The Danish FSA, February 2016

Algorithmic trading on the NASDAQ Copenhagen

Summary - Algorithmic trading on the NASDAQ Copenhagen

In recent years, trading in financial instruments has undergone structural changes on account of technological developments in computerized trading. Orders can now be made automatically, and algorithms are able to translate information into action much quicker than human share traders. EU market venues compete to attract algorithmic traders, and the resulting higher trading volume triggered by algorithmic trading. The competitive parameters include favourable transaction costs and technical facilities that enable algorithmic traders to minimise time spent on orders through the distribution system.

Algorithmic trading has replaced functions on the market that were previously carried out by specialists. For example, market marking carried out by humans has been virtually replaced by algorithms. These algorithms insert bids and asks on the market at very high speed, and they are updated at high frequency. Other algorithms break large orders into smaller ones in order to minimise the market effect, whilst other algorithms, in micro seconds, utilise small price differentials across market venues with a risk-free profit. This trend has changed the microstructure of the market, for example the liquidity and volatility, and this has an impact on the other investors.

In an international perspective, incidents have occurred involving algorithms where market prices took a considerable dive in a matter of few seconds. This has increased awareness of algorithmic trading, as well as the advantages and risks involved. So-called flash crashes have proven that there are operational risks linked to algorithmic trading, and that the market impact on the interactions of algorithmic traders is hard to predict.

In 2007, algorithms represented less than 10% of trading in terms of trading volume on the NASDAQ Copenhagen. In 2014, algorithms generated more than 50%. HFT is estimated to account for about 15% of total transactions.

In October 2012, as part of its Strategy 2015, the Danish FSA decided to analyse the market and players in order to improve the Authority's ability to identify and address the risks arising from the described developments. Against this background, the purpose of this report is to describe securities trading carried out by computers on the NASDAQ Copenhagen, as well as to review the Danish FSA's options for supervision of algorithmic trading, both according to current and future regulation. The report is broken down into three parts:

The first part describes the logical basis behind algorithmic trading by analysing the strategies used by algorithmic traders and high frequency traders. A summary of the literature shows that there are empirical bases for both the benefits and risks of HFT. In terms of liquidity, the majority of studies conclude that the spread of HFT has strengthened market liquidity. On the other hand, studies show that strategies of high frequency traders correlate more than the rest of the market, thus increasing the systemic risk of a sudden fall in prices on certain markets. According to a study conducted on the NASDAQ Stockholm, volatility has been reduced.

The second part of this report describes the extent of algorithmic trading on the NASDAQ Copenhagen, including HFT. Generally, algorithmic traders are not subject to Danish supervision. They are either direct trading members or traders who have bought access to the market venue through trading members.

The Danish FSA has analysed the effect of algorithmic trading representing an increasing part of the total trading volume on the NASDAQ Copenhagen. In terms of liquidity, the Danish FSA found that the bid-ask spread, which is a proxy for liquidity, has fallen to a degree corresponding to increased liquidity, and that market depth, which is another proxy for liquidity, has increased in the same period, as the percentage of algorithmic trading has risen. However, the best-price quantity has also fallen, but this can be explained by changed tick sizes. Overall, there are indications of improved liquidity. With regard to intra-day volatility, the introduction of an HFT market maker - a widespread HFT strategy on the NASDAQ Copenhagen - reduces intra-day volatility. Finally, there are no indications that the systemic risk has risen in line with the increase in the percentage of trading volume generated from algorithmic trading.

As for the risk of market abuse by high frequency traders, the review of trading data carried out by the Danish FSA does not indicate widespread use of trend-initiating strategies, which are considered as market abuse and can easily be exploited by high frequency traders. As trading in Danish C20 shares is widely (typically between 30-40%) traded on other markets than the NASDAQ Copenhagen, the occurrence of cross-market market abuse cannot be ruled out.

The third part of this report describes the current rules and security measures for algorithmic trading, as well as future security mechanisms which are to be introduced through a new EU regulation. In line with a number of other market venues, the NASDAQ Copenhagen has introduced automatic circuit breakers, which reduce the risk of large price fluctuations, e.g. due to misprogrammed algorithms or typing errors. The NASDAQ Copenhagen has also introduced fees on high order-to-trade ratios, as a large number of orders in proportion to the number of transactions may send the wrong signals to the market about liquidity.

The future European regulation on securities trading (MiFID II/MiFIR) will introduce a number of specific requirements for algorithmic traders and high frequency traders, and also give the Danish FSA better opportunities to monitor algorithmic trading on the NASDAQ Copenhagen. Algorithmic traders will be obliged to introduce initiatives to reduce the probability of algorithms acting inappropriately. These include testing algorithms and conducting regular risk controls. In particular, all high frequency traders must be authorised as investment firms and thus will be subject to Danish supervision or supervision by another EU Member State. This is expected to have a positive impact in relation to avoiding disturbances on the market and improving the possibility of solving market-abuse cases.

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Part 1 - The behaviour and impact of algorithmic traders

In algorithmic trading, based on its programming, a computer determines orders and inserts them on the market without human involvement. Algorithmic traders use a variety of strategies, ranging from algorithms, which replace the actions previously carried out by humans, such as execution algorithms and market making, to strategies requiring quick decision-making and execution, e.g. algorithms for arbitrage and news-based algorithms; strategies where high frequency traders play key roles. A review of the literature gives no clear indication as to whether algorithmic trading is positive for the market.

Table 1. Summary of benefits and risks of HFT from the literature

Benefits	**Risks**
• Lower transaction costs • Consistent prices on different markets • Rapidly updated prices • Lower volatility under normal market conditions • Reduced asymmetric information in situations where a high frequency trader runs a *market-maker strategy* • Higher liquidity	• *Arms race* -overinvestment in technology • Increased market-venue technology costs • Increased asymmetric information • Increased volatility in turbulent market conditions • Increased systemic risk: I. Correlating prices II. Liquidity risk • New possibilities for market abuse

1. Definitions and data

For the purposes of this report, algorithmic trading is defined as transactions where, on the basis of how it is programed, a computer algorithm has set individual order parameters. This means that the computer automatically decides one or more of the following order parameters: Whether the order should be sent to the market venue, the time of insertion of the order, price, quantity, as well as management of the insertion. In this context, decisions are taken by the computer, without human involvement[1].

Algorithmic trading cannot only be carried out by approved members on a market venue, it can also be through so-called *Direct Market Access* or *Sponsored Access:*

- Direct Market Access (DMA) is characterised by members of a market venue granting one or more customers access - through the trading member's IT infrastructure - to independently place orders on the market in the name of the trading member.

- Sponsored Access (SA) is characterised by a customer or a member of a market venue, getting his own direct access to the market venue, whereby the customer can place orders on the market in the name of the trading member. The difference compared with DMA access is that the customer's orders are not made through the member's IT infrastructure, but sent directly from the customer to the market.

For DMA and SA, the orders are made in the name of the trading member.

HFT is a sub-category of algorithmic trading. There are two approaches to identifying HFT:

- The direct approach: The trading participant must have an infrastructure aimed at minimising *latency.* This means the total time from a change on the market, to when the trader receives and analyses the information, the trader submits an order, and the order reaches the market venue. This requires the order-generating server to be placed closely to the matching system of the market venue (co-location), as well as a fast broadband connection. Using a co-location saves a millisecond delay, that would otherwise be in the distribution system, back and forth to the company's own IT system.

- The indirect approach. Several different quantitative measurements are used to define HFT (see SEC 2014[2] for an overview). In a technical advice to the European Commission[3], ESMA proposes that at least two messages per second must be submitted to the market venue. Alternatively, ESMA proposes that the criterion for becoming classified as a high frequency trader should be that the median of the lifetime of orders should be shorter than a threshold set in relation to the entire market venue.

[1] This definition is based on ESMA technical advice to the Commission: Algorithmic and HFT

[2] SEC 2014. https://www.sec.gov/rules/concept/2010/34-61358fr.pdf

[3] ESMA/2014/1569

1.1 Data

The description of algorithmic trading in this report is based on the order book from the NASDAQ Copenhagen. This data source contains information about each order and transaction carried out by trading members of the NASDAQ Copenhagen. Thus, for each order, the following can be seen:

Table 2. List of variables used in the data basis

Variable	Description
Time	The time when the order was inserted, updated or cancelled, and the time when the transaction was made, calculated down to the millisecond.
Type	Insertion of order, updating of order, cancellation of order or market transaction.
Trading member	The trading member is identified by three letters. Note that if a bank, which is not a trading member, sends an order to a trading member, who places the order on the market, the ID of the trading member will be stated.
ISIN	Identification of the financial instrument.
Price	Price calculated, as well as currency.
Volume	Number of shares.
User name	Identifies the relevant trader or algorithm responsible for sending the order to the market in the name of the trading member. The user name can be used to identify whether the order derives from an algorithm. Through combination of a trading member and user name, it is possible to identify the order and trades of an algorithm. In the same way, the combination of trading member and user name can be used to identify the SA customer. Finally, the user name can be used to identify whether the order was submitted through a DMA customer, but it cannot identify the DMA customer.

Data is available for all segments of the market, i.e. small, medium and large cap, and therefore comprises shares with different characteristics in relation to liquidity, market cap and number of market participants. This is a relatively large data set. In 2014, there were about 500 million new orders, updates of orders or cancellations of orders, as well as about 34 million market transactions. The period used is shown in each figure.

2. Behaviour of algorithmic traders

Table 3 shows a number of commonly known algorithmic strategies. Several strategies are merely automatizations of activities which previously required a physical person. However, there are other strategies such as trading strategies that have primarily arisen on the basis of the increased speed, which for such strategies is the prerequisite for achieving a positive return. In this connection, it is important to note that the use of an algorithm requires a certain volume of liquidity in the relevant instrument.

Some of the more modern and speed-dependent strategies, e.g. layering, are often considered by the authorities as price manipulation.

Table 3. Trading strategies based on algorithms

Type	Description	Use
Execution algorithm	An algorithm which breaks a large order into smaller orders. The purpose of this algorithm is to minimise the market impact from placing a large order on the market. This algorithm is not considered a HFT algorithm. It is used by investment firms acting for their own account or on behalf of a customer.	By breaking a large order into smaller orders, and placing these on the market, spread out over a period, a better price can be achieved, compared with placing a large order all at once, which may cause a price increase.
Banking algorithms	Algorithms carrying out transactions as part of the bank's operations. This could be to rebalance a portfolio on the basis of set criteria or to hedge positions for a market maker.	The algorithms may be regarded as automatization of bank operations and they save labour in addition to raising quality.
Market making	Algorithms which simultaneously insert bids and asks to make a profit on the spread.	This algorithm makes a profit on the difference between bid and ask, if there is equilibrium between buyers and sellers. Added to this are discounts from the market venue for acting as a liquidity supplier. This strategy is particularly suitable for HFT. The HFT element is included in the ability of the algorithm to quickly adapt the spread to new market conditions. The bids submitted are updated at high frequency in order to reflect a correct price. This means that the *order-to-trade ratio* will typically be high.

Arbitrage	Algorithms which analyse the correlation between instruments, and exploit any disequilibrium for short periods between the prices. This could be if an instrument is traded on two different market venues, and the price differs. In this case, the algorithm will buy the share at a low price on one market venue and sell it at a higher price on another market venue.	If the same instrument can be sold at a higher price than it can be bought at, a risk-free profit is achieved. This strategy can also be used by compositing several instruments which together give an identical cash flow as another instrument. This strategy can be used *cross market*, i.e. if the same product is traded on different market venues. This strategy can also be used *cross products*, i.e. for products, with heavily correlated prices, but which, at times, also deviate in terms of price. This strategy is particularly suitable for HFT. High frequency traders are able to capture such unstable prices within milliseconds, if not microseconds.
The use of statistically correlating instruments	This strategy resembles arbitrage, but is used for non-perfectly correlated instruments, where the transactions are then associated with a risk.	The use is similar to the arbitrage strategy, but bears a risk, in that the instruments may turn out to be less correlated than anticipated. This strategy is particularly suitable for HFT.
Direction-based/news-based	Algorithms which predict the future, short-term price direction of an instrument by scanning for information. Information should be understood in the widest terms and may thus be news flows on the internet or expectations for future order flows.	The algorithms make a profit on being the first to act on new information. This includes the ability to translate previous orders into expectations for future orders. This is possible because large orders are largely broken down into several small orders. This strategy is particularly suitable for HFT. The ability to analyse large data volumes and to translate these into action in a short period of time is vital for this strategy.
Sniffing algorithms	This algorithm tries to identify hidden liquidity, e.g. so-called "iceberg orders" in an order book. If a small order is filled quickly, it is likely that there is an underlying larger order. If an investment firm wishes to sell, this algorithm can be used to intercept bids on the market. This means that the algorithm can determine a good time for a sale. The algorithms can also be used to analyse the order book in a dark pool.	This algorithm attempts to gain information on the direction of the customer flow and thus future developments in market prices. Furthermore, a better price may be achieved if the order book and the hidden orders in it are known. This strategy is particularly suitable for HFT. The rate at which the order book is analysed is crucial to whether it can be used.
Momentum ignition/trend initiating	This algorithm will place several orders in order to initiate a trend, e.g. an upwards trend, to subsequently sell at a higher price. This strategy is mentioned as price manipulation in EU legislation.	A profit is achieved to the detriment of other market participants who are tempted to follow the trend. This strategy is particularly suitable for HFT. The rate at which it is possible to detect whether a trend has been established is crucial for the strategy.

Spoofing /Layering	This algorithm will first place a small sales order followed by large buy orders on the other side of the spread. The large bids give the impression of increased demand, and may raise the price. This means that there is a chance that another market participant places a higher bid that affects the original offer. This strategy is price manipulation.	A better price can be achieved. This strategy is particularly suitable for HFT. The rate at which the original order intended to spoof other market participants can be withdrawn is vital for this strategy.

3. Benefits and risks of algorithmic trading and HFT from the literature

This section describes a selection of the academic literature that has attempted to explain the impact on market quality of algorithmic trading, particularly HFT. After this, a known incident is reviewed, where algorithms were the cause of disturbance on the market, and against this background, the aspects of the structure of algorithmic trading and HFT that can result in market disturbance are deduced. The final section analyses some HFT strategies which are considered market abuse in EU legislation.

3.1 Benefits and risks from the literature

An empirical analysis has been conducted on whether the market becomes more or less volatile after the spread of algorithmic trading. Under normal market circumstances, HFT generates more stable prices. Broggard, Hendershott and Riordan (2013) argue that wrong pricing on the market is quickly perceived by high frequency traders, who exploit this, and adjust the prices. This generates smaller fluctuations and prices are quickly smoothed out, i.e. lower volatility.

In a stressed market, HFT may, however, increase instability. In these situations, high frequency traders start selling out of their portfolios quickly. Kirilenko, Kyle, Samadi and Tuzun (2011) state that, in certain situations, there is a risk that algorithmic traders will respond immediately and that this may reinforce volatility, while in similar situations people would consider their reaction more carefully. In the worst case scenario, a flash crash will occur.

An analysis carried out at NASDAQ Stockholm by Hagstromer and Nordén (2013) concludes that volatility is reduced as a consequence of HFT. In their article, Hagstromer and Nordén write that both high frequency traders with market-maker strategies, and high frequency traders following opportunistic strategies (arbitrage and momentum) contribute to lower volatility. The relative share of algorithmic trading on the market venue in Stockholm is comparable with the level in Copenhagen.

Another theme analysed is systemic return risk, that is, the risk that entire markets are affected inappropriately. As high frequency traders use cross-market strategies and cross-product strategies, the correlation between instruments may be stronger. Biais and Foucault (2014) argue that high frequency traders are likely to react to the same market signals and therefore will trade in the same direction. This may create downward spirals and magnify disturbance on the market. Empirically, Chaboud et al. (2009) conclude that the strategies of high frequency traders are more alike than the strategies of conventional traders. Thus prices tend to move more in the same direction. This increased correlation leads to an empirically proven systemic risk of a sudden drop in market cap on some markets.

The literature has demonstrated that the correlated reaction by the high frequency traders is significant for systemic liquidity risk. The risk arises on the basis of the algorithms following a market-maker strategy. Whereas a conventional market maker enters into a market-maker agreement on making bids and asks available, algorithmic traders following a market-maker strategy have no obligations. Therefore, they will only quote prices when the market is acting in a way that is profitable for them. In situations of volatility or general uncertainty, the algorithms will not quote bids and asks. Barnes (2010) describes how high frequency traders have built-in mechanisms to ensure that bids and asks are not quoted on the market in the event of large price fluctuations. This leads to a sudden collapse in liquidity. There is thus a systemic liquidity risk, and this has been proven empirically.

Similarly, Chaboud et al. (2014) show that high frequency traders reduce their quotes more than conventional market participants in the first minute after a large price fluctuation, but that they contribute more to liquidity than conventional market participants in the following hours.

Several articles speculate on whether HFT improves liquidity. The results point in both directions. However, the majority of studies show an improvement in liquidity with HFT. For example, Hendershott et al. (2011) show empirically that the bid-ask spread is reduced after introducing a new functionality that only considers HFT (auto-quoting) on the New York Stock Exchange.

Jones (2013) as well as Foucault et al. (2016) argue, however, that HFT may reduce liquidity. This is because, with the lower latency of high frequency traders, asymmetric information arises, as high frequency traders are able to respond more quickly to information from the market venues and news services than conventional market participants. The occurrence of HFT may force some conventional market participants to pull out. This is because the transactions entered into with high frequency traders are likely to be bad transactions, as the high frequency trader has the reaction advantage. For the same reason, a conventional market maker will quote more cautious prices or pull out entirely, resulting in an unwanted effect of asymmetric information which can expand the bid-ask spread. In other words, there can be negative effects associated with HFT which aggravate liquidity.

In the opposite situation, i.e. where a market maker is a high frequency trader, *asymmetric information* will be reduced, however. This is because the high frequency trader places passive orders and these are updated at high frequency with information from the market. Jovanovic and Menkveld (2011) show that this means that differences in information are confined between high-frequency market participants. Glosten and Milgrom (1985) argue that reduced information disadvantage can lead to a smaller bid-ask spread. This argument is from 1985, when there were no high frequency traders, and Jones (2013) transfers the notion to modern markets in that the role of the HFT market maker is to balance information. The lower costs of high-frequency market makers are likely to contribute to higher liquidity. Budish et al. (2015) argue, however, that in a market with several high frequency traders, the high-frequency market makers will quote cautiously, as there is a probability that the prices quoted are obsolete, and this might be exploited by other high frequency traders.

According to Jones (2013), the immediate benefit of algorithmic trading and HFT is that transactions can be made for a lower amount, as tasks carried out by humans can be replaced by computers. This results in lower transaction costs. As the share price reflects the present value of the future cash flows, including transaction costs, market cap will increase on introduction of algorithmic trading. A higher market cap means lower capital costs for undertakings and thus more investments.

Jones (2013) writes that the occurrence of HFT opens up for a more complete market in the form of uniform prices for the same instrument on different market venues. Price differences across market venues and the resulting arbitrage opportunity will quickly be captured by high frequency traders and thus adjusted. Also, published news will result more quickly in changed market prices.

According to Budish et al. (2015), a risk of HFT is that it leads to an *arms race*. The high frequency traders invest significant amounts in technology in order to reduce latency by a few milliseconds, even microseconds. This is not optimal in a societal perspective, as this is more or less about a zero-sum game and the amounts invested could have been invested differently to create value. The high frequency traders thus overinvest in technology in relation to the social optimum, and the race does not end until at the theoretical lower limit for latency, corresponding to orders being able to travel at the speed of light in a straight line from the high frequency trader's server to the server of the market venue.

A final risk is that the increased number of orders from high frequency traders puts pressure on market technology in the form of internet connections and servers, and this generates higher costs for the market venues that may be forwarded to conventional market participants[4].

The overall result of analysing the literature about HFT reveals no definitive answers to whether HFT is good or bad for the market. There are effects pulling either direction.

3.2 Flash Crash of 6 May 2010

The so-called Flash Crash of 6 May 2010[5], which is the best known example of disturbance on the market caused by algorithmic trading, illustrates a number of the risks mentioned.

An algorithm started selling futures contracts on the S&P 500 index, called E-Mini futures, at unusually high speed, at a time where the market was already volatile and where market depth, which is a measurement of liquidity, was low. This was because the algorithm was incorrectly programmed to execute 9% of the trading volume within the last minute, regardless of price or time. The quantity of E-mini futures sold as a consequence of this programming should normally have been sold over a period of several hours, but they were sold in just 20 minutes. The huge sales pressure was initially absorbed by other high frequency traders buying E-mini futures. This effect only lasted ten minutes, after which, high frequency traders starting liquidating their positions, as the algorithms were programmed to not hold large positions. This made the algorithm with the initial sales order increase the speed at which it was selling. The interdependence of high frequency traders thus created a sales spiral which resulted in falling prices on E-mini futures. This fall subsequently spread to the underlying shares, as other algorithms were using a cross-market arbitrage strategy, which meant that E-mini futures were bought, and the underlying shares were sold. The falling share prices meant that algorithms using a market maker strategy started pulling out of the market, as they had an in-built precautionary principle, whose design stipulated pulling back from the market in the event of falling stock prices under a given level. The market depth of E-mini futures on the buyer's side fell to 1% of what it had been in the morning of that same day. At this time, the market was in free fall, and the Dow Jones index lost 5.5% from 2:42 p.m. to 2:47 p.m. This fall was stopped by a five-second stock exchange break at Chicago Mercantile Exchange.

The incident illustrates the risk of increased instability at high volatility, as well as the amplified decline in prices as a consequence of the interdependence of the algorithms. Moreover, the Flash Crash is an example of how a decline in prices can spread to other instruments. Also the risk of market makers pulling out was confirmed. Table 4 sums up the risks demonstrated by the Flash Crash incident on 6 May 2010.

Table 4. Summary of risks learned from the Flash Crash on 6 May 2010

Operational risks	Description

[4] EU no. 65/2014 - MiFID II, preamble, Recital no. 62

[5] http://www.sec.gov/news/studies/2010/marketevents-report.pdf

Misprogramming	One or several algorithms are misprogrammed and act contrary to the intentions of the programmer.
Deployment of non-tested algorithms	When a new algorithm is deployed or an existing algorithm is changed, this may not have been sufficiently tested, with undesirable consequences to follow.
Failure to follow-up after deployment of an algorithm	After deployment of an algorithm, there is a risk that it will not act as intended. This risk is widespread if the algorithm is not tested, but even if tests have been carried out, the risk exists, as the transaction carried out by the algorithm depends on its external environment. Producing a realistic external environment in a test environment is difficult.
Failure to identify which algorithm is out of control.	If an algorithm acts inappropriately, it must be identified within a short period of time in order to abort it.
A lack of well-written risk models and security procedures.	A lack of security procedures may result in slower responsiveness in situations where algorithms act inappropriately. This also applies to non-algorithmic traders responding to a market with algorithmic trading.
Market risks	**Description**
Speed	The speed with which a price can fall. When algorithms are active on a market, the bid-ask speed is increased. This may result in sudden declines within very short periods of time.
The interdependence of the algorithms	When more than one algorithmic trader is active on a market, an interaction between these will develop. The consequences of this may be difficult to predict.
Liquidity risk	There is a risk that high-frequency market makers suddenly stop posting the bids and asks, thereby taking away liquidity.

Persons and undertakings, which use algorithms and have short-term possibilities of making financial gains, may be willing to compromise on security procedures that ought to be in place before deployment of an algorithm. These security procedures involve sufficient tests of algorithms, control of deployment of algorithms, automatic checks on the transactions of the algorithm, the possibility to identify which algorithm is acting inappropriately, as well as the possibility to quickly cancel the algorithm.

3.3 Market abuse caused by HFT

The EU Market Abuse Regulation[6], which enters into force on 3 July 2016, mentions some trading patterns which are considered as market manipulation. The Market Abuse Regulation reinforces and replaces the Market Abuse Directive from 2003 and ensures that the regulations are in line with market developments. The Regulation has been adapted to the new types of trading and automatization, i.e. algorithmic trading and HFT[7]. The illegal trading behaviour mentioned in the Market Abuse Regulation includes[8]:

- Orders are inserted to an extent where they disturb or delay the matching system of the market.

[6]EU no. 596/2014 - MAR

[7]See EU no. 596/2014 - MAR's, preamble, Recital no. 38

[8]See Article 12(2)(c) of EU no. 596/2014 - MAR

- Orders are inserted in a way that makes it difficult to identify orders aimed at trading. See spoofing/layering in table 3.

- Orders are inserted in a way that creates a misleading signal about supply, demand or the price of an instrument. Here the emphasis is on creating or bolstering a trend. See momentum ignition in table 3.

In other countries, there are examples of authority decisions on market abuse. In August 2013, the UK Financial Conduct Authority, the FCA, ordered an algorithmic trader, Panther Energy Trading LLC, to pay a fine of GBP 597,993 for market abuse of commodity contracts[9]. The market abuse strategy applied was layering. In this strategy, traders make and cancel orders that they never intend to carry out, as described in table 3.

Part 3 describes how the risks identified in this chapter are being complied with by the different security mechanisms at NASDAQ Copenhagen, the sponsoring member and future regulatory requirements.

[9] http://www.fca.org.uk/static/documents/newsletters/market-watch-44.pdf

Part 2: Analysis of algorithmic trading on the NASDAQ Copenhagen

Algorithmic trading accounts for about half of the total share trading volume on the NASDAQ Copenhagen Algorithmic trading accounts for a particularly large volume in the large-cap segment. The data available cannot determine the extent of algorithmic trading carried out by algorithms which set order parameters without human involvement, and the extent of algorithmic trading solely executing orders posted by human investors, respectively. High frequency trading is estimated to account for about 15% of trading volume on the NASDAQ Copenhagen. High frequency traders have a higher order-to-trade ratio than the remaining market participants and less time between active transactions. The part of algorithmic trading under Danish supervision is limited, however. The Danish FSA has analysed the importance of algorithmic trading for the market and concluded the following:

- *The bid-ask spread, which is a measurement of liquidity, has shrunk over the same period as the volume of algorithmic trading increased. During the same period, market depth increased, which is also a measurement of improved liquidity. As a final measurement for liquidity, the volume of orders available at the best price during the same period has decreased. However, other factors than the increasing extent of algorithmic trading can explain the developments in liquidity measurements. In particular, smaller tick sizes may explain the reduced bid-ask spread and the lower best price on the volume of orders available. Overall, there are indications of improved liquidity.*

- *Intra-day volatility falls after entry of an algorithmic market maker.*

- *No examples have been found on market abuse in the form of trend-initiating strategies carried out by algorithms.*

- *There are no indications that the systemic risk has risen, as the percentage of trading volume by algorithmic trading on the NASDAQ Copenhagen has increased.*

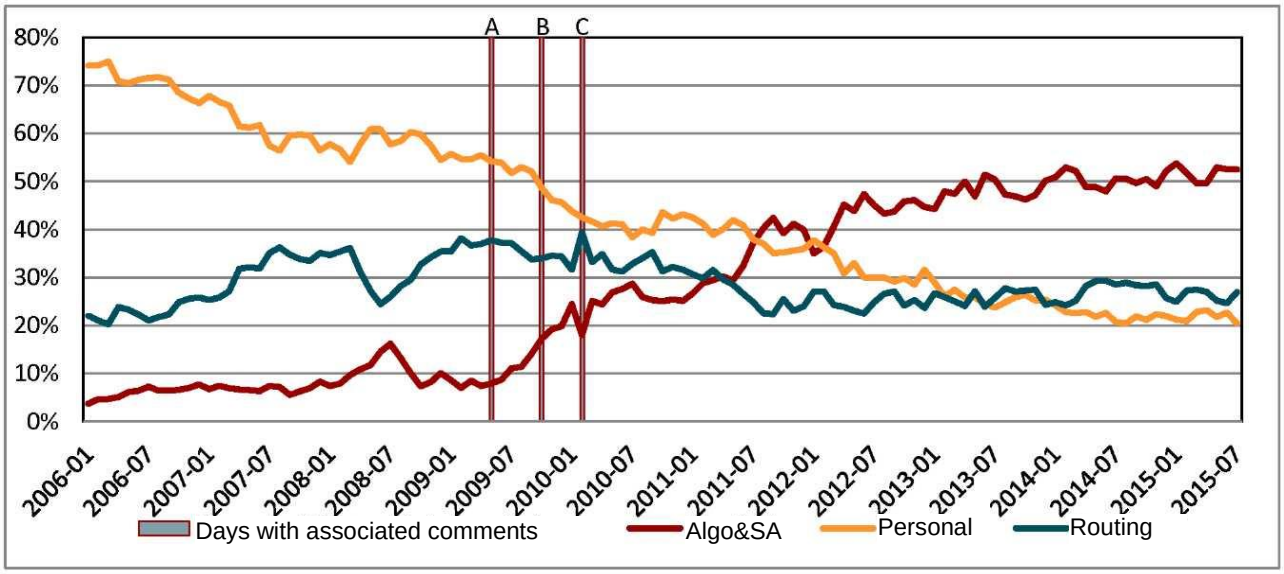
4. Extent and development of algorithmic trading

This section describes the developments in the percentage of trading volume from algorithmic trading in the order book on the NASDAQ Copenhagen. This section also describes the segments of the market in which algorithmic traders are active, as well as the extent of algorithmic traders under Danish supervision.

4.1 Trading volume

According to the NASDAQ Copenhagen, the share of algorithmic trading in shares admitted to trading on the NASDAQ Copenhagen increased from less than 10% in 2007 to about 50% of the total order-book trading volume in 2014, see figure 1. The bond market has not undergone similar developments and is generally not traded using algorithms.

Figure 1. The development in algorithmic trading, direct trading, as well as trading through DMA accesses



Note: *Personal Broker Users* are the authorised traders who trade for the members of the NASDAQ. *DMA Routing Users* are membership banks directly routing customer order flows to the market. Algorithmic & Sponsored Access (SA) users are a combination of Execution Algo and High Frequency Trading.

Note that transactions which were not a match on the NASDAQ Copenhagen[10] have been left out. If the transactions notified had been included, the total share of algorithmic trading would have been about 43% in 2014. However, the NASDAQ Copenhagen notes that there are significant uncertainties connected with the figures. The figures only include trading volume on the NASDAQ Copenhagen and not trading volume for Danish shares on foreign market venues or dark pools.

Source: NASDAQ Copenhagen

Besides the repeal of the stock exchange monopoly in MiFID I[11] and better technology, the following reasons why the percentage of trading volume on the NASDAQ Copenhagen has increased should be mentioned:

[10] Transactions carried out bypassing the market (OTC trading), but which are reported and published through the NASDAQ Copenhagen.

[11] Directive 2004/39/EC

A. In June 2009, the multilateral trading facilities, Chi-X and BATS, introduced lower tick sizes so that the smallest price change in Danish shares traded on these market venues was DKK 0.001 for shares at a price of less than DKK 10,000.

   Lower tick sizes are an immediate advantage for the algorithmic traders who are using these small price differentials across market venues for arbitrage or to market-make on the multilateral trading facilities within the spread quoted on the NASDAQ Copenhagen, by which liquidity is moved to the multilateral trading facilities.

B. In October 2009, CCP clearing for large-cap shares was introduced. This means that all transactions in a share, carried out by a trading member, will be netted off before settlement, and therefore only one central securities depository payment will be made on a given day for a given share. For algorithmic traders, which typically carry out small transactions, the costs associated with CCP cleared shares are thus lower. Algorithmic traders often net out completely, which means that there will be no CSD payment. For traditional banks acting on behalf of their customers with their own VP securities custody accounts, each custody account must still be settled, and therefore the benefits of CCP clearing are most widespread for algorithmic traders.

C. On 8 February 2010, the NASDAQ Copenhagen implemented the INET trading system, resulting in lower latency and increased capacity for the trading system. This is a direct advantage for algorithmic traders, who can exploit the lower latency.

4.2 Activities of algorithmic traders in various segments

Algorithmic traders are mostly active in the large-cap segment, regardless of whether trading volume, number of orders or number of transactions are measured, see table 5. Overall, the algorithms for the period accounted for about 50% of trading volume. In the large-cap segment, which accounts for by far the majority of the trading volume on the NASDAQ Copenhagen, algorithmic traders accounted for 52% of trading volume in the period from March 2015 to September 2015.

This also applies when considering the numbers of orders or transactions. Measured in terms of number of orders, algorithmic traders account for about 77%. Algorithmic traders in the small-cap segment also account for a large percentage of the overall orders, despite their small percentage of trading volume and transactions. This may be indicative of lower liquidity in small-cap shares.

Table 5. Transactions carried out in Danish shares by customers with an algorithm ID

Percentages carried out by algorithmic traders	Segment			
	Large	Mid	Small	Total
Percentage of trading volume	53.5%	29.5%	10.4%	51.9%
Percentage of number of orders	79.1%	64.1%	26.5%	77.1%
Percentage of number of transactions	56.7%	35.8%	15.5%	53.1%

Source: Order book data from the NASDAQ Copenhagen, March 2015 to September 2015.

Generally, algorithmic traders were active in all segments of the market. All algorithmic traders were active in the large-cap segment, whereas slightly fewer traders were active in mid-cap and small-cap segments. In the small-cap segment, algorithmic traders only represented a very small percentage of trading volume.

It is not immediately possible to assess the scope of algorithmic trading carried out through different types of algorithmic strategies, including execution algorithms.

5. Algorithmic trading subject to Danish supervision

A large part of trading volume on the NASDAQ Copenhagen is generated by algorithmic traders, but not all algorithmic traders are subject to Danish supervision. This section analyses the scope of algorithmic traders who are subject to Danish supervision, as well as the extent of trading volume generated through algorithmic traders who are subject to Danish supervision.

Algorithmic trading may be carried out through trading members themselves, through DMA accesses and through SA accesses.

Table 6. Algorithmic traders and trading volumes broken down by trading members and SA customers

	Number of undertakings		**Trading volume in % of total trading volume on the NASDAQ Copenhagen**	
Source to algorithmic trading	**Danish**	**Foreign**	**Danish**	**Foreign**
Algorithmic trading carried out by trading members	One Danish member has carried out algorithmic trading in the period. Furthermore, five banks have used the NASDAQ execution algo offering to execute large orders. There is a total of 14 Danish members and they are all under supervision.	30 foreign members have carried out algorithmic trading in the period. There is a total of 58 foreign members.	0.8%	49.7%
Algorithmic trading carried out by SA customers	One Danish SA customer who is not under supervision has been registered.	Eight SA customers have traded in the period, through seven foreign sponsoring members. There are 31 registered SA customers.	0.3%	1.1 %

Source: Order book data from the NASDAQ Copenhagen, March 2015 to September 2015.

All undertakings with authorisation as investment firm or investment managers generally have the right to be direct trading members on the NASDAQ Copenhagen[12]. The NASDAQ Copenhagen has 71[13] members, of which 14 are Danish investment firms. However, far from all trading via direct members is algorithmic trading.

For SA customers, all trading is algorithmic trading. The NASDAQ Copenhagen is informed about algorithmic trading carried out by members and their SA customers. SA accesses are only sold through foreign members of the NASDAQ Copenhagen.

Table 6 is an overview of the scope of actors under Danish supervision. During this period, algorithmic trading represented 51.9% of the total trading volume (the sum of algorithmic trading carried out by i) trading members, which includes algorithmic trading through DMA accesses, and ii) SA accesses). With regard to Danish direct members, only 0.8% of total trading volume on the NASDAQ Copenhagen in the period from March 2015 to September 2015 was from algorithmic trading. A large percentage of this is solely execution algorithms. SA customers represent only a small percentage of the total trading volume, and SA customers under Danish supervision account for around 0.3% of trading volume. This means that the total trading volume by investment firms under Danish supervision constitutes a limited percentage of total trading volume on the NASDAQ Copenhagen.

[12] Section 20 of Securities Trading etc. Act

[13] See the NASDAQ Copenhagen membership list *Equity & Derivatives members,* 10 August 2015

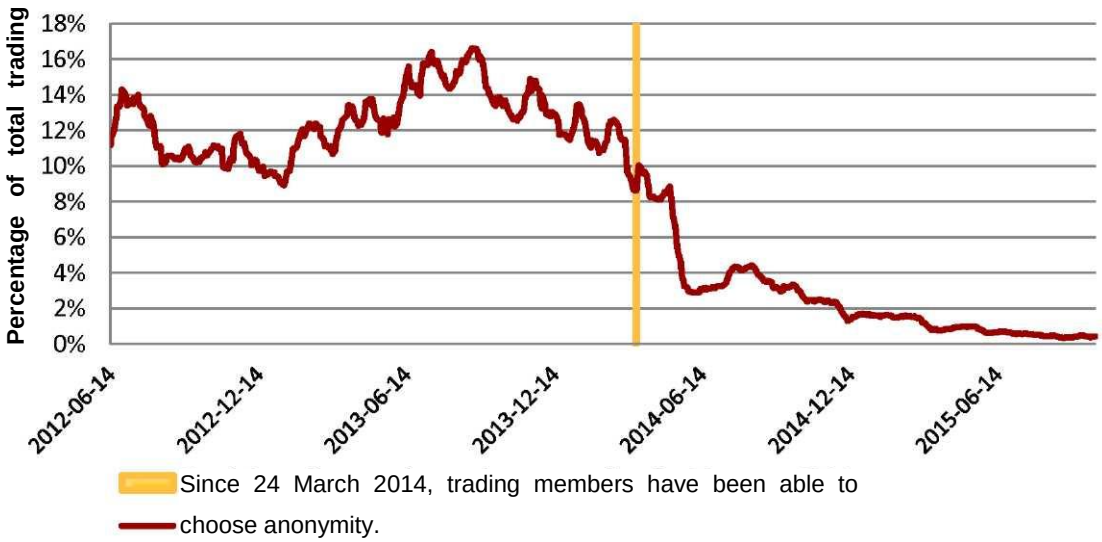
6. High Frequency Trading in Denmark

In the literature, two approaches are used to identify HFT, see section 1:

1. The direct approach: The trade participant has an infrastructure which minimises latency. SA access combined with co-location provides an infrastructure which minimises latency and thus may indicate HFT. This is because both co-location and SA access minimise latency[14]. In co-location, the NASDAQ Access Services offer to place traders' servers in the same building as the matching machine[15] to reduce the distance over which the orders are transmitted. The SA access means that orders bypass the trading member's IT and milliseconds are saved.
2. The direct approach used in the literature, comprising quantitative measurements used to define HFT, e.g. a high order-to-trade ratio.

Trading carried out through SA customers has fallen considerably since 2014, see figure 2. In the same period, the extent of algorithmic trading increased, as previously mentioned. The primary explanation is that some algorithmic traders have gone from using SA access to becoming direct members. The reason for this change is that trading members have been able to choose anonymity since 24 March 2014. This means that direct access, corresponding to using SA access, is not appropriate to describe the scope of HFT. Therefore this section will firstly describe the scope of HFT using the indirect method, which includes more than SA. Secondly, the direct method will be used to describe how the actions of high frequency traders differ from the other market participants.

Figure 2. The development in trading volume carried out by SA customers in C20 shares



Source: Order book data from the NASDAQ Copenhagen

[14] ESMA, High-frequency trading activity in EU equity markets

[15] http://www.nasdaqomx.com/transactions/connectivity-services/nordic-co-location-services

6.1 High frequency trading identified through the indirect approach

The indirect way to identify HFT is to define HFT on the basis of quantitative measurements. Today, there is no EU-based definition of HFT[16]. For the purposes of this report, the Danish FSA has defined HFT on the basis of the SEC article: Concept Release on Equity Market Structure[17]as follows:

1. Algorithmic trading - corresponding to having an algorithm ID on the NASDAQ Copenhagen.

And

> Criterion 1. There must be one hour in which the algorithm trades by transmitting more than 7,200 orders to the market venue, corresponding to 2 per second.
>
> Or
>
> Criterion 2. There must be one hour in which the algorithm trades with an order-to-trade ratio above 40
>
> Or
>
> Criterion 3. The algorithm carries out buy orders followed by sales orders in the same instrument within one second.

These criteria are used on data from the NASDAQ Copenhagen from the period March 2015 to September 2015.

If this approach is used to identify algorithmic trading, HFT accounts for 15% of the total trading volume. This is significantly lower than the 52% which algorithmic trading represents as a whole, see table 5. As expected, the percentage of total orders is somewhat higher. High frequency traders are generally only active outside auctions, where about 20% of the order-book trading volume is generated.

Table 7. High frequency trading identified through indirect approach

High frequency trading percentages by segment	Large	Mid	Small	Total
Percentage of trading volume	15.8%	3.4%	0.2%	15.0%
Percentage of number of orders	40.2%	24.5%	1.7%	38.0%
Percentage of number of transactions	18.7%	4.5%	0.5%	16.5%

Source: Order book data from the NASDAQ Copenhagen, March 2015 to September 2015.

In comparison, the SEC assesses that HFT on the American share market typically represents 50% or more of trading volume in many shares[18].

[16] In a technical advice, ESMA has proposed that the Commission use the following three draft definitions. ESMA/2014/1569

[17] https://www.sec.gov/rules/concept/2010/34-61358fr.pdf

[18] https://www.sec.gov/rules/concept/2010/34-61358fr.pdf

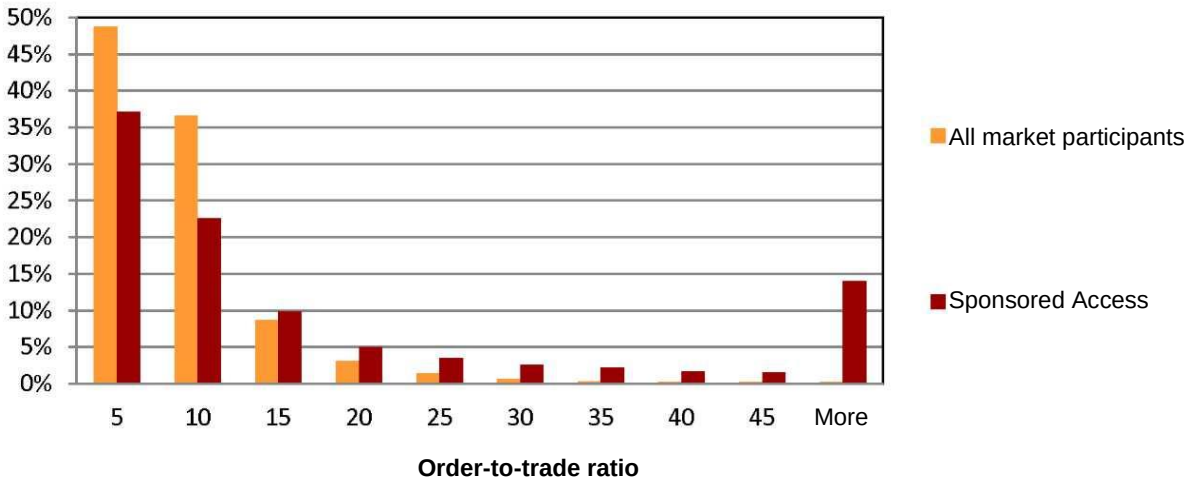
6.2 Characteristics of HFT

Even though HFT identified through the direct approach, SA customers can no longer be used to estimate HFT on the NASDAQ Copenhagen, data for these may be used to characterise how HFT differs from other trading. In this section, this is done by analysing order-to-trade ratio and the lifetime of these orders.

6.2.1 Order-to-trade ratio

Taking into account the breakdown of order-to-trade ratio[19][20] on the NASDAQ Copenhagen for trading carried out by SA customers and for the market as a whole, the order-to-trade ratio of SA customers covers a wide field, but is generally higher than for the entire market venue, see figure 3. Thus the average order-to-trade ratio is about 67 for SA customers, which is somewhat higher than the overall average for all members on the NASDAQ Copenhagen, which, in comparison, have an average order-to-trade ratio of 12.7. The order-to-trade ratio depends very much on the strategy. For example, for a high frequency trader, there is a high order-to-trade ratio if the trader is following a market-maker strategy which provides liquidity.

Figure 3: The distribution of order-to-trade ratio on the NASDAQ Copenhagen



Source: Order book data from the NASDAQ Copenhagen, April 2015 up to and including June 2015.

A large part of the SA trading has a low order-to-trade ratio, however, and about 37% has a lower order-to-trade ratio than 5. About 14% has an order-to-trade ratio exceeding 50, of which, some have a high order-to-trade ratio exceeding 1,000. See section 8.2 for rules on fees in connection with high order-to-trade ratios.

6.2.2 The lifetime of the orders

The breakdown of time between active transactions calculated on SA customers and trading carried out through trading members without an algorithm ID is shown in table 8. This could be the time between inserting an order and cancelling an order, or the time from inserting an order to updating an order. For SA customers, the median is about 0.38 seconds. In half the cases, the SA customer will wait less than this before the order is changed or cancelled. The 25% percentile is 0.027 seconds. This means that in

[19]For this report, the Danish FSA defines order-to-trade ratio as the total number of messages transmitted, i.e. insertion of orders, cancellation of orders and updating of orders. The NASDAQ has order types where the price is automatically updated by the NASDAQ trading system. Even though the order is updated by the NASDAQ trading system, this update counts as a new order in this report.

[20]The NASDAQ calculates an order-to-trade ratio such that the orders are weighted against the distance to the best bid and ask:

http://www.nasdaqomx.com/digitalAssets/97/97598_cash-market-fee-list-sep-2014.pdf

25% of the cases there is an active reaction within a fraction of a second. 10% of the waiting times are less than 14 milliseconds.

Table 8. Breakdown of time between active transactions

Seconds between active order incidents (insert, update, cancel)		
	SA	**Not algo**
Average	50.9	550.8
Median	0.381	45.5
Other percentiles		
10%	0.014	1.1
25%	0.027	8.1

Source: Order book data from the NASDAQ Copenhagen, April 2015

In comparison, the median of intervals between active transactions for non-algorithms is 45.5 seconds and the 25% percentile is about 8.1 seconds, see table 8. This means that, for the remainder of the market, there is a significantly longer latency between active transactions than there is among the SA customers. The short latency indicates that some SA customers use strategies requiring quick reaction, e.g. market making, arbitrage or news-based strategies. In addition to this, algorithmic traders are more likely to use *immediate or cancel orders*, which are orders executed immediately, if possible, and otherwise deleted. Such orders have extremely short lifetimes, as the lifetime is solely the time it takes for the NASDAQ Copenhagen trading system to find a match for the order.

7. Significance of algorithmic trading for the market

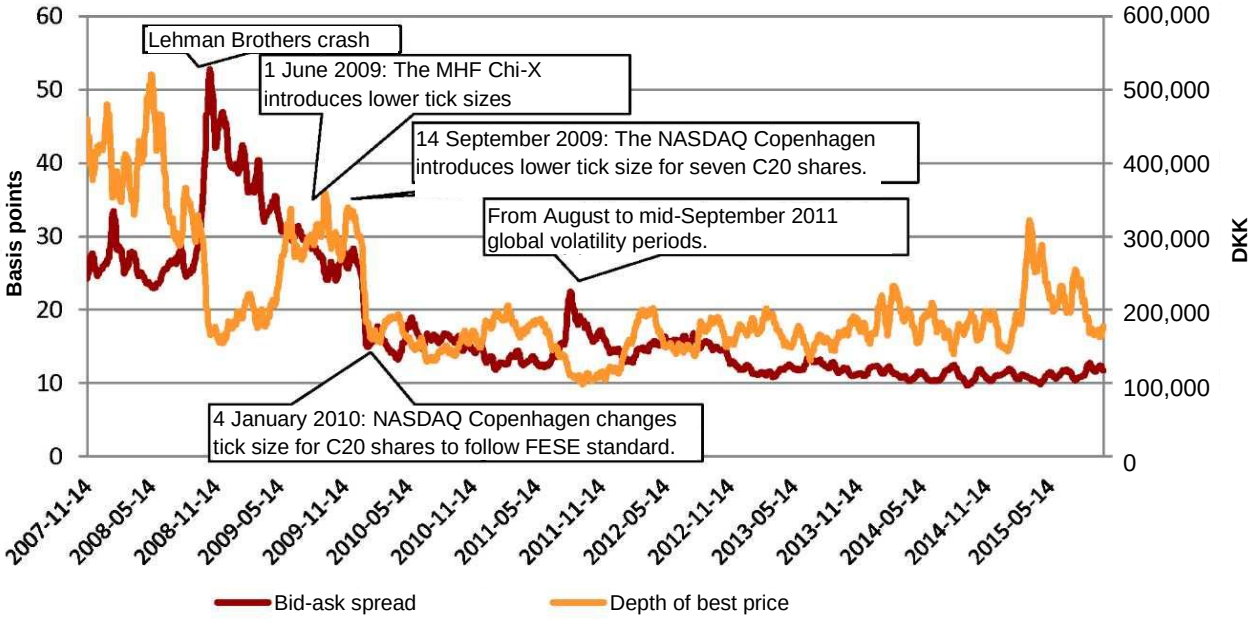
As mentioned in part 1, some literature stresses that algorithmic trading and HFT have a positive impact for the other investors in the form of more correct pricing, lower volatility and increased liquidity. This section seeks to analyse some of these arguments on the Danish share market.

7.1 Impact on liquidity

The Danish FSA has used three indicators to measure the development in liquidity: The bid-ask spread, the volume of orders available at the best price, and the market depth of all prices. Several liquidity indicators are used, as a single definition of liquidity does not exist.

A liquidity indicator is the difference between best bid and best ask, the so-called bid-ask spread. If the spread is low, it is possible to buy an instrument and resell it without major costs. A reduced spread means lower costs for the investor. The average spread in C20 shares has fallen over time, and thus, according to this measurement, liquidity has improved, see figure 4. It seems reasonable that algorithmic traders and high frequency traders contribute to this narrowing of the spread due to increased competition on the market-making area, and because spread imperfections are limited as a consequence of the arbitrage strategies of algorithmic traders and high frequency traders. However, other factors than the increasing extent of algorithmic trading may explain these developments. The spread also follows market situations and changed tick sizes. In September 2009, the NASDAQ Copenhagen lowered the tick size of seven shares in the C20 index because the Chi-X market venue lowered its tick size on Danish shares in an attempt to move liquidity to the market venue from the NASDAQ Copenhagen. In January 2010, the NASDAQ Copenhagen implemented tick sizes developed together with FESE[21]. After introduction of the lower tick sizes, the spread fell.

Figure 4: Average relative bid-ask spread in C20 shares



Note: The bid-ask spread is calculated using the relative spreads (best ask - best bid)/best ask, and then a time-weighted average has been calculated from this. Market depth of the best price is a time-weighted average of orders within continuous trading. The graphs show a ten-day rolling average.

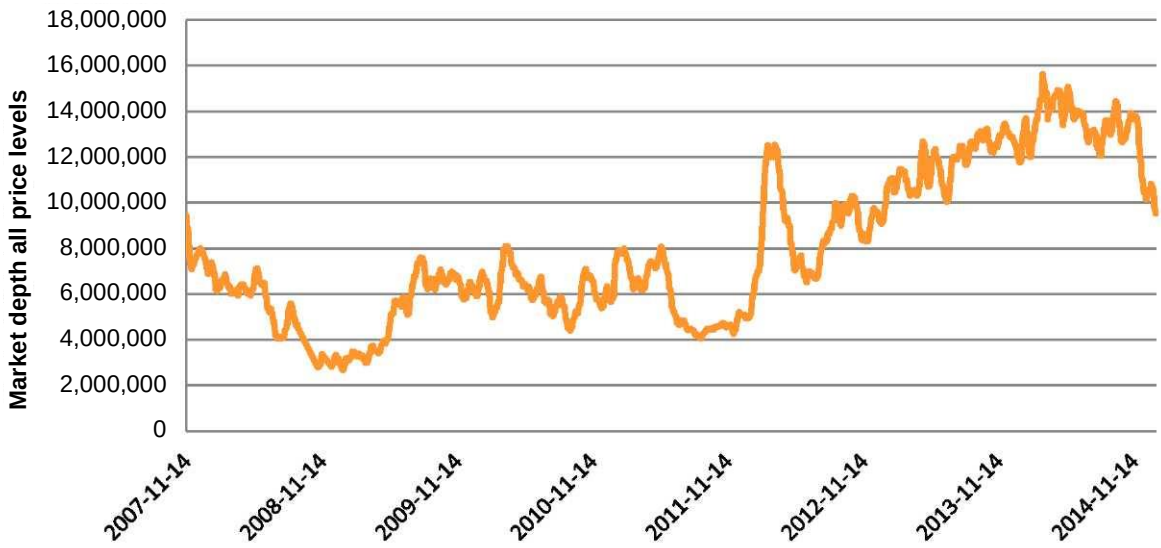
Source: NASDAQ Copenhagen

[21] Federation of European Securities Exchanges

The volume of orders available at best price, i.e. the volume that on average can actually be bought and sold at best price, was reduced in the same period, see figure 4. However, this liquidity indicator shows a reduced volume available at best price because liquidity is spread out over several tick sizes. In January 2010, the NASDAQ Copenhagen introduced lower tick sizes, and these were reflected in the volume of orders available at best price, which dropped at the same time.

However, if the total market depth is taken into account, i.e. the volume bought and sold at all price levels, this measurement of liquidity did not fall for the period, but has increased since 2012, as algorithmic trading has increased on the NASDAQ Copenhagen, see figure 5. The total market depth is thus a proxy for liquidity, which shows an improvement in liquidity in line with the increase in algorithmic trading.

Figure 5: Full order depth



Note: The market depth is the time-weighted market depth of all prices taken as a rolling average over ten days.

Source: NASDAQ Copenhagen

Figures 4 and 5 have not been adjusted to eliminate ghost orders, which are orders posted simultaneously on several market venues. When the order is met on one market venue, the order on the other market venue is deleted. This means that liquidity seems higher than it really is. ESMA is examining the scope of false liquidity on European market venues. Danish shares are also traded on foreign market venues, and therefore some orders on the NASDAQ Copenhagen are likely to be ghost orders. In any event, these orders will be genuine as long as they are registered in the order book.

Overall, this is a sign that liquidity has improved in the same period as the percentage of algorithmic trading has increased on the NASDAQ Copenhagen. However, other factors than algorithmic trading contribute to explaining this trend, such as smaller tick sizes.

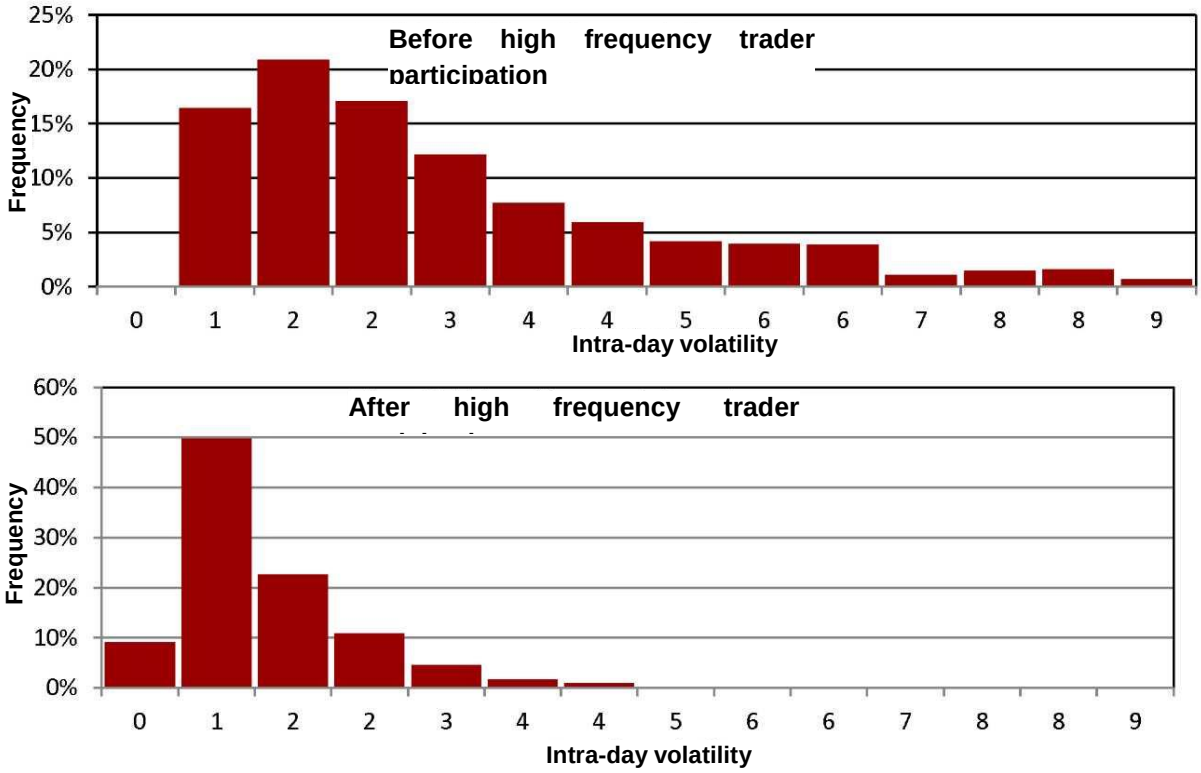
7.2 Impact on volatility

The Danish FSA has analysed intra-day volatility in selected shares. The analysis shows that volatility has fallen after the entry of high frequency traders as market makers in the selected shares.

High frequency traders conduct a market-maker strategy, which may be decisive for the falling volatility. High frequency traders make passive bids and asks, updated at high frequency, thus adding liquidity and market depth to the share. Furthermore, in this passive manner, high frequency traders share how they have converted available information to price formation of a share. This means that, at any point in time, all market participants will have the same information, and the risk of entering into a "bad" transaction will be reduced. Incorrect pricing of the share will also be seen immediately and this may even out the effect on the price.

For example, intra-day volatility in the Vestas share was significantly higher statistically in the period before a high frequency trader entered as market maker, compared with the period after a high frequency trader began acting as market maker, see figure 6. However, such analysis presupposes that the general volatility is the same in the two periods.

Figure 6. Intra-day volatility in the Vestas share before and after a high frequency trader enters as market maker



Source: Order book data from the NASDAQ Copenhagen.

To adjust for the general volatility, a number of macro-economic variables and share-specific variables are used as control variables which may have an impact on the volatility of the Vestas share. Even after adjusting for these variables, the conclusion is that the market maker reduces volatility. See the annex for a more detailed analysis of this example.

A similar development in intra-day volatility before and after entry of a high frequency trader as market maker was also found for other C20 shares.

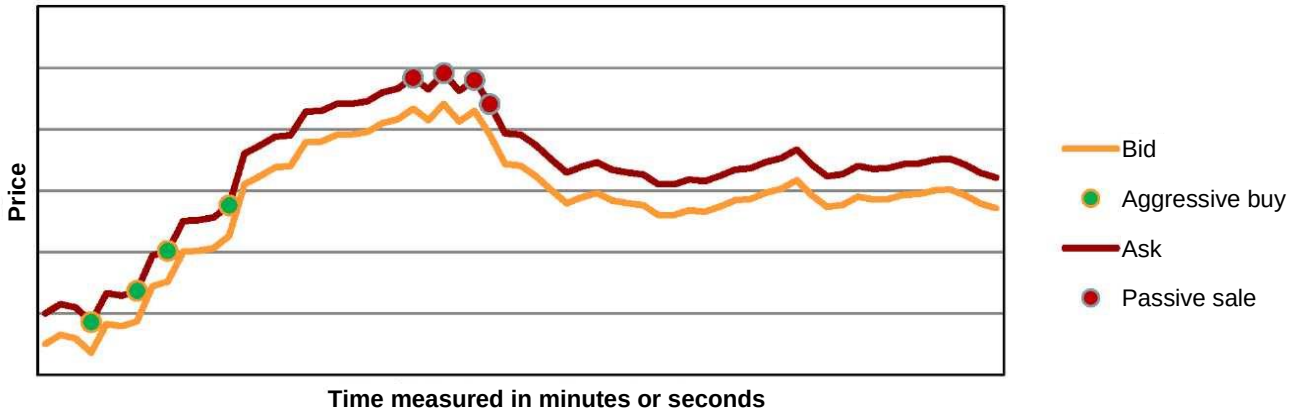
7.3 Algorithm-induced market abuse

In specific situations, high frequency traders have been accused of market abuse, as several strategies particularly suitable for algorithms and used inappropriately or intentionally, may be seen as market abuse. Today, market abuse is detected in different ways. The NASDAQ Copenhagen regularly monitors trading carried out on own markets, among other things to identify market abuse. It is not possible for the NASDAQ Copenhagen to monitor trading carried out on other market venues. The investment firms monitor trading carried out through the individual investment firm. The NASDAQ Copenhagen and the investment firms notify suspicious transactions to the Danish FSA. Furthermore, the Danish FSA itself has access to data from the NASDAQ Copenhagen and investment firms, and it carries out market surveillance. Market surveillance carried out by the Danish FSA is on a case-by-case basis, in which cases can be identified through patterns in the Danish FSA's data basis, or cases may be reported by the NASDAQ Copenhagen or by investment firms when they observe suspicious trading behaviour. Such cases are typically either shelved or reported to the Police.

7.3.1 Trend-initiating algorithms

A strategy which may have a negative effect on the market is characterised by an aggressive algorithm, e.g. buying a share in an attempt to initiate a trend. In other words, the purpose of this algorithm is to make other market participants "ride the wave", as the algorithm may subsequently sell the share back at a higher price, within a short period of time. This strategy is called *momentum ignition*.

Figure 7. Example of momentum-initiating strategy



The algorithm pursuing a *momentum ignition* strategy makes aggressive orders, which lead to immediate buys and price increases. This is repeated until an upwards trend has been created. Other market participants start buying and this makes the price increase even more. The algorithm will now post cautious sales orders. This means that the algorithm will post sales orders on the bid side at a higher price than it bought them. Because of the upwards trend, these orders will be affected and the algorithm will collect a profit, see figure 7. This strategy impairs returns for the other market participants following the trend, as they will buy at a higher price than the share would otherwise have been worth, and because the price will typically then fall to its initial level. Such market behaviour is considered price manipulation.

When reviewing the data, the Danish FSA examined whether some algorithms follow such a strategy, but did not find examples of this. Therefore, the Danish FSA assesses that such strategies by algorithms are not frequently used on the NASDAQ Copenhagen.

7.3.2 Market abuse carried out cross market

Some types of market abuse involve trading and insertion of orders on several market venues simultaneously. For example, a *spoofing* strategy is as follows: A high frequency trader posts a buy order on market venue A. A moment later, large sales orders in the same share are posted on market venue B. The large sales orders will make the price drop - first on market venue B and immediately afterwards on market venue A due to other algorithms conducting an arbitrage strategy. The initial buy order is met on market venue A at a lower price than what would have otherwise been achieved, and the sales orders on market venue B which the high frequency trader had no intentions of meeting, are cancelled. As the strategy is carried out on different market venues, monitoring by the market venues makes it more difficult to identify market abuse.

The Danish FSA has investigated fragmentation of trading in Danish C20 shares. More than 30% of the trading volume in Danish C20 shares is carried out on other market venues than the NASDAQ Copenhagen, see table 9. Therefore, there are the conditions required for cross-market market abuse.

Table 9. The trading volume in Danish shares carried out on the NASDAQ Copenhagen and foreign market venues in 2014

Shares Expressed as a percentage	NASDAQ Copenhagen	Percentage - other than NASDAQ Copenhagen	BATS -CHIX	Turquoise	Burgundy
TDC	55.8	44.2	33.9	7.8	2.0
Topdanmark	60.2	39.8	28.0	10.5	1.1
GN Store Nord	62.4	37.6	21.8	13.9	1.2
William Demant Holding	62.8	37.2	29.9	6.3	0.9
Lundbeck	63.4	36.6	22.9	11.6	1.5
Novo Nordisk B	63.6	36.4	25.9	8.5	1.5
Carlsberg B	63.7	36.3	25.6	8.5	1.9
Coloplast B	63.8	36.2	22.2	12.1	1.2
DSV	64.2	35.8	26.5	7.7	1.2
A.P. Møller - Mærsk B	64.8	35.2	23.7	8.8	2.4
Chr. Hansen Holding	64.8	35.2	24.7	9.3	0.9
Danske Bank	66.9	33.1	23.7	7.2	1.7
Novozymes B	68.1	31.9	21.0	9.5	1.2
Tryg	68.8	31.2	20.5	10.0	0.6
Pandora	69.1	30.9	18.6	10.8	1.2
Jyske Bank	69.6	30.4	21.6	7.9	0.7

Source: ESMA.

The Danish FSA does not have access to order book data from other market venues. Effective monitoring of whether cross-market market abuse by algorithms is taking place requires that the Danish FSA has access to order book data from other market venues, and that data is accurately time-synchronized, which is not the case today. MiFIR introduces regulations on the synchronization of watches and this will make it possible to analyse cross-market market abuse cases, see section 10.

7.4 Importance for systemic risk

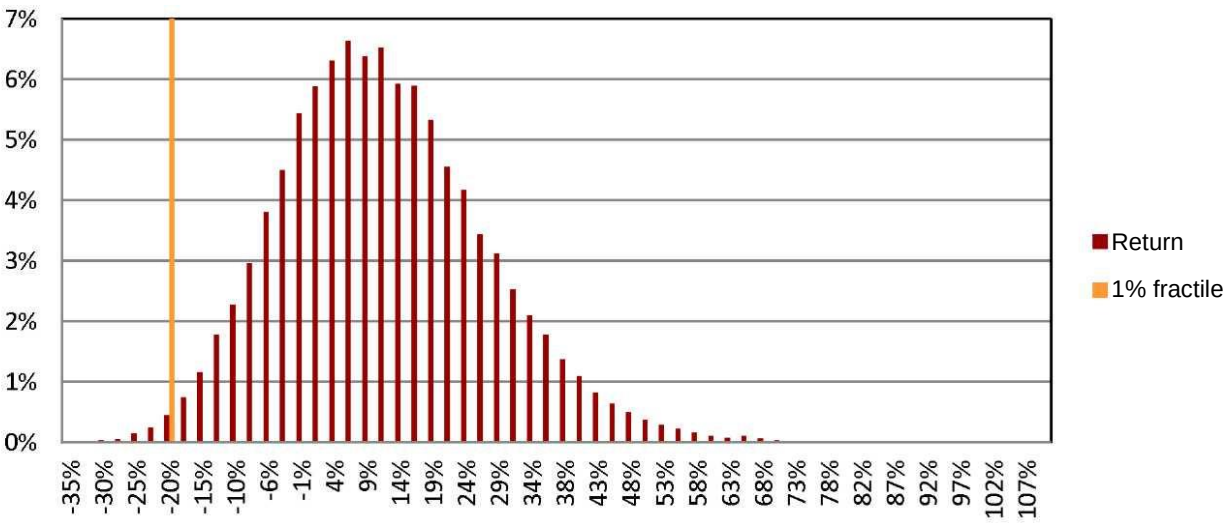
Systemic risk was described in section 3.1. The Danish FSA has examined the systemic return risk over time by simulating the return of a portfolio comprising the 13 shares which had been in the C20 index the entire period from 1995 to 2014. Using a simulation, the portfolio was rebalanced daily in order to ensure as large a spread as possible. The hypothesis is that, with an increased percentage of the profit being generated from algorithmic trading, the shares will be more strongly correlated, thus increasing the systemic return risk: If some share prices fall, the rest will likely follow suit, and vice versa, If some share prices rise, the rest will likely follow suit. Thus the distribution of the portfolio's return is more likely to generate very high returns and very high losses. On the basis of this distribution, the Value at Risk[22] (VaR) is calculated and used as a measurement of risk.

The analysis method selected, *bootstrapping* generally means:

1. Daily return on a portfolio comprising equal percentages in 13 shares, calculated based on closing prices. Every day, this amount is reinvested in the same way.

2. The daily return is used for one year at the time to simulate the distribution of an annual return using the method *bootstrapping*. As the return on a portfolio is used, correlations between the 13 shares are incorporated in the analysis.

Figure 8. The breakdown in returns in 2014 for a daily investment in 13 different C20 shares

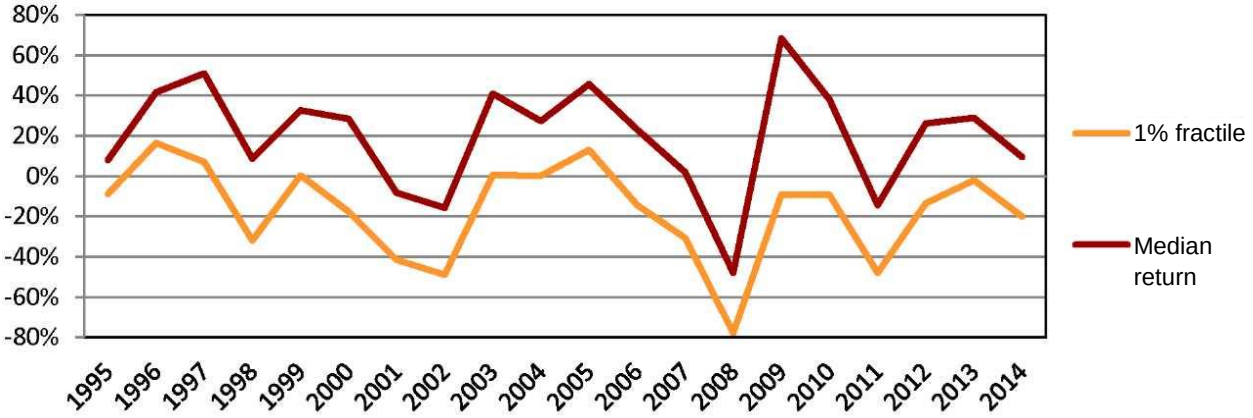


Note: Example of return distribution achieved through simulation of the value of the portfolio in 2014. In this example, there is a 1% probability of losing 20% or more of the assets.

The portfolio comprising 13 shares has had a relatively constant risk, apart from in 2008, when there is a 1% probability of losing 78%, see figure 9.

[22]Value at Risk defined as the return that, with 1% probability, will be generated, or worse.

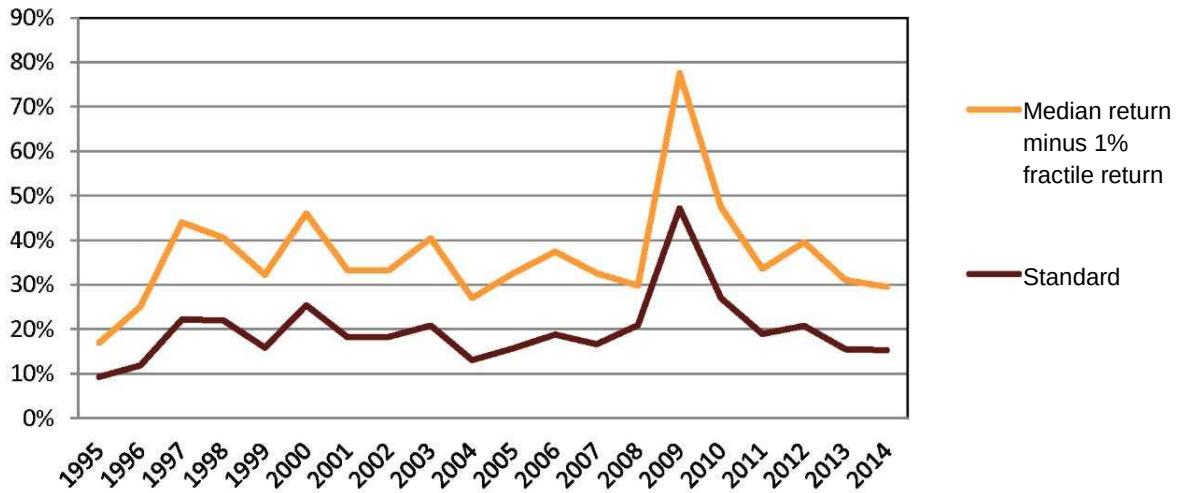
Figure 9. VaR as 1% fractile over time



Source: Calculations by the Danish FSA carried out through bootstrapping based on data from Bloomberg.

The standard deviation on the distribution of the return is relatively constant over time as well. As a final risk measurement, the median minus 1% fractile is used. This measurement shows the difference on the return that half the investors would obtain, compared with what the one percent most unfortunate investors would obtain. This means that adjustments have been made for good and bad years. This risk measurement is also relatively constant over time, except for 2009, when there was a large difference between the median and the bottom 1% return, see figure 10. The unfortunate investor will have a significantly lower profit in this year than the return generally in this year.

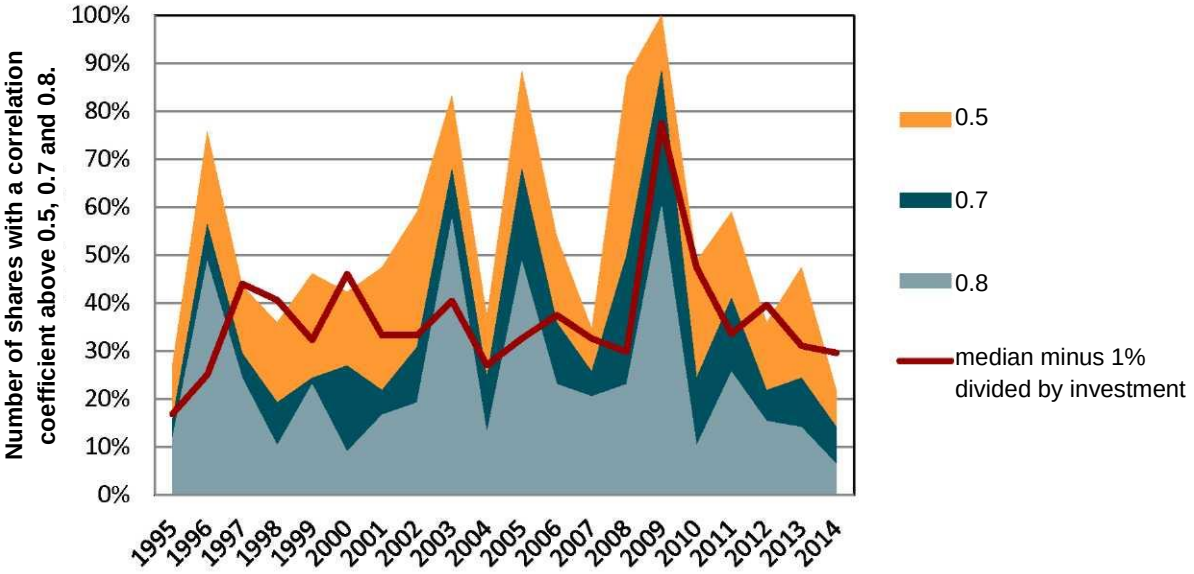
Figure 10. The standard deviation of an annual return from 1995 to 2014 for daily investment in 13 different C20 shares, as well as the median minus the 1% fractile on the same portfolio



Source: Calculations by the Danish FSA carried out through bootstrapping based on data from Bloomberg.

The systemic risk has thus not increased in the period when algorithmic trading became considerably more widespread. Equally, the correlation between the shares has not become stronger, see figure 11. The greatest correlations were in 2008 and 2009, when the financial crisis was at its peak. In 2010, the correlation between the C20 shares was nearly at the same level as before the financial crisis, and this does not seem to increase in the period from 2010 to 2014, when the scope of algorithmic trading on the NASDAQ Copenhagen increased from about 20% to 50%.

Figure 11. Development in the number of correlating shares in the period 1995 to 2014



Note: The number of shares out of the 13 shares in the data set, which, in a given year, has a correlation factor greater than 0.5, 0.7 and 0.8, respectively.

Source: Calculations by the Danish FSA carried out through bootstrapping based on data from Bloomberg.

Part 3 Security measures for algorithmic trading

The future regulatory requirements mean that the Danish FSA will have extended access to data and this will improve the possibility of monitoring trading with a view to identifying any market abuse. Preventive initiatives for effective tests must be introduced at algorithmic traders, sponsoring members and market venues. If an algorithm still acts inappropriately, additional security measures must be in place, in the form of circuit breakers on the market venue in the event of major price fluctuations, and obligations on the algorithmic traders to refrain from pulling out as market makers. Finally, the market venues will need to introduce rules to minimize the advantages of algorithmic traders as a consequence of their computing muscle. This involves rules on tick size and a ceiling on the order-to-trade ratio. The NASDAQ Copenhagen has already introduced rules on tick size, circuit breakers and a fee for violation of a threshold for order-to-trade ratio. The MiFID II improves both the preventive effects regarding algorithmic trading, and the opportunities of the Danish FSA to supervise algorithmic trading.

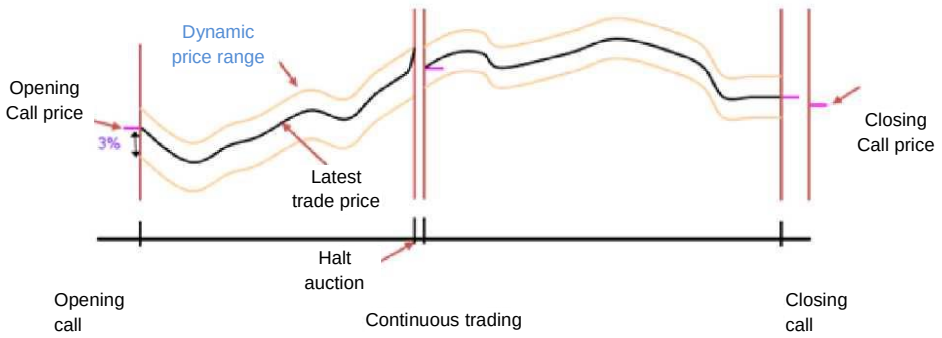
8. Security measures on the NASDAQ Copenhagen and the sponsoring member

8.1 Volatility guards

Following among other things the flash crash in May 2010, a number of market venues have introduced security mechanisms in the form of trading disruptors, also called *volatility guards* or *circuit breakers.* The NASDAQ Copenhagen upgraded its security mechanisms in September 2010[23]. Volatility guards work by triggering a short-term auction period in the event of large price fluctuations. During the auction period, orders inserted may be cancelled. This is intended to reduce the risk of major price fluctuations, e.g. as a consequence of a misprogrammed algorithm or keying mistakes.

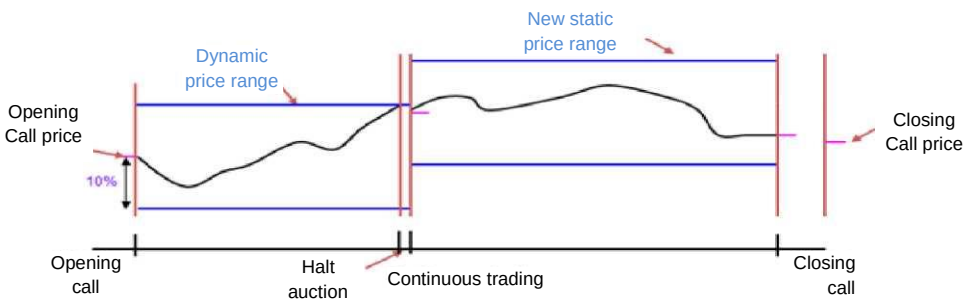
The NASDAQ Copenhagen uses two types of volatility guards[24]: A dynamic one and a static one. The dynamic volatility guard is based on the most recently paid price. If a suggested transaction takes place outside the realms of the dynamic threshold, this will trigger an automatic trading stop, followed by a 60-second auction.

Figure 12: Dynamic volatility guard. Source: The NASDAQ Copenhagen



The static volatility guard is based on a call price, most often the price set at the latest auction. If the price breaks the statically set threshold, the transaction in the share will be discontinued, and a 180-second auction will be held, after which a new call price will be set.

Figure 13: Static volatility guard. Source: The NASDAQ Copenhagen



[23] http://www.nasdaqomx.com/digitalAssets/69/69482_newsletter.pdf

[24] The NASDAQ OMX Nordic Market Model

The thresholds for the volatility guards are set on the basis of the liquidity of the different shares. The thresholds for C20 shares are thus narrower than for shares with lower liquidity. The NASDAQ Copenhagen has set the following limits for shares on the Danish market[25][26]:

Table 10. Dynamic and static thresholds in volatility guards on the NASDAQ Copenhagen

Type of share	Dynamic	Static
OMXC20	3%	10%
Other shares and EFT (investment associations)	5%	15%
First North or where the spread is >= 3%	10%	15%
Penny shares:		
DKK 0.25 to 5	25%	50%
DKK 0.1 to 0.25	40%	75%
DKK 0.05 to 0.1	50%	100%
DKK 0 to 0.05	100%	200%

Source: NASDAQ Copenhagen

Internationally, volatility guards are seen as protection against flash crashes and this is reflected in the statutory requirements laid down by MiFID II[27]. A flash crash has not been observed on the NASDAQ Copenhagen. This may indicate that the volatility guards are working, or that a "run-away" algorithm is yet to be seen on the NASDAQ Copenhagen.

In addition to the NASDAQ Copenhagen carrying out real-time market surveillance of all orders and transactions, there is an extra set of surveillance tools designed to monitor members' data traffic at port level. The system continuously shows the ports inside the INET trading system with the most traffic. Based on this information, the operator is able to see which ports are more active and take appropriate steps, if necessary, including closing the port of a trading member in the event of a sudden large number of order messages.

8.2 Limitation on order-to-trade ratio

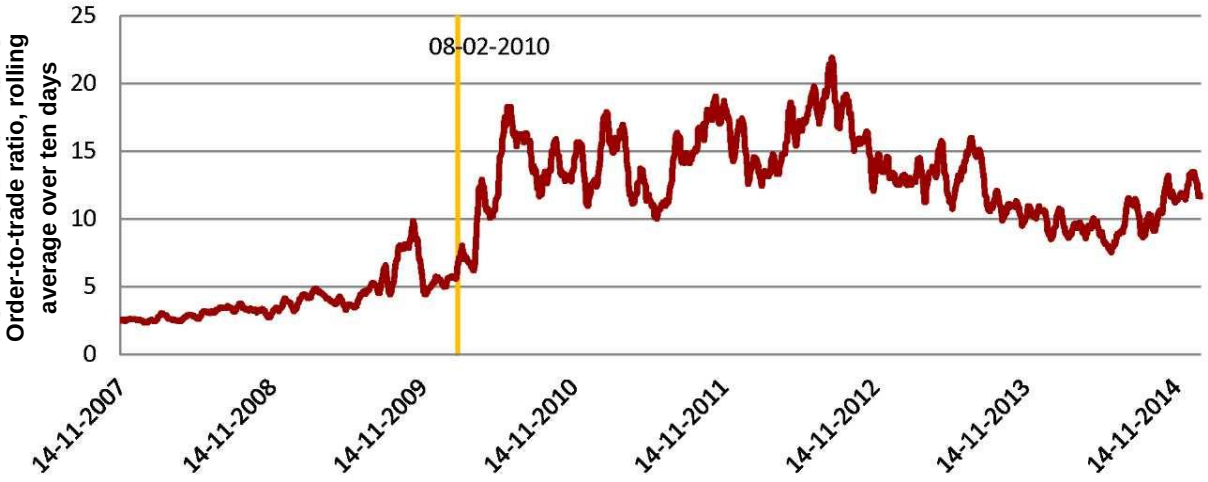
Algorithmic traders have low costs per order insertion, which means that, on average, they have more orders than conventional share traders. For example, large transactions are broken into smaller bites to avoid creating large price fluctuations. A very large number of orders in proportion to the number of transactions may, as stated in MiFID II, create or contribute to irregular trading terms on the market. Such orders may disturb the market, as potentially they will send the wrong signal about liquidity and increase the costs of technology for the market venue.

[25] The NASDAQ Market Model Inet Nordic, appendix M

[26] Extended limits applies when the issuer is about to provide company information.

[27] Directive 2014/65/EU

Figure 14. Order-to-trade ratio on the NASDAQ Copenhagen calculated on all market participants



Source: Order book data from the NASDAQ Copenhagen.

Note: On 8 February 2010, the NASDAQ Copenhagen transferred to the INET trading system and this meant a change in the calculation of order messages.

The NASDAQ Copenhagen has addressed this issue by charging a fee to market participants in the event of an excessive order-to-trade ratio[28]. This was introduced in July 2011, when the limit was set at 250. In November 2013, the limit was reduced to 100, and at the same time, the calculation was changed to a monthly basis. Orders will be weighted with the best distance between bid and offer (BBO). The weighting means that orders which are close to BBO weigh less than 1 and orders which are far from BBO weigh more than 1. This means there is an incentive to post orders close to BBO. If the order-to-trade ratio threshold is exceeded, the NASDAQ Copenhagen fee is DKK 0.07 per order above the threshold.

The order-to-trade ratio increased from 2007 until the summer of 2010, see figure 14. After this, the level fluctuated and declined from the summer of 2012.

8.3 Rules of the NASDAQ Copenhagen for tick size

The tick size is the least possible price change in an instrument. If there is no tick size, the best bid on a market venue could be overbid by an infinitely small amount. This is particularly suitable for algorithmic traders, who can quickly identify the best bid and make a marginally better offer. The costs of making a higher bid will thus be extremely low and this will affect market depth negatively and remove any liquidity suppliers on the market.

[28] http://www.nasdaqomx.com/digitalAssets/94/94075_cashmarketfeelist-1sep2014.pdf

On the NASDAQ Copenhagen, the following tick sizes apply for the large-cap segment[29]:

Table 11. *Tick size* broken down by price level applicable on the NASDAQ Copenhagen from January 2011

DKK from	DKK to	Tick Size
-	0.4999	0.0001
0.5	0.9995	0.0005
1	4.999	0.001
5	9.995	0.005
10	49.99	0.01
50	99.95	0.05
100	499.9	0.1
500	999.5	0.5
1,000.00	4,999.00	1
5,000.00	9,995.00	5
10,000.00	49,990.00	10
50,000.00	-	50

Source: NASDAQ Copenhagen

A high frequency trader who exercises a market-maker strategy has larger profits per transaction when the relative bid-ask spread is high[30]. Thus, there is a risk that a high-frequency market maker will pull out in a situation where the rate of an instrument drops from one tick size class to another, as the profitability of being a market maker decreases.

8.4 NASDAQ Copenhagen regulations to counter unrealistic trading intentions

According to the membership rules for the NASDAQ Copenhagen, orders in the order book must reflect the market price of the financial instrument, but must also comprise real orders intended for trading. Membership rules stipulate that orders must not be inserted which lack a commercial purpose. Furthermore, membership rules stipulate that a member has the same order obligations through an SA as orders placed differently. This means that the rules should make SA customers meet the same requirements as trading members.

8.5 Requirements for internal procedures at trading members

The NASDAQ Copenhagen is informed about all algorithmic trading by trading members, as well as algorithmic trading carried out through SA accesses. In principle, algorithmic trading may be carried out through DMA access without the NASDAQ Copenhagen having any knowledge about this.

[29] http://www.nasdaqomx.com/digitalAssets/72/72734_global_data_products_newsletter_2011-03.pdf

[30] Relative spread = (bid-ask)/price

This section is about selected requirements set by the NASDAQ Copenhagen to its trading members[31] before they may sell direct access, i.e. DMA and SA accesses used for algorithmic trading to third parties.

A trading member who has been granted DMA or SA access, has the same obligations for the orders sent through the DMA or SA access in the name of the trading member as for the trading member's own orders. The trading member must, for each DMA or SA access, enter into an agreement which includes a ceiling on the maximum risks to be taken by the client, and entitling the trading member to discontinue the connection at any time. The member is also responsible for monitoring the client's orders. In order for a trading member to sell DMA or SA access, the member must apply for and obtain authorisation from the NASDAQ Copenhagen. The application must, as a minimum, include[32]:

1) A description of the due diligence carried out by the member of its client, including a fit and proper assessment.
2) A description of the security measures of the trading member, including how the member can identify a client, and how the order will be verified, before it is forwarded to the market venue.
3) A description of the internal routines of the member for monitoring of the DMA access.
4) A description of the client's use of the DMA access.

9. Future regulatory requirements

This section describes the future regulatory requirements resulting from MiFID II/MiFIR that enter into force on 3 January 2017. As the use of trading technology has developed considerably since the entry into force of MiFID in 2007, and since then, algorithmic trading has become significantly more widespread, it is natural that the risks of algorithmic trading be regulated. This section describes the new possibilities for the Danish FSA provided by MiFID II/MiFIR to monitor algorithmic trading, the requirements set for algorithmic traders, the steps to be taken by sponsoring members, and finally the steps the market venues have to take.

9.1 Future possibilities to monitor algorithmic trading

With MiFID II, the Danish FSA will be able to monitor algorithmic traders. All investment firms carrying out algorithmic trading on market venues in Denmark must notify the Danish FSA, irrespective of whether they are Danish or foreign investment firms[33]. However, the Danish FSA should only be notified in the event that the investment firm is a member of a Danish market venue. This means that the Danish FSA will be able to carry out a targeted supervision of algorithmic traders and the requirements set for them. For example, the Danish FSA may order traders to submit information about the algorithm, i.e. about trading parameters and the risk controls used. High frequency traders, in particular, must obtain authorisation as investment firms[34].

Further to this, since 2007, investment firms have been notifying the Danish FSA about the details of each transaction in shares made in their own book or on behalf of clients. These notifications are

[31] http://www.nasdaqomx.com/digitalAssets/96/96063_nasdaq-omx-nordic-member-rules_version-2-6--effective-december-1-2014-final.pdf

[32] The NASDAQ OMX Nordic Member Rules of December 2014, section 4.9

[33] 2014/65/EU - Article 17(2) of MiFID II

[34] 2014/65/EU - Article 2(1)(d)(iii) of MiFID II

becoming more detailed[35] [36], and in the future they will include an algorithmic ID, both for the executing algorithm, and for the algorithm making the investment decision. This will enable the Danish FSA to identify transactions carried out by a specific algorithm at a given investment firm in its database. In turn, this will facilitate analysis of market abuse and the general use of algorithm. This analysis can be detailed down to each individual algorithm, or for more algorithms with interdependencies.

Investment firms and operators of a market venue must store all information about transactions and orders placed by their algorithms for at least five years[37] [38]. This enables the Danish FSA to analyse cases about possible market abuse back in time. Requirements have been set to synchronize market venue watches[39] and this enables analysis of cross-market market abuse cases, as the consolidated course of events over more market venues can be restored.

Besides the requirements in MiFID II/MiFIR, the MAR particularly addresses the risk of market abuse. Market venues and investment firms must have schemes, systems and procedures to prevent and expose market abuse[40].

There are thus requirements that market venues and investment firms must have automatic monitoring, i.e. an automated system that generates alarms in the event that suspicious transactions or orders have been executed[41]. Market venues and investment firms must train staff to identify suspicious transactions and orders. Possible market abuse observed by investment firms or market venues must be notified to the supervisory authority[42]. Furthermore, legislation on what should be considered as market abuse will become clearer, as some strategies will explicitly be mentioned as examples of market abuse. This is shown in Recital 38:

"To reflect that transactions in financial instruments are increasingly automated, the definition of market manipulation should preferably provide examples of specific abuse strategies, which may be carried out by means of any trading instrument available, including algorithmic trading and HFT".

See the ESMA Final Report - consultancy about possible delegated legislative instruments under the MAR[43].

9.2 Future regulation of investment firms who use algorithmic trading[44]

The future regulation affects algorithmic traders in different ways.

a) Before deployment of algorithms

The company must test algorithms before deployment using methods that ensure that the algorithm complies with regulatory requirements, as well as the rules of market venue. Specifically, tests must examine whether the algorithm works continually on a stressed market. The company must have a test environment such that testing algorithms can be carried out without impacting the market. Deployment

[35] 2014/600/EU - Article 26 of MiFIR

[36] ESMA/2015/1464 RTS no. 22

[37] 2014/600/EU - Article 25 of MiFIR

[38] ESMA/2015/1464 RTS no. 24

[39] ESMA/2015/64 RTS no. 25

[40] Article 16 of the MAR

[41] ESMA/2015/1455 Annex XI, as well as ESMA/2015/1464 RTS, no. 6

[42] ESMA/2015/1455 Annex XI

[43] ESMA/2015/224

[44] ESMA/2015/1464 RTS no. 6

of the algorithm to the production environment must take place in a controlled manner, and any deployment must be approved by senior management and entered into the log with name, date/time and justification.

b) After deployment of algorithms

The algorithms must be limited so that they cannot trade more than a given number of instruments, a limited number of orders, on a limited number of markets, as well as have limitations on prices. Furthermore, the company must carry out real-time monitoring of the algorithms, including checking whether there are signs of activity carried out by the algorithm that is disturbing the market, or may be market abuse, including from a cross-market and cross-product perspective. The monitoring must be carried out by the employee responsible for the algorithm, and also by an independent risk-control function in the company. Real-time monitoring must encompass automatically generated alarms to identify incidents where the algorithm is acting in an unexpected manner, including repeating a strategy more than a given number of times, limitations on prices and the size of orders. The monitoring employees must have authority to take corrective action. The company must have an emergency switch that immediately cancels all outstanding orders, either on all market venues simultaneously, on selected market venues, or for selected algorithms. The company must be able to identify the algorithm making the unwanted transaction and be able to document this to the Danish FSA.

c) Other requirements for the company

The company must carry out an annual stress test as well as validation of its algorithms. The Danish FSA may request the validation report. Furthermore, there are requirements for the compliance department to establish clarity about the company's obligations, requirements that the company has a sufficient number of employees with the required skills to manage trading systems and algorithms, sufficient training of employees to comply with regulation, and also, the company has procedures in place with comprehensive contingency plans in the event of system errors and market scenarios, as well as IT security.

The future requirements for investment firms using algorithmic trading address several of the risks noted in section 3. Generally, this type of control is being increased, and it is likely that the time from when a market opportunity is spotted until deployment of a new algorithm will become longer due to requirements for testing algorithms before deployment. The risk of inappropriate algorithms being deployed and disturbing the market will become smaller. If an algorithm still acts inappropriately, this is more likely to be detected in due time, and the possibilities of quickly closing down the algorithm will be greater.

The risk of deployment of a misprogrammed algorithm has not been entirely eliminated, however. This is because tests of algorithms must be in a closed environment. As the environment is closed, the interdependence of the newly developed algorithm of other high-frequency-trader algorithms will not be tested.

9.3Future regulation of sponsors selling direct access[45] [46]

The future regulation affects the sale of DMA and SA access in different ways.

a) Before allocation of direct access

The investment firm must carry out *due diligence* before allocating direct access to its client. As a minimum, this process must include subjects such as strategies, checks of any pre-trading controls by

[45] 2014/65/EU - Article 17(5) of MiFID II
[46] ESMA/2015/1464 RTS no. 6

third parties, the persons responsible for errors and remediation, historical trading patterns, clients' ability to meet their financial obligations, and, if resale of direct access is permitted, requirements for *due diligence*.

b) After allocation of direct access

The sponsoring investment firm must regularly supervise the orders of DMA clients. All orders must be subject to market surveillance by the trading member of each client, and orders in instruments in which the DMA and SA client has no authorisation to trade must be blocked. Pre-trading and post-trading controls must be established, including thresholds for prices and trading volumes. Furthermore, the credit and market risk to which the sponsoring investment firm is exposed must be monitored on an intra-day basis.

c) Other requirements for the sponsoring investment firm

The sponsoring investment firm must reassess clients' systems and controls at least once a year, and also reassesses the method in which *due diligence* is carried out. Moreover, order data must be stored for each individual client for use by the relevant authority.

Future requirements for investment firms who sell direct access will increase controls on algorithmic traders and minimise the risk that the sponsoring investment firm uncritically sells direct access and thus also the risk of incorrectly programmed algorithms. Ongoing checks on the sponsoring investment firm work as an additional control phase, in addition to the client's own controls.

9.4 Future regulation of markets concerning algorithmic trading

The future regulation of market venues affects algorithmic trading in different ways.

a) Requirements for market makers to not pull out randomly[47]

An investment firm making bids and asks on a financial instrument in at least 50% of the trading time on a market venue is obliged to enter into a market-maker agreement with the market venue[48]. As a minimum, this agreement must include specific obligations concerning trading time, and this must be at least 50% of the trading time, the size of the bid and the spread. The agreement must include incentives given by the market venue to the market maker to maintain the market-maker function. Particularly, there must be an incentive to maintain the market-maker function and thus contribute with liquidity under stressed market conditions. In exceptional circumstances, including extreme volatility, technological issues and macro-economic events, the obligation to place simultaneous bids and asks will lapse.

The obligation to enter into a market-maker agreement and the way this should be worded can help reduce the systemic risk described in section 3 for situations where liquidity providers suddenly stop placing regularly updated bids and asks on the market venue with a resulting sudden collapse in liquidity. However, the risk will still be there in exceptional circumstances when the market maker is exempt from its obligations. This exemption in the rules is necessary, as otherwise no investment firms would act as a market maker.

[47] 2014/65/EU - Article 17(7)(b) of MiFID II

[48] ESMA 2015/1464 RTS no. 8

b) Maximum order-to-trade ratio as well as price structure[49] [50]

Market venues must have a threshold order-to-trade ratio for classes of instruments. If the order-to-trade ratio for a market participant exceeds this threshold, the market venue can impose a fee on the market participant. For each class of instruments, there are two thresholds:

1) Total trading volume in orders divided by total trading volume executed
2) Number of orders divided by number of executed (wholly or partly) orders

In addition, market venues may not have a price structure that gives their members an incentive to trade in a way that contributes to disturbance on the market. The price structure must not be offered such that, if transaction by a member exceeds a threshold, all transactions, also retrospectively, benefit from a discount[51].[52]

Thresholds for the order-to-trade ratio, as well as a price structure that does not give incentive to place many orders, address the risk that market technology may be under pressure as it is likely there will be a lower number of orders. It is also likely that, to a certain extent, the limits will help prevent orders that give misleading signals about supply and demand for a given instrument. This will reduce the likelihood of market abuse carried out by algorithmic traders, as described in section 3.

c) Rules on co-location[53] [54]

The rules of a market venue concerning co-location must be fair, non-discriminatory and transparent. This will mean that all trading members will be able to gain access to co-location. For example, the cable length must be the same for all buyers of a co-location. Obtaining a co-location will still be associated with costs, but it must be possible to buy only the services required. These regulations may increase opportunities for the market participants experiencing that they react slower than other market participants, and thus possibly reduce the asymmetric information described in section 3.

d) Minimum tick size[55]

Market venues must, as a minimum, have tick sizes for shares and similar products. The NASDAQ Copenhagen has already introduced such limits, but the new limits will depend on both the price level of a share and the liquidity of the share[56]. On the one hand, this ensures adequately high costs to obtain best bid and offer. On the other hand, when the minimum tick size depends on liquidity, the bid-ask spread will not be too large for liquid shares[57]. Future tick sizes for some instruments will be smaller med MiFID II compared with the current tick sizes on the NASDAQ Copenhagen.

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[49] 2014/65/EU - Article 48(6) of MiFID II

[50] ESMA/2015/1464 RTS no. 9

[51] 2014/65/EU - Article 48(9) of MiFID II

[52] ESMA/2015/1464 RTS no. 10

[53] 2014/65/EU - Article 48(8) of MiFID II

[54] ESMA/2015/10 RTS no. 10

[55] 2014/65/EU - Article 49(3) of MiFID II

[56] Today, tick sizes on the NASDAQ depend on the price and on whether or not the share is large cap. http://www.nasdaqomx.com/digitalAssets/97/97551_nasdaq-omx-nordic-market-model-2015_03.pdf

[57] ESMA/2015/1464 RTS no. 11

e) volatility guards

Regulated markets must have measures such that orders above a given size, or if the price exceeds a given threshold, are cancelled[58] [59]. The NASDAQ Copenhagen has already introduced volatility guards, as described in section 8.1.

f) Test of algorithms[60] [61]

The market venue must require from its members that they test their algorithms in order to prevent disturbing the market. The market venue must set up scenarios with functionality and structures that recreate a realistic trading environment. As a minimum, the member must test algorithms before deployment, through the test facilities of the market venue. The member's algorithms cannot be used on the market venue until they have passed the test scenarios of the market venue.

10. Role of the Danish FSA in relation to algorithmic trading

The Danish FSA is the supervisory authority for Danish investment managers and banks, and as such, supervises Danish investment firms. The Danish FSA is also the supervisory authority for Danish market venues and monitors trading, including algorithmic trading. This section analyses the possibilities of the Danish FSA to supervise algorithmic trading, both according to the current regulation and after implementation of the coming MiFID II Directive.

10.1 Supervision of algorithmic trading in relation to disturbance on the market

After implementation of MiFID II, all high frequency traders trading on a market venue in the EU must be authorised as an investment firm. This means that the undertaking must have system controls and risk controls as well as comply with certain organisational requirements. All transactions carried out by a high frequency trader on the NASDAQ Copenhagen will thus be carried out by an undertaking subject to supervision in Denmark or another EU Member State. This applies regardless of whether the high frequency trader is a trading member, DMA customer or SA customer. However, the Danish FSA will not have direct supervisory authorisation relative to foreign trading members and their foreign DMA and SA customers, which, as stated in this report, account for the majority of algorithmic trading on the NASDAQ Copenhagen. However, the Danish FSA has well-established international cooperation with foreign supervisory authorities and will be able to communicate with such authorities about issues relating to foreign algorithmic traders.

As a consequence of MiFID II, far more explicit legislation is on the way. This new legislation will strengthen supervision of the NASDAQ Copenhagen and of the investment firms who either carry out algorithmic trading themselves or sell access to third parties who conduct algorithmic trading. The new legislation introduces safety measures of a preventive nature, such as algorithm testing, and of a direct nature, such as volatility guards. This clear legislation means that the Danish FSA can refer to legislation to an extent that is not possible today, for example on items such as algorithm testing, minimum requirements for due diligence and safety measures on the market venue. This specification will reduce the risk of disturbance on the market as a consequence of algorithms, and enhance the Danish FSA's possibilities to supervise algorithmic trading. As algorithmic trading is widely carried out by foreign

[58] 2014/65/EU - Article 48(4) of MiFID II

[59] ESMA/2015/1464 RTS no. 7

[60] 2014/65/EU - Article 48(6) of MiFID II

[61] ESMA/2015/1464 RTS no. 7

market participants, supervision by the Danish FSA must be primarily based on this indirect supervision of algorithmic trading, supervision of the NASDAQ Copenhagen and the sale of direct access.

In a number of points, MiFID II introduces a *level playing field* for market venues through harmonisation of rules applicable across borders. For example, there are currently no rules governing tick sizes on a market venue. Today, market venues have incentives to reduce tick sizes to attract algorithmic traders who can exploit the resulting arbitrage possibilities. This has resulted in inappropriate competition between market venues, which underbid with lower tick sizes, thereby reducing market depth and creating more disturbance on the market. With the implementation of MiFID II, rules across markets will be harmonised and this will reduce disturbance on the market.

10.2 Supervision of algorithmic trading in relation to market abuse

With regard to market abuse, the Danish FSA has significantly more direct authority than with regard to disturbance on the market as a consequence of algorithms trading inappropriately. This is because the market abuse regulations comprise all regulations on the NASDAQ Copenhagen, irrespective of whether the customer or trading member is Danish or foreign. If, through its market surveillance, the Danish FSA discovers a possible violation of the market abuse regulations, the Danish FSA may report this to the Police.

Both Danish and foreign trading members and their DMA and SA customers, and any underlying customers, may be reported to the Police.

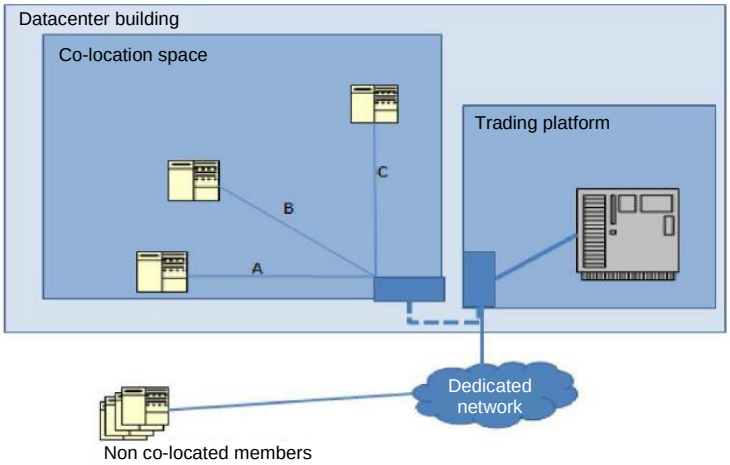
The data basis available to the Danish FSA today to identify market abuse is not suitable for market abuse cases involving algorithmic trading. With MiFID II, the Danish FSA will gain an insight into the strategies used by algorithms on the NASDAQ Copenhagen. In addition, the Danish FSA will receive better quality information about the transaction data on trading in Danish financial instruments, as, for example, the Danish FSA will in future receive information about the algorithm used to carry out a transaction. The Danish FSA will subsequently be able to examine whether a transaction carried out by an algorithm could be used for price manipulation.

The current data basis prevents effective identification of cross-market market abuse. Therefore, another important element in the Danish FSA's future market surveillance is access to order book data from market venues in the EU, as well as synchronization of order book watches. In order to be able to identify cross-market market abuse carried out by high frequency traders, synchronized market watches are required. This is because high frequency traders operate in a very short timescale and therefore recreation of the trading process on several market venues is not possible without this synchronization. This makes it essential for market surveillance that all market venues use synchronized watches.

With the market abuse regulation, which enters into force in mid-2016, the prosecution authorities - in Denmark, the Public Prosecutor for Serious Economic and International Crime *(Statsadvokaten for Særlig Økonomisk og International Kriminalitet)*- are able to refer to clearer legislation, as the regulation explicitly mentions some trading strategies which must be considered as price manipulation, including an indicative list of HFT strategies considered market abuse.

The new regulations will strengthen the Danish FSA’s supervision options and its authority. This applies both in the supervision of market participants and market venues, primarily the NASDAQ Copenhagen. The new authorities will be used with regard to Danish investment firms who use algorithms either directly or indirectly on behalf of customers. However, considering the nature of trading on the NASDAQ Copenhagen today, in the short-term, the Danish FSA's authorities will primarily be used to supervise the NASDAQ Copenhagen. The Danish FSA will use its strengthened supervisory basis in its market surveillance in order to identify potential market abuse.

Glossary

Word	Explanation
Algorithmic trading	Trading where a computer automatically decides different trading parameters, including whether to trade, the time and price of orders.
Arms race	A situation where competitors compete for a leading position, where large sums are invested and where by far the fewest competitors make a profit on their investment.
Asymmetric information	Situation where two parties do not have the same information and therefore one party is in a better position than the other.
BBO	Best Bid and Offer, best bid and ask price
C20 index	A share index comprising the 20 most traded shares on the NASDAQ Copenhagen.
Circuit breakers	See "volatility guard"
Co-location	Computer placed close to the matching system at the market venue. **Figure 15. Illustration of co-location** 
Cross market	Term describing something that takes place simultaneously on more than one market venue. E.g. in connection with cross-market strategies, which are strategies involving several market venues at the same time.
Dark pool	Transactions carried out in a dark pool enable trading in financial instruments without announcing large orders. Dark refers to the lack of transparency in contrast to a regulated market. This is used particularly in large orders which could change the price if they were public.
DEA	Direct Electronic Access: Joint term for DMA and SA.
DMA	Direct Market Access: Access to a market venue through the access of a trading member and through the IT infrastructure of this trading member.
Due diligence	Investigation of a party before signing a contract.
ESMA	European Securities and Markets Authority: An EU financial regulatory institution.
FCA	The Financial Conduct Authority is an authority which supervises the financial sector in the UK.
Fit and proper assessment	An assessment of fitness and propriety.

Flash Crash	A price drop on financial instruments within a very short horizon.
Investment manager	An undertaking which is authorised to trade in securities.
Volatility guard	A mechanism which temporarily breaks trading in the event of large sudden fluctuations in the price of a security.
HFT	High Frequency Trading: A computer sends a large number of messages to a market venue at a high frequency.
Immediate or cancel order	An order which is matched immediately on the market, if possible, and otherwise cancelled immediately.
Indirect trading member	An undertaking which is not a direct member of a market venue, but that trades through a member, i.e. through a DMA or SA access.
Intra-day volatility	Volatility measured on points within the same day. The analysis in section 7.2. uses 2-minute intervals.
Knight Capital	American financial undertaking which had the largest trading volume on the American stock market up to the flash crash in August 2012 when the company lost USD 460 million due to a misprogrammed algorithm. The company was subsequently bought up.
Large cap	NASDAQ Copenhagen defines large-cap companies as companies with a market cap exceeding EUR 1 bn.
Latency	The sum of the following: The time from the occurrence of a change on the market until the trader receives the information. The time it takes to analyse the change on the market until the trader issues an order message. The time it takes for the order message to reach the market venue.
Layering	A form of price manipulation where a dealer inserts orders on one side of the *bid-ask spread* without intending that these orders are to be met, and at the same time the dealer trades on the other side of the *bid-ask spread*.
MAR	Market Abuse Regulation: Regulation EU No. 596/2014
Market Cap	The total value of shares in issue. Calculated as the number of shares in issue times the share price.
Market maker	A trading participant who inserts passive bids and asks in a security. When the transactions are met, a profit is made on the bid-ask spread. The passive orders contribute to liquidity in the security concerned.
Mid Cap	NASDAQ Copenhagen defines mid-cap companies as companies with a market cap between EUR 150 mill. and EUR 1 bn.
MiFID	Markets in Financial Instruments Directive: Regulation EU No. 39/2004
MiFID II	Markets in Financial Instruments Directive: Regulation EU No. 65/2014
MiFIR	Markets in Financial Instruments Regulation: Regulation EU No. 600/2014
Operational risks	Risks from factors such as incomplete internal procedures, human errors and system errors. Should be considered as the opposite of market risk.
Order-to-trade ratio	The ratio between the number of orders and the number of transactions.

Regulated market	A multilateral trading facility that matches buy and sell interests in a non-discriminatory manner. The regulated market must have an authorization which can be granted after compliance with a number of requirements described in MiFID.
SA	Sponsored Access: Access to a market venue through the access of a trading member and through the IT infrastructure of said trading member. Contrast this with DMA.
Small Cap	NASDAQ Copenhagen defines small-cap companies as companies with a market cap of less than EUR 150 mill.
Spoofing	A strategy which is considered price manipulation, where a party with a long position in an instrument places a large anonymous bid on the same share with no intention of trading. The bid drives the instrument up as other parties see the great demand for the instrument. The initial bid is cancelled and the party then sells at a higher price than would otherwise have been possible. This strategy is also called a phantom bid.
Spread	The difference between best bid and ask.
Tick Size	The smallest change in price which can be made in a security. On NASDAQ Copenhagen this depends on the price of the security.
VIX-index	Implicit volatility calculated on the basis of prices of options on the S&P 500 index.
Value at Risk (VaR)	A measurement of risk corresponding to losing more money than this amount with a probability of (usually) 1%.
Volatility guards	See "volatility guard"

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Annex

- Macroeconomic:
  - The VIX index - a global index for volatility, calculated on the basis of option prices. A positive correlation between the volatility in Vestas and VIX is expected.
  - Oil price
  - Orders for wind turbines.
  - The interest rate on five-year Danish government bonds. Lower interest rates provide better possibilities for loans and less uncertainty.
- Undertaking-specific:
  - Debt to Assets. A high debt in relation to the value of the undertaking is expected to be positively correlated with the volatility due to greater uncertainty about whether Vestas will go into liquidation.
  - Turnover in DKK million in the Vestas share as a measurement of liquidity.

The following regression is carried out:

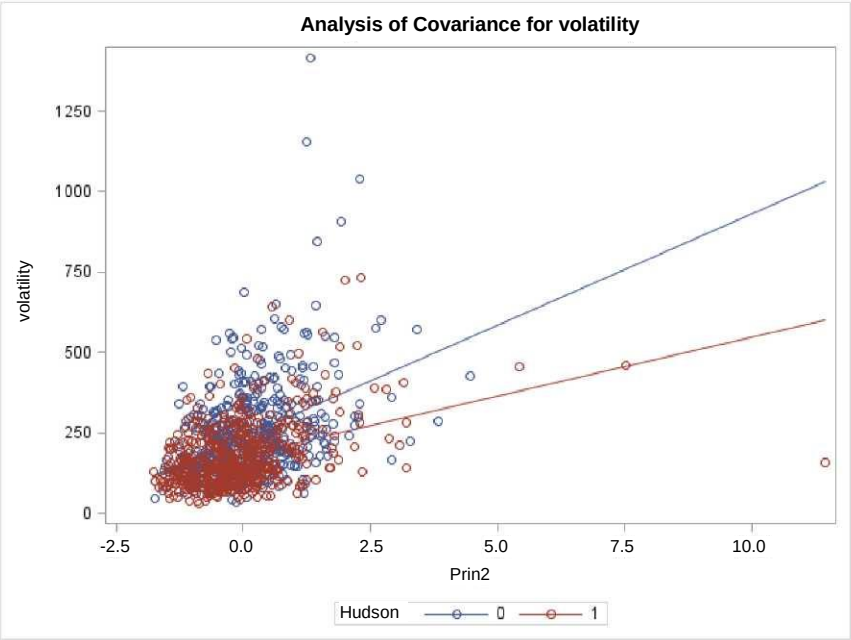
$$\text{Intraday volatility} = \beta \cdot \text{Market Maker} + a_1 \cdot M + a_2 \cdot V,$$

where Market Maker is a variable with the value of 1 for the period in which the high frequency trader is the market maker and 0 otherwise. M is the list of macroeconomic variables and V is the list of undertaking-specific variables. Finally, Intraday Volatility is calculated on the basis of the Vestas share price in 2-minute intervals in the period 2007 to 2015.

The result of the regression shows that there is a positive correlation between intraday volatility of the C20 share and the VIX index. The share-specific variables, debt-to-asset and turnover, are also significant. The other macro-economic variables are not significant. The variable market maker is significant and shows that when the high frequency trader is a market maker, the phase in the regression is significantly smaller than when the high frequency trader is not the market maker. After checking for changes in general volatility by including more variables in the regression, the market-maker variable is found to be significant. The high frequency trader seems to have an effect on volatility in the Vestas share, even after adjusting for general volatility.

As there are checks with several variables, this control is not possible to illustrate. A principal component analysis is carried out to circumvent this issue. The first principal component explains most of the variance and is a combination of the control variables. Figure 8 shows that volatility in a C20 share prior to entry of the high frequency trader as *market maker* was more dependent on market circumstances such as the *VIX index* used as a general volatility. Graphically, this is seen in the way that the blue line is significantly steeper than the red one. This means that, after the high frequency trader started acting as *market maker* in the share, the volatility of the share did not increase correspondingly with an increase in general market volatility. The volatility of the share is thus lower and more stable.

Figure 16. Intraday volatility in a C20 share against the first principal component



Note: Intraday volatility against the first principal component in two periods:

Blue line: Prior to the high frequency trader becoming a market maker

Red line: After the high frequency trader entered as a market maker.