a large volume (Goldstein, Kavajecz 2000; Jones, Lipson 2001).

Summarizing, the reduction of the minimum tick size in March 2019 caused certain effects in liquidity of stocks listed on the WSE and in the ATS as well. On the one hand, we can observe an improvement in stock liquidity in terms of tightness, as evidenced by the reduction of transaction costs, proxied by *PQCS* and *PECS*. However, on the other hand we can observe a deterioration in liquidity in terms of depth, as evidenced by the decrease in *TURN*. These changes are observed to a bigger extent for stocks listed on the WSE and stocks with lower ADNT. Changes in liquidity did not occur immediately after the reduction of tick size, but are only noticeable over a longer period. Interestingly, the improvement in liquidity in terms of tightness occurred mainly for stocks whose minimum tick size was equal or higher than 0.01 PLN, or whose minimum tick size increased due to the regulatory changes. In turn, a deterioration in liquidity in terms of depth mainly affected shares whose minimum tick sizes decreased as compared to the month prior to the changes, and those for which it was lower than one penny after the changes.

5. Robustness tests

Stock liquidity may be affected by seasonality and may depend on the month of the year. As an example, Chordia, Roll and Subrahmanyam (2001) observed that there are strong day-of-the-week effects in stock liquidity and that liquidity deteriorates in holiday periods due to the reduced trading activity. Stock liquidity is also relatively higher in summer and early autumn (July-September) and relatively lower in October (Chordia, Sarkar, Subrahmanyam 2005). For this reason, the analyses covering the months immediately preceding and immediately succeeding the tick size reduction may be biased due to seasonality, as they do not cover the entire year. The preceding nine-month period

covers the months from June to February, while the nine-month period succeeding covers the months from April to December.

Thus, in order to verify whether the results presented earlier are not biased by seasonality, we carried out a robustness test in which a preceding nine-month period covered the months from April 2018 to December 2018, and a preceding one-month period covered April 2018. Tables 9–14 present the results. They do not change the conclusions described in Section 4: the reduction of the minimum tick size up to 0.0001 PLN in March 2019 resulted in an improvement in liquidity in terms of tightness and a deterioration of it in terms of depth.

Only one of all the cases presented in Tables 9–14 provides statistically significant results that are contrary to the basic analyses, as presented in Tables 3–8. This applies to the *TURN* of stocks listed on the WSE if we take into account one-month preceding and one-month succeeding the changes. The basic results indicated a deterioration in liquidity of these stocks (decrease in *TURN* by 0.00964), while in the robustness test we claim an improvement in liquidity in terms of depth (increase in *TURN* by 0.00473). However, we can conclude that our results are thus robust for potential seasonality in stock liquidity.

In addition to seasonality, the results of the analyses presented in Section 4 may be biased by the method of averaging the values of liquidity measures in the nine-month preceding and succeeding periods. Basically it was computed as the average value of nine monthly values which, in turn, were computed as the average of daily values. The average calculated in this way assigns higher weights to daily observations in the months with a lower number of observations. This means that the values of liquidity measures in less liquid months are assigned with relatively higher weight than the respective values in more liquid months. In order to verify whether this fact could significantly bias our results, we carried out another robustness test. To this end we calculate the average value of each liquidity measure in nine-month periods based on daily observations, rather than on monthly ones. The results are presented in Tables 15–17. The results that we got are similar, both in terms of the order of magnitude and statistical significance, to our basic results. Therefore, it is justified to claim, that our results are not biased by the liquidity of the least liquid shares.

6. Summary

Liquidity plays an important role in financial markets, especially in stock markets. Its importance arises from the fact that it affects asset pricing, portfolio selection and risk management as well. Studies on the factors influencing its level should be (and are) an important stream of research on capital markets. The minimum tick size is indicated as one of the factors determining stock liquidity. Since March 2019, on the Warsaw Stock Exchange (on the main market and in the Alternative Trading System as well) stock prices can be quoted with an accuracy of up to 0.0001 PLN (as compared to 0.01 PLN before the change). The purpose of this paper was to investigate whether the change in the minimum tick size introduced on the WSE in March 2019 has resulted in changes in stock liquidity in the short- and long-term perspective.

Our study has proved that the minimum tick size reduction introduced in March 2019 resulted in changes in liquidity of stocks listed on the WSE and in the ATS as well. On the one hand, we can observe an improvement in stock liquidity in terms of tightness, evidenced by a reduction in transaction

costs. On the other hand, we observe a deterioration in stock liquidity in terms of depth, evidenced by a decrease in trading volumes. The changes in stock liquidity are more noticeable for stocks listed on the WSE rather than for stock listed in the ATS. The changes in liquidity are also more significant for stocks with a lower average daily number of transactions. Thus, the reduction in the minimum tick size on the Warsaw Stock Exchange has caused changes in stock liquidity similar to the respective changes introduced in US markets at the turn of the millennium.

The above-mentioned changes in liquidity did not occur immediately after the tick size reduction, but are only noticeable in the long-term. Interestingly, an improvement in stock liquidity in terms of tightness is observed mainly for stocks that have not been directly affected by the changes introduced, i.e. their tick size remained higher or equal to 0.01 PLN. In turn, a deterioration in liquidity in terms of depth concerns mainly stocks whose minimum tick sizes decreased, in particular to the value below 0.01 PLN.

Our study presented in the paper suggests that the introduction in March 2019 of new regulations on the minimum tick size may be used in future studies on stock liquidity as a quasi-natural experiment. This is due to the fact that all the changes in liquidity are exogenous and are unaffected by companies. The use of such quasi-natural experiments makes it possible to analyse the causality between liquidity and various phenomena, e.g. with the use of the difference-in-differences method. The occurrence of similar events is thus desired for academics dealing with liquidity of shares and other financial instruments.

References

Ahn H., Cai J., Yang C. (2018), Which liquidity proxy measures liquidity best in emerging markets?, *Economies*, 6(67), 1–31, https://doi.org/10.3390/economies6040067.

Aït-Sahalia Y., Yu J. (2009), High frequency market microstructure noise estimates and liquidity measures, *Annals of Applied Statistics*, 3(1), 422–457, https://doi.org/10.1214/08-AOAS200.

Amihud Y. (2002), Illiquidity and stock returns: cross-section and time series effects, *Journal of Financial Markets*, 5, 31–56, https://doi.org/10.1016/S1386-4181(01)00024-6.

Amihud Y., Levi S. (2018), *The effect of stock liquidity on the firm's investment and production*, https://doi.org/10.2139/ssrn.3183091.

Amihud Y., Mendelson H., Lauterbach B. (1997), Market microstructure and securities values: evidence from the Tel Aviv Stock Exchange, *Journal of Financial Economics*, 45, 365–390.

Amihud Y., Mendelson H., Pedersen L.H. (2005), Liquidity and asset prices, *Foundations and Trends in Finance*, 1(4), 269–364, https://doi.org/10.1561/0500000003.

Amihud Y., Mendelson H., Uno J. (1999), Number of shareholders and stock prices: evidence from Japan, *Journal of Finance*, 54(3), 1169–1184.

Będowska-Sójka B. (2016), Liquidity dynamics around jumps: the evidence from the Warsaw Stock Exchange, *Emerging Markets Finance and Trade*, 52(12), 2740–2755, https://doi.org/10.1080/1540496X.2016.1216937.

Będowska-Sójka B. (2018), The coherence of liquidity measures. The evidence from the emerging market, *Finance Research Letters*, 27(C), 118–123, https://doi.org/10.1016/j.frl.2018.02.014.

Bessembinder H. (2003), Trade execution costs and market quality after decimalization, *Journal of Financial and Quantitative Analysis*, 38(4), 747–777, https://doi.org/10.2307/4126742.

Brennan M.J., Subrahmanyam A. (1996), Market microstructure and asset pricing: on the compensation for illiquidity in stock returns, *Journal of Financial Economics*, 41, 441–464, https://doi.org/10.1016/0304-405X(95)00870-K.

Chen Y., Ge R., Louis H., Zolotoy L. (2019), Stock liquidity and corporate tax avoidance, *Review of Accounting Studies*, 24(1), 309–340.

Chen Y., Rhee S.G., Veeraraghavan M., Zolotoy L. (2015), Stock liquidity and managerial short-termism, *Journal of Banking and Finance*, 60, 44–59, https://doi.org/10.1016/j.jbankfin.2015.07.007.

Cheung W., Im H.J., Noe T., Zhang B. (2019), Liquidity, information production, and debt-equity choice, https://doi.org/10.2139/ssrn.3426640.

Chordia T., Roll R., Subrahmanyam A. (2001), Market liquidity and trading activity, *Journal of Finance*, 56(2), 501–530, https://doi.org/10.1111/0022-1082.00335.

Chordia T., Roll R., Subrahmanyam A. (2008), Liquidity and market efficiency, *Journal of Financial Economics*, 87(2), 249–268, https://doi.org/10.1016/j.jfineco.2007.03.005.

Chordia T., Roll R., Subrahmanyam A. (2011), Recent trends in trading activity and market quality, *Journal of Financial Economics*, 101(2), 243–263, https://doi.org/10.1016/j.jfineco.2011.03.008.

Chordia T., Sarkar A., Subrahmanyam A. (2005), An empirical analysis of stock and bond market liquidity, *Review of Financial Studies*, 18(1), 85–129, https://doi.org/10.1093/rfs/hhi010.

Chordia T., Shivakumar L., Subrahmanyam A. (2004), Liquidity dynamics across small and large firms, *Economic Notes*, 33(1), 111–143.

Chou P.-H., Ko K.-C., Wei K.C.J. (2011), *What Drives the Liquidity Premium: Factors or Characteristics?*, SSRN Electronic Journal, Available at: https://ssrn.com/abstract=1765003.

Chou P.-H., Ko K.-C., Wei K.C.J. (2013), *Sources of the Liquidity Premium*, The 21st Conference on the Theories and Practices of Securities and Financial Markets, Kaohsiung, Taiwan, 12/2013, https://sfm.finance.nsysu.edu.tw/21stSFM/pdf/2013pdf/022-1635497334.pdf.

Chung K.H., Zhang H. (2014), A simple approximation of intraday spreads using daily data, *Journal of Financial Markets*, 17(1), 94–120, https://doi.org/10.1016/j.finmar.2013.02.004.

Datar V.T., Naik N.Y., Radcliffe R. (1998), Liquidity and stock returns: an alternative test, *Journal of Financial Markets*, 1(2), 203–219, https://doi.org/10.1016/S1386-4181(97)00004-9.

Eaton G.W. (2015), *The effects of market liquidity on the firm: does liquidity impact firm value?,* SSRN Electronic Journal, Available at: http://dx.doi.org/10.2139/ssrn.2756563.

Fang V.W., Noe T.H., Tice S. (2009), Stock market liquidity and firm value, *Journal of Financial Economics,* 94, 150–169, https://doi.org/10.1016/j.jfineco.2008.08.007.

Fang V.W., Tian X., Tice S. (2014), Does stock liquidity enhance or impede firm innovation?, *Journal of Finance*, 69(5), 2085–2125, https://doi.org/10.1111/jofi.12187.

Fong K.Y.L., Holden C.W., Trzcinka C.A. (2017), What are the best liquidity proxies for global research?, *Review of Finance*, 21(4), 1355–1401, https://doi.org/10.1093/rof/rfx003.

Goldstein M.A., Kavajecz K.A. (2000), Eighths, sixteenths, and market depth: changes in tick size and liquidity provision on the NYSE, *Journal of Financial Economics*, 56(1), 125–149, https://doi.org/10.1016/S0304-405X(99)00061-6.

Gourieroux C., Jasiak J., Le Fol G. (1999), Intra-day market activity*, Journal of Financial Markets,* 2, 193–226.

Hasbrouck J. (2009), Trading costs and returns for U.S. equities: estimating effective costs from daily data, *Journal of Finance*, 64(3), 1445–1477, https://doi.org/10.1111/j.1540-6261.2009.01469.x.

Hu Y., Li Y., Zeng J. (2019), Stock liquidity and corporate cash holdings, *Finance Research Letters*, 28, 416–422, https://doi.org/10.1016/j.frl.2018.06.018.

Huang K., Lao B., McPhee G. (2017), Does stock liquidity affect accrual-based earnings management?, *Journal of Business Finance and Accounting*, 44(4), 417–447, https://doi.org/10.1111/jbfa.12236.

Jankowski R., Olbryś J. (2015), Wymiary płynności rynku papierów wartościowych, *Zeszyty Naukowe Uniwersytetu Szczecińskiego. Finanse, Rynki Finansowe, Ubezpieczenia,* 73, 645–658.

Jensen G.R., Moorman T. (2010), Inter-temporal variation in the illiquidity premium, *Journal of Financial Economics*, 98(2), 338–358, https://doi.org/10.1016/j.jfineco.2010.05.008.

Jones C.M., Lipson M.L. (2001), Sixteenths: direct evidence on institutional execution costs, *Journal of Financial Economics,* 59(2), 253–278, https://doi.org/10.1016/S0304-405X(00)00087-8.

Kowalke K. (2017), Płynność obrotu Giełdy Papierów Wartościowych w Warszawie na tle płynności giełd europejskich, *Zeszyty Naukowe Uniwersytetu Szczecińskiego. Finanse, Rynki Finansowe, Ubezpieczenia*, 86, 273–286, https://doi.org/10.18276/frfu.2017.86-23.

Li D., Xia Y. (2021), Gauging the effects of stock liquidity on earnings management: evidence from the SEC tick size pilot test, *Journal of Corporate Finance*, 67, 101904.

Marcinkiewicz E. (2012), Wpływ krótkiej sprzedaży na efektywność transakcyjną rynku kapitałowego w aspekcie płynności, *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu*, 261, 218–230.

Otola I., Grabowska M. (2012), Empiryczna analiza płynności rynku akcji w oparciu o wybrane mierniki, *Acta Universitas Lodziensis. Foila Oeconomica*, 262, 125–137.

Salighehdar A., Liu Y., Bozdog D., Florescu I. (2017), Cluster analysis of liquidity measures in a stock market using high frequency data, *Journal of Management Science and Business Intelligence*, 2(2), 1–8, https://doi.org/10.5281/zenodo.808452.

Sarr A., Lybek T. (2002), *Measuring liquidity in financial markets,* IMF Working Paper, WP/02/232, https://doi.org/10.1093/rfs/hhv132.

Sobczyk M. (2019), *Statystyka*, Wydawnictwo Naukowe PWN.

Stereńczak S. (2019), In search of the best proxy for liquidity in asset pricing studies on the Warsaw Stock Exchange, in: W. Tarczyński, K. Nermend (eds.), *Effective Investments on Capital Markets. 10th Capital Market Effective Investments Conference (CMEI 2018)*, Springer International Publishing, https://doi.org/10.1007/978-3-030-21274-2_3.

Stereńczak S., Zaremba A., Umar Z. (2020), Is there an illiquidity premium in frontier markets?, *Emerging Markets Review*, 42, 100673, https://doi.org/10.1016/j.ememar.2019.100673.

Subrahmanyam A. (2009), The implications of liquidity and order flows for neoclassical finance, *Pacific Basin Finance Journal*, 17(5), 527–532, https://doi.org/10.1016/j.pacfin.2008.08.001.

Tayal R., Thomas S. (2012), *Measuring and explaining the asymmetry of liquidity*, SSRN Electronic Journal, https://ssrn.com/abstract=2239492.

Vayanos D., Wang J. (2011), Theories of liquidity, *Foundations and Trends in Finance*, 6(4), 221–317, https://doi.org/10.1561/0500000014.

Vayanos D., Wang J. (2013), *Market liquidity – theory and empirical evidence*, NBER Working Paper Series, 18251, https://doi.org/10.3386/w18251.

Zhao W., Wang M. (2015), On the computation of LOT liquidity measure, *Economics Letters*, 136, 76–80.

Appendix

Table 1
Minimum tick sizes for stocks listed on the WSE and in the NewConnect

Price range	ADNT < 10	10 ≤ ADNT < 80	80 ≤ ADNT < 600	600 ≤ ADNT < 2,000	2,000 ≤ ADNT < 9,000	9,000 ≤ ADNT
	Table 1	**Table 2**	**Table 3**	**Table 4**	**Table 5**	**Table 6**
0.01 ≤ P < 0.1	0.0005	0.0002	0.0001	0.0001	0.0001	0.0001
0.1 ≤ P < 0.2	0.001	0.0005	0.0002	0.0001	0.0001	0.0001
0.2 ≤ P < 0.5	0.002	0.001	0.0005	0.0002	0.0001	0.0001
0.5 ≤ P < 1	0.005	0.002	0.001	0.0005	0.0002	0.0001
1 ≤ P < 2	0.01	0.005	0.002	0.001	0.0005	0.0002
2 ≤ P < 5	0.02	0.01	0.005	0.002	0.001	0.0005
5 ≤ P < 10	0.05	0.02	0.01	0.005	0.002	0.001
10 ≤ P < 20	0.1	0.05	0.02	0.01	0.005	0.002
20 ≤ P < 50	0.2	0.1	0.05	0.02	0.01	0.005
50 ≤ P < 100	0.5	0.2	0.1	0.05	0.02	0.01
100 ≤ P < 200	1	0.5	0.2	0.1	0.05	0.02
200 ≤ P < 500	2	1	0.5	0.2	0.1	0.05
500 ≤ P < 1,000	5	2	1	0.5	0.2	0.1
1,000 ≤ P < 2,000	10	5	2	1	0.5	0.2
2,000 ≤ P < 5,000	20	10	5	2	1	0.5
5,000 ≤ P < 10,000	50	20	10	5	2	1
10,000 ≤ P < 20,000	100	50	20	10	5	2
20,000 ≤ P < 50,000	200	100	50	20	10	5
50,000 ≤ P	500	200	100	50	20	10

ADNT – Average Daily Number of Transactions

Source: https://www.gpw.pl/tick-size (accessed: 21.01.2020).

Table 2
Descriptive statistics for liquidity measures

Measure	PQCS	PECS	ILLIQ	TURN
Panel A: whole sample (n = 502)				
Mean	0.0424	0.0221	96.757	0.0201
Median	0.0306	0.0152	8.3905	0.0058
Std. deviation	0.0378	0.0214	289.24	0.0755
Skewness	1.6532	2.0922	14.472	39.507
Kurtosis	2.8889	5.7388	594.20	2723.0
Panel B: shares listed on the WSE (n = 358)				
Mean	0.0284	0.0147	56.884	0.0194
Median	0.0229	0.0113	2.8294	0.0059
Std. deviation	0.0234	0.0135	170.81	0.0825
Skewness	2.1361	2.7345	8.6660	41.866
Kurtosis	7.5715	12.433	136.20	2687.4
Panel C: shares listed in the ATS (n = 144)				
Mean	0.0773	0.0403	195.89	0.0219
Median	0.0696	0.0351	52.937	0.0055
Std. deviation	0.0438	0.0261	453.18	0.0547
Skewness	0.7637	1.2756	12.305	6.4411
Kurtosis	0.1956	2.0965	325.27	57.318

Source: own elaboration.

Table 3
Change in the level of liquidity due to the minimum tick size reduction – preceding period: June 2018 to February 2019, succeeding period: April 2019 to December 2019

Measure	PQCS	PECS	ILLIQ	TURN
Panel A: whole sample (n = 502)				
Before	0.04485	0.02343	104.343	0.02112
After	0.04238	0.02194	100.163	0.01789
Mean difference $\bar{d}$	-0.00246***	-0.00149***	-4.180	-0.00322**
Std. deviation S(d)	0.0194	0.0116	169.283	0.0304
t-statistics	2.839	2.873	0.553	2.375
Panel B: shares listed on the WSE (n = 358)				
Before	0.03027	0.01569	57.727	0.02049
After	0.02829	0.01461	61.966	0.01703
Mean difference $\bar{d}$	-0.00198***	-0.00108***	4.239	-0.00346**
Std. deviation S(d)	0.0120	0.0074	84.678	0.0281
t-statistics	3.130	2.742	0.947	2.326
Panel C: shares listed in the ATS (n = 144)				
Before	0.08109	0.04268	220.235	0.02267
After	0.07742	0.04017	195.124	0.02004
Mean difference $\bar{d}$	-0.00367	-0.00251*	-25.111	-0.00263
Std. deviation S(d)	0.0311	0.0182	286.146	0.0355
t-statistics	1.417	1.651	1.053	0.890

***, ** and * denote statistical significance at 0.01, 0.05 and 0.1 level of confidence respectively.

Source: own elaboration.

Table 4
Change in the level of liquidity due to the minimum tick size reduction – preceding period: February 2019, succeeding period: April 2019

Measure	PQCS	PECS	ILLIQ	TURN
Panel A: whole sample (n = 502)				
Before	0.04006	0.02086	76.852	0.02681
After	0.03885	0.02022	85.444	0.01889
Mean difference $\bar{d}$	-0.00122	-0.00064	8.592	-0.00792**
Std. deviation S(d)	0.0232	0.0149	261.655	0.0700
t-statistics	1.172	0.960	0.735	2.531
Panel B: shares listed on the WSE (n = 358)				
Before	0.02575	0.01290	38.901	0.02839
After	0.02544	0.01355	52.864	0.01875
Mean difference $\bar{d}$	-0.00032	0.00065	13.962*	-0.00964**
Std. deviation S(d)	0.0147	0.0092	153.738	0.0804
t-statistics	0.407	1.333	1.718	2.269
Panel C: shares listed in the ATS (n = 144)				
Before	0.07564	0.04063	171.202	0.02289
After	0.07218	0.03678	166.442	0.01925
Mean difference $\bar{d}$	-0.00345	-0.00385*	-4.760	-0.00364
Std. deviation S(d)	0.0367	0.0234	424.974	0.0319
t-statistics	1.130	1.969	0.134	1.368

***, ** and * denote statistical significance at 0.01, 0.05 and 0.1 level of confidence respectively.

Source: own elaboration.

Table 5
Change in the level of liquidity due to the minimum tick size reduction and liquidity band – preceding period: June 2018 to February 2019, succeeding period: April 2019 to December 2019

Band	*n*	PQCS	PECS	ILLIQ	TURN
Panel A: whole sample (n = 502)					
ADNT < 10	215	-0.00293*	-0.00204*	-19.547	0.00217*
10 ≤ DNT < 80	189	-0.00237*	-0.00116*	9.416	-0.00226
80 ≤ ADNT < 600	58	-0.00187**	-0.00091*	-6.874	-0.0233***
600 ≤ ADNT < 2,000	22	-0.00278**	-0.00045	1.277	-0.01168
2,000 ≤ ADNT < 9,000	8	-0.00128***	-0.00062***	-0.00002	-0.00399**
9,000 ≤ ADNT	10	0.00220	-0.00219	69.514	-0.00133
Panel B: shares listed on the WSE (n = 358)					
ADNT < 10	108	-0.00214	-0.00139	7.700	0.00057
10 ≤ ADNT < 80	161	-0.00187**	-0.00094*	6.057	0.00066
80 ≤ ADNT < 600	55	-0.00194**	-0.00097*	-7.309	-0.0249***
600 ≤ ADNT < 2,000	21	-0.00290**	-0.00048	1.337	-0.00031
2,000 ≤ ADNT < 9,000	8	-0.00128***	-0.00062***	-0.00002	-0.00399**
9,000 ≤ ADNT	5	0.00049	-0.00323	16.938	-0.00022*
Panel C: shares listed in the ATS (n = 144)					
ADNT < 10	107	-0.00373	-0.00270	-47.048	0.00378*
10 ≤ ADNT < 80	28	-0.00522	-0.00241	28.729	-0.01907**
80 ≤ ADNT < 600	3	-0.00057	0.00017	1.091	0.00446
600 ≤ ADNT < 2,000	1	N/A	N/A	N/A	N/A
2,000 ≤ ADNT < 9,000	0	N/A	N/A	N/A	N/A
9,000 ≤ ADNT	5	0.00391	-0.00115	122.090	-0.00243

***, ** and * denote statistical significance at 0.01, 0.05 and 0.1 level of confidence respectively.

Source: own elaboration.

Table 6
Change in the level of liquidity due to the minimum tick size reduction and liquidity band – preceding period: February 2019, succeeding period: April 2019

Band	*n*	PQCS	PECS	ILLIQ	TURN
Panel A: whole sample (n = 502)					
ADNT < 10	215	-0.00142	-0.00095	27.819	-0.00253
10 ≤ ADNT < 80	189	-0.00106	-0.00014	-0.541	-0.00129
80 ≤ ADNT < 600	58	-0.00174**	-0.00097*	2.021	-0.05148**
600 ≤ ADNT < 2,000	22	-0.00011	0.00023	-4.461	-0.00579
2,000 ≤ ADNT < 9,000	8	-0.00035	-0.00019	0.000006	-0.00303
9,000 ≤ ADNT	10	0.00005	-0.00374	-158.462	-0.00505
Panel B: shares listed on the WSE (n = 358)					
ADNT < 10	108	-0.00079	0.00160	45.260	-0.00432
10 ≤ ADNT < 80	161	0.00029	0.00053	1.024	0.00019
80 ≤ ADNT < 600	55	-0.00175**	-0.00099*	2.136	-0.05361**
600 ≤ ADNT < 2,000	21	-0.00002	0.00030	-4.674	-0.00191
2,000 ≤ ADNT < 9,000	8	-0.00035	-0.00019	0.000006	-0.00303
9,000 ≤ ADNT	5	0.00484*	0.00508**	-14.743	-0.00043
Panel C: shares listed in the ATS (n = 144)					
ADNT < 10	107	-0.00205	-0.00352	10.215	-0.00071
10 ≤ ADNT < 80	28	-0.00881	-0.00398	-9.542	-0.00984
80 ≤ ADNT < 600	3	-0.00169	-0.00061	-0.086	-0.01232
600 ≤ ADNT < 2,000	1	N/A	N/A	N/A	N/A
2,000 ≤ ADNT < 9,000	0	N/A	N/A	N/A	N/A
9,000 ≤ ADNT	5	-0.00474	-0.01255	-302.181	-0.00968

***, ** and * denote statistical significance at 0.01, 0.05 and 0.1 level of confidence respectively.

Source: own elaboration.

Table 7
Change in the level of liquidity due to the minimum tick size reduction and tick size – preceding period: June 2018 to February 2019, succeeding period: April 2019 to December 2019

Tick size	*n*	PQCS	PECS	ILLIQ	TURN
Panel A: whole sample (n = 502)					
< 0.01	167	-0.00111	-0.00017	-0.756	-0.0111***
≥ 0.01	335	-0.00314***	-0.00215***	-5.887	0.00071
Reduction	243	-0.00216	-0.00094	-5.306	-0.0063***
No change/increase	259	-0.00275***	-0.00200***	-3.124	-0.00036
Panel B: shares listed on the WSE (n = 358)					
< 0.01	87	-0.00026	0.000251	18.622*	-0.0148***
≥ 0.01	271	-0.00253***	-0.00151***	-0.378	0.00018
Reduction	154	-0.00225**	-0.00124*	2.551	-0.00596*
No change/increase	204	-0.00178**	-0.00096*	5.513	-0.00157*
Panel C: shares listed in the ATS (n = 144)					
< 0.01	80	-0.00204	-0.00062	-21.829	-0.00712**
≥ 0.01	64	-0.00570*	-0.00487***	-29.218	0.00298
Reduction	89	-0.00201	-0.00042	-18.900	-0.0068**
No change/increase	55	-0.00634*	-0.00588***	-35.161	0.00412

***, ** and * denote statistical significance at 0.01, 0.05 and 0.1 level of confidence respectively.

Source: own elaboration.

Table 8
Change in the level of liquidity due to the minimum tick size reduction and tick size – preceding period: February 2019, succeeding period: April 2019

Tick size	*n*	PQCS	PECS	ILLIQ	TURN
Panel A: whole sample (n = 502)					
< 0.01	167	-0.00177	-0.00102	-6.749	-0.0244***
≥ 0.01	335	-0.00094	-0.00045	16.239	0.00028
Reduction	243	-0.00101	-0.00056	-1.494	-0.01492**
No change/increase	259	-0.00141	-0.00071	18.055	-0.00135
Panel B: shares listed on the WSE (n = 358)					
< 0.01	87	-0.00061	0.00110	10.069	-0.04204**
≥ 0.01	271	-0.00022	0.00051	15.212	0.00077
Reduction	154	-0.00007	0.00121*	13.559	-0.02068**
No change/increase	204	-0.00050	0.00023	14.267	-0.00130
Panel C: shares listed in the ATS (n = 144)					
< 0.01	80	-0.00302	-0.00332	-25.037	-0.00512
≥ 0.01	64	-0.00399	-0.00450	20.588	-0.00180
Reduction	89	-0.00262	-0.00363	-27.540	-0.00495
No change/increase	55	-0.00480	-0.00420	32.104	-0.00152

***, ** and * denote statistical significance at 0.01, 0.05 and 0.1 level of confidence respectively.

Source: own elaboration.

Table 9
Change in the level of liquidity due to the minimum tick size reduction – preceding period: April 2018 to December 2018, succeeding period: April 2019 to December 2019

Measure	PQCS	PECS	ILLIQ	TURN
Panel A: whole sample (n = 502)				
Before	0.04526	0.02363	106.229	0.01936
After	0.04238	0.02194	100.163	0.01789
Mean difference $\bar{d}$	-0.00287***	-0.00168***	-6.067	-0.00147
t-statistics	3.086	2.992	0.786	1.045
Panel B: shares listed on the WSE (n = 358)				
Before	0.03059	0.01607	60.061	0.01848
After	0.02829	0.01461	61.966	0.01703
Mean difference $\bar{d}$	-0.00230***	-0.00146***	1.905	-0.00145
t-statistics	3.305	3.314	0.413	0.994
Panel C: shares listed in the ATS (n = 144)				
Before	0.08171	0.04243	221.010	0.02155
After	0.07742	0.04017	195.124	0.02004
Mean difference $\bar{d}$	-0.00429	-0.00225	-25.886	-0.00151
t-statistics	1.562	1.377	1.064	0.459

***, ** and * denote statistical significance at 0.01, 0.05 and 0.1 level of confidence respectively.

Source: own elaboration.

Table 10
Change in the level of liquidity due to the minimum tick size reduction – preceding period: April 2018, succeeding period: April 2019

Measure	PQCS	PECS	ILLIQ	TURN
Panel A: whole sample (n = 502)				
Before	0.04045	0.02098	99.269	0.01594
After	0.03885	0.02022	85.444	0.01889
Mean difference $\bar{d}$	-0.00160	-0.00077	-13.825	0.00296
t-statistics	1.364	1.035	1.043	1.237
Panel B: shares listed on the WSE (n = 358)				
Before	0.02696	0.01428	59.072	0.01402
After	0.02544	0.01355	52.864	0.01875
Mean difference $\bar{d}$	-0.00153*	-0.00073	-6.208	0.00473*
t-statistics	1.720	1.020	0.597	1.686
Panel C: shares listed in the ATS (n = 144)				
Before	0.07340	0.03764	199.205	0.02069
After	0.07218	0.03678	166.442	0.01925
Mean difference $\bar{d}$	-0.00179	-0.00086	-32.762	-0.00144
t-statistics	0.517	0.457	0.854	0.315

***, ** and * denote statistical significance at 0.01, 0.05 and 0.1 level of confidence respectively.

Source: own elaboration.

Table 11
Change in the level of liquidity due to the minimum tick size reduction and liquidity band – preceding period: April 2018 to December 2018, succeeding period: April 2019 to December 2019

Band	*n*	PQCS	PECS	ILLIQ	TURN
Panel A: whole sample (n = 502)					
ADNT < 10	215	-0.00314*	-0.00199*	-23.968	0.00333***
10 ≤ ADNT < 80	189	-0.00294**	-0.00166**	9.021	-0.00181
80 ≤ ADNT < 600	58	-0.00224***	-0.00109**	-7.136	-0.01352*
600 ≤ ADNT < 2,000	22	-0.00322**	-0.00060*	1.690	-0.01340
2,000 ≤ ADNT < 9,000	8	-0.00143***	-0.00068***	-0.00006	-0.00272
9,000 ≤ ADNT	10	0.00001	-0.00221	77.906	-0.00093
Panel B: shares listed on the WSE (n = 358)					
ADNT < 10	108	-0.00209	-0.00174	2.240	0.00126
10≤ADNT < 80	161	-0.00236**	-0.00140**	4.535	0.00141
80 ≤ ADNT < 600	55	-0.00230***	-0.00114**	-7.585	-0.01550**
600 ≤ ADNT < 2,000	21	-0.00330**	-0.0062*	1.787	-0.00026
2,000 ≤ ADNT < 9,000	8	-0.00143***	-0.00068***	-0.00006	-0.00272
9,000 ≤ ADNT	5	-0.00238	-0.00552	17.974	-0.00042**
Panel C: shares listed in the ATS (n = 144)					
ADNT < 10	107	-0.00420	-0.00224	-50.420	0.00542**
10 ≤ ADNT < 80	28	-0.00626	-0.00319	34.818*	-0.02036**
80 ≤ ADNT < 600	3	-0.00115	-0.00008	1.084	0.0227
600 ≤ ADNT < 2,000	1	N/A	N/A	N/A	N/A
2,000 ≤ ADNT < 9,000	0	N/A	N/A	N/A	N/A
9,000 ≤ ADNT	5	0.00240	0.00111	137.838	-0.00144

***, ** and * denote statistical significance at 0.01, 0.05 and 0.1 level of confidence respectively.

Source: own elaboration.

Table 12
Change in the level of liquidity due to the minimum tick size reduction and liquidity band – preceding period: April 2018, succeeding period: April 2019

Band	*n*	PQCS	PECS	ILLIQ	TURN
Panel A: whole sample (n = 502)					
ADNT < 10	215	-0.00032	0.00040	-21.351	0.00298*
10 ≤ ADNT < 80	189	-0.00268*	-0.00201*	-9.050	0.00011
80 ≤ ADNT < 600	58	-0.00259***	-0.00097*	-4.788	0.01630
600 ≤ ADNT < 2,000	22	-0.00200***	-0.00060**	-0.671	-0.00514
2,000 ≤ ADNT < 9,000	8	-0.00104***	-0.00049***	-0.00014**	-0.00068
9,000 ≤ ADNT	10	-0.00293	-0.00168	-34.674	-0.00028
Panel B: shares listed on the WSE (n = 358)					
ADNT < 10	108	-0.00024	0.00079	-3.378	0.00132
10 ≤ ADNT < 80	161	-0.00184	-0.00159	-9.508	0.00524
80 ≤ ADNT < 600	55	-0.00263***	-0.00099*	-5.046	0.01388
600 ≤ ADNT < 2,000	21	-0.00168***	-0.00045**	-0.700	-0.00240
2,000 ≤ ADNT < 9,000	8	-0.00104***	-0.00049***	-0.00014**	-0.00068
9,000 ≤ ADNT	5	-0.00725	-0.00441*	-6.920	-0.00011
Panel C: shares listed in the ATS (n = 144)					
ADNT < 10	107	-0.00040	0.00001	-39.491	0.00466
10 ≤ ADNT < 80	28	-0.00715	-0.00443	-6.422	-0.02940
80 ≤ ADNT < 600	3	-0.00178	-0.00071	-0.067	0.06063
600 ≤ ADNT < 2,000	1	N/A	N/A	N/A	N/A
2,000 ≤ ADNT < 9,000	0	N/A	N/A	N/A	N/A
9,000 ≤ ADNT	5	0.00140	0.00105	-62.427	-0.00045

***, ** and * denote statistical significance at 0.01, 0.05 and 0.1 level of confidence respectively.

Source: own elaboration.

Table 13
Change in the level of liquidity due to the minimum tick size reduction and tick size – preceding period: April 2018 to December 2018, succeeding period: April 2019 to December 2019

Tick size	*n*	PQCS	PECS	ILLIQ	TURN
Panel A: whole sample (n = 502)					
< 0.01	167	-0.00099	0.00014	-3.142	-0.00621**
≥ 0.01	335	-0.00381***	-0.00259***	-7.525	0.00090
Reduction	243	-0.00222	-0.00092	-6.839	-0.00250
No change/increase	259	-0.00349***	-0.00240***	-5.343	-0.00050
Panel B: shares listed on the WSE (n = 358)					
< 0.01	87	-0.00031	0.00006	14.443	-0.00728*
≥ 0.01	271	-0.00294***	-0.00194***	-2.120	0.00043
Reduction	154	-0.00259**	-0.00173**	-1.058	-0.00116
No change/increase	204	-0.00209**	-0.00125**	4.142	-0.00166
Panel C: shares listed in the ATS (n = 144)					
< 0.01	80	-0.00172	0.00023	-22.264	-0.00504
≥ 0.01	64	-0.00750**	-0.00535**	-30.413	0.00290
Reduction	89	-0.00157	0.00048	-16.842	-0.00481
No change/increase	55	-0.00869**	-0.00667***	-40.521	0.00381

***, ** and * denote statistical significance at 0.01, 0.05 and 0.1 level of confidence respectively.

Source: own elaboration.

Table 14
Change in the level of liquidity due to the minimum tick size reduction and tick size – preceding period: April 2018, succeeding period: April 2019

Tick size	*n*	PQCS	PECS	ILLIQ	TURN
Panel A: whole sample (n = 502)					
< 0.01	167	-0.00041	0.00067	-39.944	0.00362
≥ 0.01	335	-0.00220*	-0.00148*	-0.805	0.002629
Reduction	243	-0.00103	-0.00016	-25.904	0.00601
No change/increase	259	-0.00215	-0.00134	-2.492	0.00010
Panel B: shares listed on the WSE (n = 358)					
< 0.01	87	-0.00209	-0.00021	-29.225	0.01070
≥ 0.01	271	-0.00135	-0.00090	1.181	0.00281
Reduction	154	-0.00274**	-0.00131	-18.108	0.01145*
No change/increase	204	-0.00061	-0.00029	2.776	-0.00035
Panel C: shares listed in the ATS (n = 144)					
< 0.01	80	0.00142	0.00163	-51.601	-0.00407
≥ 0.01	64	-0.00581	-0.00397*	-9.215	0.00185
Reduction	89	0.00195	0.00184	-39.393	-0.00342
No change/increase	55	-0.00784	-0.00523*	-22.032	0.00176

***, ** and * denote statistical significance at 0.01, 0.05 and 0.1 level of confidence respectively.

Source: own elaboration.

Table 15
Change in the level of liquidity due to the minimum tick size reduction – preceding period: June 2018 to February 2019, succeeding period: April 2019 to December 2019

Measure	PQCS	PECS	ILLIQ	TURN
Panel A: whole sample (n = 502)				
Before	0.04425	0.02323	99.134	0.00109
After	0.04171	0.02169	96.584	0.00095
Mean difference $\bar{d}$	-0.00253***	-0.00154***	-2.551	-0.00013*
Std. deviation S(d)	0.0190	0.0114	139.844	0.0015
t-statistics	2.987	3.025	0.409	1 .998
Panel B: shares listed on the WSE (n = 358)				
Before	0.02983	0.01548	57.580	0.00102
After	0.02805	0.01450	59.910	0.00086
Mean difference $\bar{d}$	-0.00178***	-0.00098**	2.329	-0.00016**
Std. deviation S(d)	0.0117	0.0073	79.032	0.0014
t-statistics	2.887	2.542	0.558	2.195
Panel C: shares listed in the ATS (n = 144)				
Before	0.08008	0.04250	202.442	0.00126
After	0.07568	0.03958	187.759	0.00119
Mean difference $\bar{d}$	-0.00440*	-0.00292*	-14.683	-0.00007
Std. deviation S(d)	0.0303	0.0178	229.597	0.0018
t-statistics	1.741	1.964	0.767	0.478

***, ** and * denote statistical significance at 0.01, 0.05 and 0.1 level of confidence respectively.

Source: own elaboration.

Table 16
Change in the level of liquidity due to the minimum tick size reduction and liquidity band – preceding period: June 2018 to February 2019, succeeding period: April 2019 to December 2019

Band	*n*	PQCS	PECS	ILLIQ	TURN
Panel A: whole sample (n = 502)					
ADNT < 10	215	-0.00297*	-0.00213**	-13.577	0.00013*
10 ≤ ADNT < 80	189	-0.00251*	-0.00120*	7.578	-0.00009
80 ≤ ADNT < 600	58	-0.00174**	-0.00093*	-7.138	-0.0011***
600 ≤ ADNT < 2,000	22	-0.00272**	-0.00066***	1.375	-0.00054
2,000 ≤ ADNT < 9,000	8	-0.00124***	-0.00060***	-0.00005	-0.00017*
9,000 ≤ ADNT	10	0.00130	-0.00127	59.013	-0.00008
Panel B: shares listed on the WSE (n = 358)					
ADNT < 10	108	-0.00167	-0.00117	3.897	0.00002
10 ≤ ADNT < 80	161	-0.00187**	-0.00089*	4.915	0.00004
80 ≤ ADNT < 600	55	-0.00183**	-0.00099*	-7.588	-0.0012***
600 ≤ ADNT < 2,000	21	-0.00285**	-0.00071***	1.440	0.000002
2,000 ≤ ADNT < 9,000	8	-0.00124***	-0.00060***	-0.00005	-0.00017*
9,000 ≤ ADNT	5	0.00241	-0.00135	1.746	-0.00001
Panel C: shares listed in the ATS (n = 144)					
ADNT < 10	107	-0.00430	-0.00310*	-31.215	0.00023*
10 ≤ ADNT < 80	28	-0.00623	-0.00297	22.889	-0.00082**
80 ≤ ADNT < 600	3	-0.00007	0.00020	1.115	0.00028
600 ≤ ADNT < 2,000	1	N/A	N/A	N/A	N/A
2,000 ≤ ADNT < 9,000	0	N/A	N/A	N/A	N/A
9,000 ≤ ADNT	5	0.00020	-0.00118	116.279	-0.00015

***, ** and * denote statistical significance at 0.01, 0.05 and 0.1 level of confidence respectively.

Source: own elaboration.

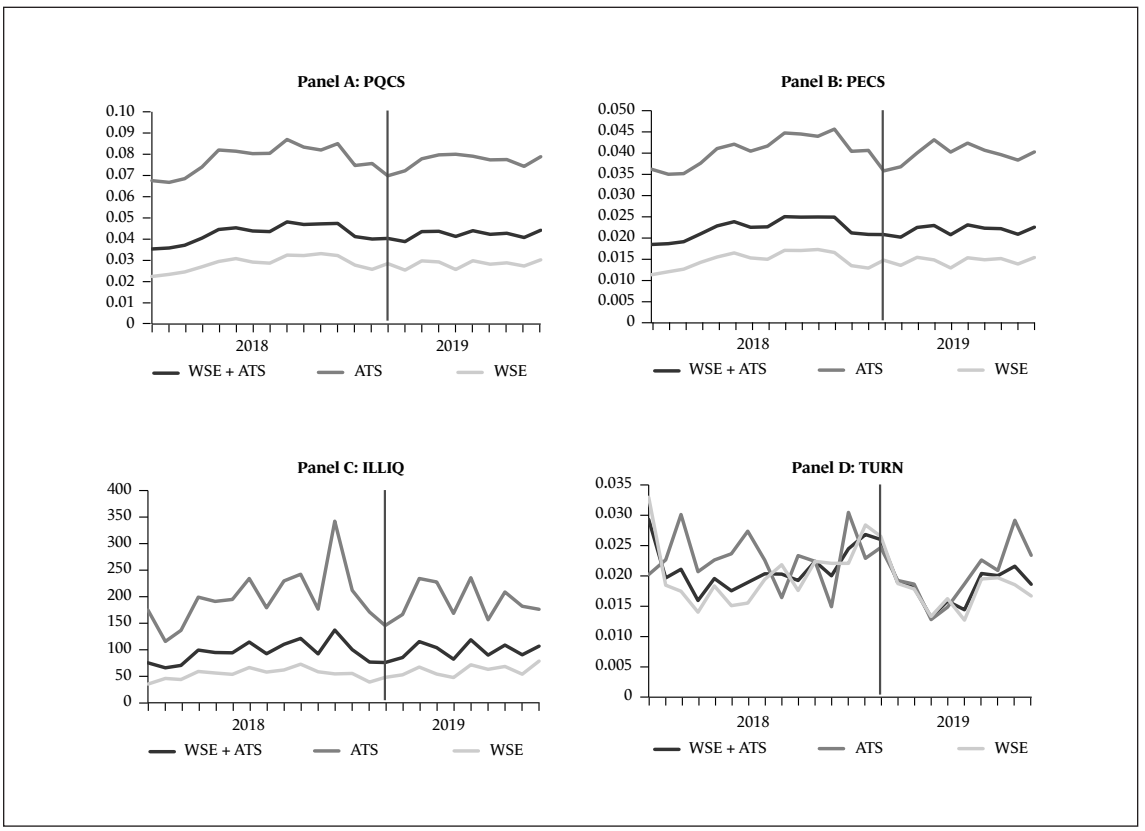
Table 17
Change in the level of liquidity due to the minimum tick size reduction and tick size – preceding period: June 2018 to February 2019, succeeding period: April 2019 to December 2019

Tick size	n	PQCS	PECS	ILLIQ	TURN
Panel A: whole sample (n = 502)					
< 0.01	167	-0.00178	-0.00057	8.878	-0.0005***
≥ 0.01	335	-0.00291***	-0.00202***	-8.245	0.00004
Reduction	243	-0.00254*	-0.0012	1.269	-0.00027**
No change/increase	259	-0.00253**	-0.00185***	-6.135	-0.000005
Panel B: shares listed on the WSE (n = 358)					
< 0.01	87	-0.00035	0.00022	18.699*	-0.0007***
≥ 0.01	271	-0.00224***	-0.00136***	-2.926	0.00001
Reduction	154	-0.00223**	-0.00126*	2.022	-0.00027*
No change/increase	204	-0.00145*	-0.00077*	2.561	-0.00007*
Panel C: shares listed in the ATS (n = 144)					
< 0.01	80	-0.00333	-0.00143	-1.804	-0.00028*
≥ 0.01	64	-0.00573*	-0.00477***	-30.782	0.00019
Reduction	89	-0.00307	-0.00110	-0.032	-0.00027*
No change/increase	55	-0.00655*	-0.00585***	-38.391*	0.00025

***, ** and * denote statistical significance at 0.01, 0.05 and 0.1 level of confidence respectively.

Source: own elaboration.

Figure 1
Dynamics of liquidity measure in the analysed period



Source: own elaboration.