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A method is proposed for estimating the effect of transaction costs on volatility, using the tick-size as proxy. The method follows three steps: 1) collect only the cases where the tick-size changes from one regime to another, 2) estimate the effect with and without the order book size, and 3) use local data on tick-size and volatility, but instruments from international markets. The first step handles stationarity and dependence. The second step is used to infer the effect of a symmetric transaction cost as tick-size is a revenue and not a cost for liquidity providers. A regression with and without the order book may therefore indicate how much this asymmetry is likely to affect the result. The third step handles endogeneity. The method is applied on intraday data from the Norwegian Stock Exchange (OSE). The results show that both the tick-size and inferred transaction costs seem to have surprisingly little impact on volatility.

Keywords: finance, financial transaction tax, FTT, security transaction tax, STT, Tobin tax, tick-size
JEL Classification: G12, G14, H25, G28

1. Introduction

Understanding how transaction costs affect the market is important in order to understand how exchanges should manage their markets in the best way possible and how government should regulate financial markets. Furthermore, many economists and NGOs argue in favor of a financial transaction tax (FTT) that raises transaction costs. The idea is that the tax will acts as "sand in the machinery" (Tobin, 1978), slow the speed of transactions and thereby stabilize the market. This study will shed some light on this debate.

The main problem with estimating the effect of transaction costs is that changes in such costs occur infrequently. A solution is to compile the few cases where governments have imposed or removed FTTs or similar costs. The advantage with such studies is that there is a tight relationship between what is studied and what is observed, but a weakness is that a small number of observations gives limited power.

The approach taken in this study is to use the tick-size, the smallest permissible difference between ask and bid quotes, as a proxy for transaction costs. With this approach, every traded stock is a natural experiment. However, there are three main challenges with having tick-size as a proxy for transaction costs, and the solution to these are the main contributions of this paper.

First, there is a considerable amount of non-stationarity both in terms of autocorrelation and heteroscedasticity in the sample. The tick-size is determined by the tick-size scheme defined by the exchange (see Table 1 in section 3.3). This scheme defines different tick-sizes for different price ranges, so the tick-size is determined by the price range that a stock's price lies within. The underlying problem is therefore that if the tick-size and price do not change, the next observation is only a version of the previous.

For this reason, only the days where the tick-size changed were included. After collecting only these cases, the log change in all involved variables was calculated. This took a heavy toll on the number of observations. Originally, there were 111,822 daily observations extracted from intraday data at the Oslo Stock Exchange (OSE) for the period 2003-2010 for 150 Norwegian shares. After filtering, there were 1,369 observations remaining. The size of the remaining sample is however sufficient to provide tests with good power if observations are reasonably independent, which diagnostics suggest is the case. Statistics also indicated that the restrictive filtering resulted in a very dispersed sample.

Second, for the traders that submit limit orders (liquidity providers) a larger spread is a revenue and not a cost. However, we do have data on the amount of liquidity provided, so it is possible to infer what would have happened if the response of the liquidity providers was reversed. Specifically, a regression with and without the order book size and a regressing the tick-size on the order book size can help us understand how a symmetric transaction cost may affect volatility in a different way. We can then infer how volatility would be affected if the interaction between liquidity provision and tick-size was reversed, as we would expect with a symmetric transaction cost.

Third, there is an endogeneity problem. The tick size is reasonably exogenous, at least when we have the price as a control. However, there may be endogeneity between this price and volatility, and between order book size and volatility. This problem can be addressed by using instrumental variables. As a relatively small exchange, it is unlikely that stock prices or volatility at Oslo Stock Exchange affect international financial data much. Data from other markets are therefore used as instruments to check whether the results are robust with respect to endogeneity.

A more trivial problem is also a well-known problem that the common measure of volatility is inflated in intraday data due to the discreetness of the pricing grid. This is addressed by using the range volatility measure, which is well known to be a very robust volatility measure.

The (Grossman, 1981) model (GS) can be a useful framework for interpreting the results. In the GS model, we have noise traders, informed traders and uninformed traders. The noise traders have a destabilizing role, adding volatility to the price that would otherwise not be there. The informed on the other hand, have a stabilizing role, keeping the price close to fundamentals.

Hence, the more informed traders there are, the less volatile the price will be. The effect of transaction costs on stability is therefore, in the GS model, determined by which trader type is most affected. If noise traders are more discouraged by increased costs, we would expect a tax to have a stabilizing effect. If the informed traders or uninformed are affected more, the relative increase in noise trading will raise volatility and make the market less stable. The framework of GS will be used to interpret the results in the discussion section.

The plan of the paper is as follows. The literature is reviewed in the next section. In section 2, the data is described and presented. In section 3, the model and results of the regressions are presented. In section 4 the results are discussed.

2. Literature

Both Ke, et al. (2004) and Bessembinder (2000) finds that volatility and the tick-size are positively related, the former using intraday and the latter using daily observations. However, the effect of a tax is an issue in Hau (2006), who uses the range estimator to control for microstructure noise. Hau also conclude that an increase in tick-size increases volatility. Neither of these studies discuss how interaction with the order book can be used to infer the effect of transaction cost, and neither consider only the cases when stocks shift from one tick-size regime to another.

Aliber, et al. (2003) use estimated transaction costs inferred from deviations in the covered interest rate parity and find that higher trading costs in terms of the spread are associated with higher volatility. However, as noted by Werner (2003), this creates an endogeneity problem. It is difficult to determine the extent to which the volatility is a cause or an effect of the spread. Lanne and Vesala (2010) attempt to mitigate this problem by controlling for fundamental volatility using the news count as a proxy.

Mulherin (1990) uses changes in initial margin requirements and the "uptick rule" as proxy for transaction costs. He studies annual volatility and estimated trading costs in an extensive period from 1887 to 1987. He is however not able to find conclusive evidence in either direction.

Except for these, studies on the effect of transaction costs on volatility for the most part focus on market-wide regulatory modifications or observed spread (as opposed to minimum spread/tick-size). The regulatory modifications may be changes in tick-size rules or changes in taxes or fees.

Clearly, those studies that focus on changes in an actual transaction tax or fee (Campbell and Froot, 1994; Colliard and Hoffmann, 2013; Ness, et al., 2000; Saporta and Kan, 1997; Umlauf, 1993) have the advantage that the variable analyzed and the phenomenon they try to explain are more tightly connected. The main disadvantage is that such studies are often sensitive to accidental fluctuations in volatility at the time of the change.

Pomeranets and Weaver (2013) also consider a sample of several changes in market-wide regulations. They evaluate nine modifications in the New York State Securities Transaction Tax between 1932 and 1981 and find that individual stock volatility increased the volatility and widened the bid–ask spreads. There was, however, no significant effect on the volatility of portfolios.

(Deng, et al., 2018) considers market-wide changes in stamp-duty, but for stocks that are cross-listed in Hong Kong and Mainland China. Transaction costs change in only one of these exchanges, providing a proper counterfactual.

Most of the purely theoretical work either concludes that an FTT reduces volatility (Bianconia, et al., 2009; Ehrenstein, 2002; Ehrenstein, et al., 2005; Mannaro, et al., 2008; Stiglitz, 1989; Westerhoff, 2003; Westerhoff and Dieci, 2006) or finds an ambiguous effect (Hanke, et al., 2010; Shi and Xu, 2009). However, not all studies reach this conclusion (Rosenthal and Thomas, 2012).

In Kirchler, et al. (2011), a lab experiment shows that when investors are allowed to place limit orders, as is the case in most modern stock markets, a unilateral Tobin tax will increase the volatility. However, an encompassing tax has no effect.

In the literature, there are a couple of examples of rational expectations models in which the effect of a transaction tax on volatility is modelled. Song and Zhang (2005) and Kupiec (1996) assume overlapping generations.

(Dávila and Parlatore, 2019) derive the effect of transaction costs in a Grossman Stiglitz type of model. They conclude that one cannot argue that a transaction tax will make prices informative without knowing more in detail about what sort of heterogeneity describes the marketplace.

3. Data

The data were constructed from the Oslo Stock Exchange (OSE) data feed in the period January 2003 to April 2010 and contain all orders and trades for all instruments available in that period. There is at present no transaction tax in the Norwegian stock market.

There is a considerable advantage for the analysis that the tick-size at the OSE varies across multiple price ranges and that the data include the entire order book. The dispersion of liquidity in the sample is also beneficial, since liquidity and turnover are vital in this paper. Although the OSE is a peripheral exchange, foreign investors account for 88% of the trade.[1]

The total sample consisted of 111,822 daily observations for 146 different companies and 1,746 trading days. Prices were sampled at 60-second intervals, which meant about 440 data points each day with uninterrupted trading throughout the entire day.

3.1. Variation in the data

There is substantial dispersion in the companies listed on the Oslo Stock Exchange (OSE) with respect to both size and liquidity. The largest company is Statoil, which is a large corporation even by international standards, ranking as the sixty-seventh largest in the world.[2] The company has a daily average of 15,000 orders and close to 3,000 trades per day, not including transactions on the NYSE, on which it is also listed. On the opposite side of the scale, there are companies with very poor liquidity, so a minimum amount of trading activity (50 trades per day) was required to be included in the sample.

The most liquid stock in terms of trades per day was Renewable Energy Corporation with 3,353 trades per day. The least liquid stock in the sample was Inmeta, with average trades per day equal to the minimum requirement. Hence, the sample contains a mix of liquid and quite illiquid shares, which is an advantage since the number of trades plays an important role in this paper.

There is also considerable variation across time, with a substantial increase in trading activity at the end of the sample period.

3.2. Order book construction

The database contains the data feed that the OSE sends in real-time to its clients. The feed provides information on all the changes to the order book during opening hours. To transform the data into an order book, all the order book changes during a day for a specific company were retrieved from the database. The changes were then processed by an algorithm that reconstructed the order book by sequentially adding, removing, or modifying bids and asks according to the data feed.

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[1] Value weighted. http://www.vps.no/public/vps_eng/vps.no/About-us/Statistics

[2] According to Fortune: http://money.cnn.com/magazines/fortune/global500/2011/full_list/

After reconstruction, snapshots were taken of all levels in the order book with 60-second intervals. If no orders arrived within a 60-second interval, the snapshot would be a copy of the previous order book.

3.3. Description of the variables

Range (*latent volatility*) is a well-known volatility measure that Hau (2006) proposed for this type of studies. The traditional average mean square measure is inflated if the data is restricted to a price grid, as financial data often is. The expected asymptotic bias has been obtained by (Ball, 1988 ; Gottlieb and Kalay, 1985). It can be shown mathematically that the Range-measure does not have this bias, and own simulations as well as those in Hau (2006) confirms it. The Range measure is defined as

$$\hat{\sigma} = \frac{1}{T}\sum_{t=1}^{T} 2 \cdot \frac{p_{max,t} - p_{min,t}}{p_{max,t} + p_{min,t}}$$

where $p_{max,t}$ and $p_{min,t}$ are the maximum and minimum prices observed in sub-sample t. I calculated the minima and maxima from hourly sub-samples in which the price was sampled every 60 seconds.

RelTick (*relative tick-size*) is the proxy for transaction costs. RelRick is the tick-size relative to the daily mean price. The advantage with using the tick-size is that it is reasonably exogenous. The tick-size on Oslo Stock Exchange is mainly by the price level as seen in Table 1.

Table 1:

Tick-size regimes. Type refers to the type of stocks to which the regimes apply. "From date" means the date on which the tick-size regime was introduced (a regime ends when a new regime is introduced). Price from is the lowest price for which the associated tick-size is the minimum permissible spread. From 25 September 2006, the largest and most liquid stocks (the stocks included in the OBX index) were subject to a different tick-size regime. In addition, exchange traded funds (ETFs) have been subject to a separate scheme since 2009.

Type	From date	Price from	Tick-size
All	Pre 2000	0	0.01
		10	0.1
		50	0.5
		1000	1
All	2003-23-06	0	0.01
		10	0.1
		50	0.25
		150	0.5
		1000	1
All	2006-09-25	0	0.01
		10	0.05
		15	0.1
		50	0.25
		100	0.5
		250	1
OBX	2006-09-25	0	0.01
		15	0.05
		50	0.1
		100	0.25
		250	0.5
		500	1
OBX	2009-07-06	0	0.01
OBX	2009-08-30	0	0.0001
		0.5	0.0005
		1	0.001
		5	0.005
		10	0.01
		50	0.05
		100	0.1
		500	0.5
		1 000	1
		5 000	5
		10 000	10
ETF	2009-08-30	0.01	0.01
		5	0.05
		100	0.1
		250	0.25
		500	0.5
		5000	1

This tick-size scheme implies that a high price does not necessarily mean a small relative tick-size. RelTick is therefore given by the stocks position within the tick-size price range rather than the general price level. This ensures that the relative tick-size is determined by a considerable amount of randomness. However, within each price range, there will be some correlation between the price and the relative tick-size. For this reason, the mean daily **Price** is added as a control variable.

Since 2006, two tick-size tables existed for ordinary stocks. The table that applied for a specific stock depended on whether the stock belonged to "OBX", an index of the most liquid stocks at the exchange.

Since the tick-size regime depends on properties of the stock from 2006, the dummy variable **tz_type** is added to all regressions to capture this selectioneffect. tz_type is True if the stock is in the OBX index, and False if not.

TotOBVol (*total order book volume*) is the average total monetary amount in the order book throughout the trading day.

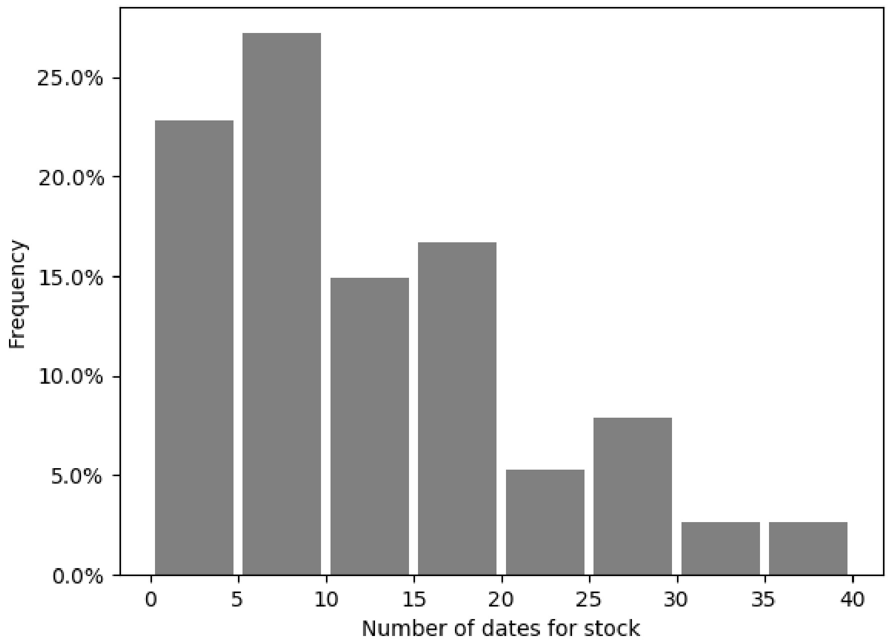
3.4. Filtering

Of full the sample of 111,822 trading days, only the cases where the minimum tick-size changed from one day to the other was selected, and the change in the relevant variables from the previous to the current tick-size regime was computed. To eliminate autocorrelation and heteroscedasticity as much as possible, successive shifts in and out of a tick-size regime were not included. The log difference between the variables before and after the tick-size change, was then computed. There were 1,929 such changes in the tick-size in the sample.

In addition, it was required that the tick-size had been binding (spread equal to the tick-size) on average more than 30% of the time before or after the tick-size change. It is of course much less chance that the tick-size is binding when the price is at its highest within an interval, than when it is at its lowest. Applying the threshold to either date, therefore ensured balance between the number of observations with increasing versus decreasing tick-size. 51.1 percent of the observations were increases in the tick-size. This requirement reduced the sample by 560 observations to 1,369. After this filter was applied the average frequency that the tick-size was binding was 45 percent. Since the tick-size is more likely to bind when the price is low in tick-size range, the tick-size was binding more often when it had increased, with an average bindingness for these observations of 70 percent.

The filtering reduced the number of unique dates from 1746 to 821 and unique firms from 146 to 114. The maximum number of dates for the same firm was reduced from 1,744 (99.9 percent of available dates) to 40 (4.9 percent of available dates). As seen from Figure 1 the number of observations were considerably smaller for most stocks. This dispersion resulted in a set of reasonably independent observations, as we shall see.

__Figure 1__: Frequency of observations for the stocks in the panel. The figure shows the fraction of the sample where the number of dates of the stocks lies in the interval indicated by the x-axis.



3.5. Descriptive statistics

The correlations after filtering are reported in Table 2. The correlation between the variables and the descriptive statistics are given in Table 3.

__Table 2__: Correlation matrix og the log change in the range volatility measure (Range), relative tick-size (RelTickSize), average price of the trading day (avgPrice) and the average order book volume during the trading day (orderBookVol). N=2,000.

	DLNRange	DLNRelTickSize	DLNavgPrice	DLNorderBookVol
DLNRange	1.00	-0.10	-0.11	0.19
DLNRelTickSize	-0.10	1.00	0.12	0.14
DLNavgPrice	-0.11	0.12	1.00	-0.28
DLNorderBookVol	0.19	0.14	-0.28	1.00

Table 3*: Descriptive statistics (before log transformations). The number of firms was 146 and the number of trading dates was 1,738. The sample period was January 2003 – April 2010. '=USD 1000.*

	Range	**RelTickSize**	**avgPrice**	**orderBookVol**
#obs	1,369	1,369	1,369	1,369
mean	-4.44	0.33 %	64	252,387
std	0.60	0.24 %	64	494,458
range	4.25	1.04 %	523	9,962,226
max	-2.31	1.05 %	527	9,966,460
min	-6.56	0.00 %	4	4,234
mode	-4.21	0.10 %	15	171,858
median	-4.48	0.25 %	51	106,578
skew	0.22	1.19	2.10	8.64
kurtosis	3.20	4.01	8.78	131.76

4. Model and results

To estimate the effect of transaction costs on volatility, log change in tick-size is regressed on change in range volatility at dates where the absolute tick-size has changed for a share. Selecting only the dates where there is a change in the tick-size significantly reduces problems with non-stationarity and dependence. Because the change in tick-size is associated with a change in price, the price change is added to the regression as a control variable. The results of the main model are presented in Table 4.

Table 4*: Regression of log change of relative tick-size, price and order book volume on the log change in the range volatility measure at dates when the absolute tick-size level changes.*

```
                            GLS Regression Results
==============================================================================
Dep. Variable:               DLNRange   R-squared:                       0.020
Model:                            GLS   Adj. R-squared:                  0.019
Method:                 Least Squares   F-statistic:                     8.990
Date:                Wed, 03 Mar 2021   Prob (F-statistic):           0.000132
Time:                        12:16:05   Log-Likelihood:                -1016.9
No. Observations:                1369   AIC:                             2040.
Df Residuals:                    1366   BIC:                             2055.
Df Model:                           2
Covariance Type:                  HC3
===============================================================================
                  coef    std err          z      P>|z|      [0.025      0.975]
-------------------------------------------------------------------------------
Intercept       0.0687      0.014      4.960      0.000       0.042       0.096
DLNTickSize    -0.0388      0.012     -3.205      0.001      -0.063      -0.015
DLNavgPrice    -0.1948      0.098     -1.993      0.046      -0.386      -0.003
==============================================================================
Omnibus:                       82.318   Durbin-Watson:                   2.040
Prob(Omnibus):                  0.000   Jarque-Bera (JB):              202.214
Skew:                           0.335   Prob(JB):                     1.23e-44
Kurtosis:                       4.759   Cond. No.                         6.16
==============================================================================

Notes:
[1] Standard Errors are heteroscedasticity robust (HC3)
```

As we can see, the tick-size has a slightly stabilizing effect of -0.0388. It is small and explains very little of the variance though, with an adjusted R-squared of only 2 percent.

The filtering reduced the sample to only 1.2 percent of original size. As indicated by the Durbin-Watson statistic in Table 4, the remaining observations are reasonably independent. The sample is sorted on firm identity and the Durbin-Watson statistic is very close to two, suggesting there is little correlation between observations for the same firm. As Figure 1 shows, this is probably because the number of observations for most firms is quite low. Though this is still a panel, the low correlation between observations makes it unnecessary to assume random or fixed effects.

In Table 5 an asymmetry dummy is added to the model in Table 4, which is positive if the change in the absolute dummy was positive. As we can see, the effect of tick-size is significant in both cases, but it switches sign in Table 5 and becomes positive. The effect of the dummy on the other hand is very significant and negative.

Table 5*: Measuring asymmetry. Regression as in Table 4, but with a dummy for the cases when the minimum tick-size has increased (DMinTickSizeUp).*

GLS Regression Results

Dep. Variable:	DLNRange	R-squared:	0.044
Model:	GLS	Adj. R-squared:	0.042
Method:	Least Squares	F-statistic:	21.14
Date:	Wed, 03 Mar 2021	Prob (F-statistic):	2.19e-13
Time:	12:16:07	Log-Likelihood:	-1000.0
No. Observations:	1369	AIC:	2008.
Df Residuals:	1365	BIC:	2029.
Df Model:	3		
Covariance Type:	HC3		

	coef	std err	z	P>|z|	[0.025	0.975]
Intercept	0.2381	0.033	7.116	0.000	0.173	0.304
DMinTickSizeUp[T.True]	-0.3435	0.061	-5.661	0.000	-0.462	-0.225
DLNTickSize	0.0805	0.026	3.091	0.002	0.029	0.132
DLNavgPrice	-0.1763	0.084	-2.103	0.035	-0.341	-0.012

Omnibus:	69.218	Durbin-Watson:	2.024
Prob(Omnibus):	0.000	Jarque-Bera (JB):	146.418
Skew:	0.322	Prob(JB):	1.61e-32
Kurtosis:	4.467	Cond. No.	7.14

Notes:
[1] Standard Errors are heteroscedasticity robust (HC3)

This suggest that it is mainly the increase in the absolute tick-size that produces the negative effect on volatility. This is puzzling, since it suggests that for some reason a reduction in the tick-size does not destabilize in the same way as an increase stabilize. A possible explanation may be that the market participants are forced to comply with the new tick-size regime when the tick-size increases. However, when the price falls, they are not forced to reduce the spread, so it may take time for the market participants to realize that the tick-size has taken effect. If there is a period where the spread is "too large" after a tick-size reduction, a smaller destabilizing effect would be expected.

4.1. The effect of transaction costs vs. tick-size

We can get an idea of how transaction costs would affect this market by assuming that liquidity providers behave exactly opposite when facing changes in transaction costs rather than changes in the tick-size. If liquidity providers behave opposite with respect to the tick-size, we may conjecture that the impact of tick-size on the order book size is reversed when the tick-size is substituted for a symmetric transaction cost. In order to get an idea of how this may affect results, order book volume is added to the regressors in Table 6.

Table 6*: Full GLS model. Regression of log change in relative tick-size, price and order book volume on the log change in the range volatility measure when the absolute tick-size level changes.*

GLS Regression Results

Dep. Variable:	DLNRange	R-squared:	0.056
Model:	GLS	Adj. R-squared:	0.054
Method:	Least Squares	F-statistic:	13.51
Date:	Wed, 03 Mar 2021	Prob (F-statistic):	1.08e-08
Time:	12:16:13	Log-Likelihood:	-991.26
No. Observations:	1369	AIC:	1991.
Df Residuals:	1365	BIC:	2011.
Df Model:	3		
Covariance Type:	HC3		

	coef	std err	z	P>|z|	[0.025	0.975]
Intercept	0.0602	0.014	4.432	0.000	0.034	0.087
DLNTickSize	-0.0535	0.012	-4.427	0.000	-0.077	-0.030
DLNavgPrice	-0.0355	0.122	-0.291	0.771	-0.275	0.204
DLNorderBookVol	0.1860	0.045	4.096	0.000	0.097	0.275

Omnibus:	68.738	Durbin-Watson:	2.004
Prob(Omnibus):	0.000	Jarque-Bera (JB):	204.832
Skew:	0.178	Prob(JB):	3.32e-45
Kurtosis:	4.861	Cond. No.	6.56

Notes:
[1] Standard Errors are heteroscedasticity robust (HC3)

As we can see, adding the order book size reduces the effect of the tick-size from -0.0388 in Table 4 to -0.0535 in Table 6. It follows from standard regression theory that adding the order book size to the regression means that its interaction with volatility through the tick-size is removed from the tick-size coefficient, since the effect is now delivered directly form the order book size. The difference of 0.0147 is therefore mainly the indirect effect of the tick-size on volatility that goes through the order book size (since the change in tick-size is reasonably exogenous). In Table 7 the change in tick-size is regressed on the order book size, and we see that the interaction is indeed positive.

Table 7*: Effect of the order book on relative tick-size. Regression of log change in order book volume on log change in relative tick-size when the absolute tick-size level changes.*

GLS Regression Results

Dep. Variable:	DLNorderBookVol	R-squared:	0.007
Model:	GLS	Adj. R-squared:	0.006
Method:	Least Squares	F-statistic:	6.751
Date:	Wed, 03 Mar 2021	Prob (F-statistic):	0.00947
Time:	12:16:17	Log-Likelihood:	-1131.5
No. Observations:	1369	AIC:	2267.
Df Residuals:	1367	BIC:	2277.
Df Model:	1		
Covariance Type:	HC3		

	coef	std err	z	P>|z|	[0.025	0.975]
Intercept	0.0555	0.015	3.743	0.000	0.026	0.085
DLNTickSize	0.0366	0.014	2.598	0.009	0.009	0.064

Omnibus:	437.215	Durbin-Watson:	2.075
Prob(Omnibus):	0.000	Jarque-Bera (JB):	21511.008
Skew:	-0.693	Prob(JB):	0.00
Kurtosis:	22.370	Cond. No.	1.27

Notes:
[1] Standard Errors are heteroscedasticity robust (HC3)

So, if we now assume, as mentioned above, that the impact of a transaction cost is exactly opposite, the indirect effect should be -0.0147 rather than +0.0147. Hence, we may conjecture that if the tick-size was replaced by a transaction cost, the effect would have been -0.0535-0.0147=-0.0682, rather than -0.0535+0.0147=-0.0388. Therefore, under the assumption of an exact opposite response by liquidity providers, we would expect that the stabilizing elasticity of transaction costs would be approximately -7 percent rather than approximately -4 percent from the tick-size.

4.2. Endogeneity

The above analysis does however assume that the independent variables are exogenous with respect to the dependent. It is reasonable to assume that the tick-size change is exogenous, if we do control for price change as is done. However, the price is not necessarily exogenous with respect to volatility, and neither are the actions of liquidity providers, measured by the order book size.

However, since the data here is from a relatively small national exchange, international financial variables are good candidates for instruments. The problem with endogeneity is the recurring interaction that occurs if the independent variables are affected by the dependent. It is usually modelled by assuming that the residual depends on the independent variables (Reiersøl, 1945; Wright, 1928).

The bias caused by this recurring interaction may go either way, it is impossible to know what harm is caused by just observing the endogenous variables. The only solution is to use variables that cannot be caused by the dependent variable. As a relatively small exchange, it is highly unlikely that the

Oslo Stock Exchange has any significant effect on internationally observed financial time series. The following variables will therefore be used as instruments for the model: NASDAQ composite index level, volume and range (the volatility measure, with no sub-periods, i.e. using the daily high and low), the petroleum price[3] and the US-EUR exchange rate.

As seen in Table 8, the relative tick-size is no longer significant when instruments are used. The results are similar in an unreported regression with the order book size. This suggest that the previous results are caused by endogeneity. Without instruments, one could incorrectly conclude that transaction costs have a small stabilizing effect, with an elasticity of about seven percentage on volatility. However, the instrumental variable analysis shows that this is most likely due to interaction between the order book and price variables.

Table 8*: IV-GLS model. Regression of log change in relative tick-size and price on the log change in the range volatility measure when the absolute tick-size level changes, estimated with the log change in relative tick-size, NASDAQ composite index level, volume and range (volatility), petroleum price[3] and the US-EUR exchange rate as instruments.*

```
                            GLS Regression Results
==============================================================================
Dep. Variable:               DLNRange   R-squared:                       0.016
Model:                            GLS   Adj. R-squared:                  0.015
Method:                 Least Squares   F-statistic:                     8.988
Date:                Thu, 04 Mar 2021   Prob (F-statistic):           0.000132
Time:                        14:36:35   Log-Likelihood:                -1020.0
No. Observations:                1369   AIC:                             2046.
Df Residuals:                    1366   BIC:                             2062.
Df Model:                           2
Covariance Type:                  HC3
==================================================================================
                     coef    std err          z      P>|z|      [0.025      0.975]
----------------------------------------------------------------------------------
Intercept_IV       0.0579      0.017      3.449      0.001       0.025       0.091
DLNTickSize_IV     0.0066      0.043      0.155      0.877      -0.077       0.090
DLNavgPrice_IV    -1.1132      0.841     -1.324      0.186      -2.761       0.535
==============================================================================
Omnibus:                       82.494   Durbin-Watson:                   2.039
Prob(Omnibus):                  0.000   Jarque-Bera (JB):              203.883
Skew:                           0.334   Prob(JB):                     5.34e-45
Kurtosis:                       4.769   Cond. No.                         67.3
==============================================================================

Notes:
[1] Standard Errors are heteroscedasticity robust (HC3)
```

5. Summary and conclusion

This study shows that the tick-size and transaction costs have surprisingly little impact on market volatility. It follows immediately from (Grossman and Stiglitz, 1980) that price volatility depends on the ratio of noise traders to informed and uninformed traders. Let us call the latter two types, in lack of a better word, the "rational" traders. In the original model, the number of

[3] Brent, https://datahub.io/core/oil-prices

rational traders is normalized to one, which means that the right-hand side of the demand-supply relation represents the number of noise traders per rational trader. It is straight forward from the (Grossman and Stiglitz, 1980) model that price volatility is increasing in the demand volatility of noise trading, when the number that acquire information is endogenous. Volatility of noise trading is in turn related to the number of noise traders per rational trader, due to the normalization and basic statistical theory.

It follows from this that if transaction costs raise the number of noise trades more than the number of rational traders, then volatility will increase. If it is the other way, increased costs will have a stabilizing effect. In the framework of Grossman and Stigliz, the results suggest that either none of the trader types reacts much to transaction costs or tick-size, or they are affected in a similar way so that the ration of noise to rational traders do not change much.

The analysis suggests that after keeping only the observations where the tick-size change, it is found that an increase in tick-size lowers volatility by 4 percent. It is further assumed that liquidity providers react exactly opposite to a transaction cost compared to a change in tick-size, so that the effect of tick-size has the opposite effect on order book size than estimated. If this is the case, it is inferred that an increase in transaction cost by one percent is likely to reduce volatility by 7 percent.

However, these estimates assume that the price and order book size are exogenous variables, which they are not. International financial time series are therefore used as instruments. After instrumental variables, it is found that the effect of both tick-size and order book becomes insignificant, suggesting that neither tick-size nor transaction costs have noticeable effects on volatility.

It is improbable that large changes in tick-size or transaction costs do not affect volatility. The results in this paper relates to the range of the tick-size reported in Table 1. It is likely that the exchange sets the price limits of the tick-size scheme in a way that it considers best. The fact that there seems to be little effect on moving from one tick-size regime to another, suggests that the scheme used in the period does a reasonably good job.

Though the results in this paper relates to relatively small tick-sizes or inferred transaction costs, they are still relevant for understanding how transaction costs affect volatility. In most cases, transaction costs are small. With respect to the debate on a financial transaction tax, the idea is usually that this tax should be quite small. The French tax currently in place is 0.2%. The size is this sample is, as one can see from Table 1, up to one percentage of the price.

Of course, one cannot conclude from a statistical test that an effect does not exist. Lack of significance only means that it is undetectable within a margin of error. However, with 1369 reasonably independent observations, we should have been able to pick up an effect of any economic significance. The results therefore suggest that both thick size and transaction costs seems to have surprisingly little effect on volatility.

6. Literature

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