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Market and limit orders and their role in the price discovery process

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Abstract

The information level of market participants and finally, the order types and submission mechanisms of either market or limit orders – including hidden orders, have a significant price impact. An important area in the domain of price impact research is high-frequency trading (HFT), which contrary to many opinions and controversies (e.g. the false responsibility in the Flash-Crash of 6 May 2010) may in fact have a positive effect in market efficiency. In addition, they may also reduce transaction costs (spread) as a result of, for example, better price synchronization of financial instruments across markets.

Performing literature research on both theoretical and empirical studies on market and limit orders and their impact in the price discovery process, it is shown that the choice between the order types is a strategic decision – even when considering that limit orders have the most long--term price impact. In addition, limit orders are preferred by informed traders as it limits adverse selection exposure. Similar reactions will be seen with HFT traders through limit orders aiming to reduce adverse selection risk and transaction costs, which in turn leads to an increase in transaction profits.

Keywords: order book, information asymmetry, market efficiency, market microstructure

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1 Introduction

The price discovery process of financial instruments is an area of interest of many market participants and is an important topic in the market microstructure discipline and analysis performed therein. Investors are willing to construct better price forecasting models, liquidity providers expect to better understand the market shape and reactions at a very specific moment in order to optimise the bid--ask prices. Researchers, thanks to a better visualisation of a given market, may better understand the incentives behind order submission and trading decisions, which are dependent on market conditions. In addition, it seems important to better understand the existent mechanisms at the microstructural level and the demand and supply mechanisms present in the price discovery process.

Trading venues, regardless of whether they are regulated or not (as in the case of dark pools), are places aimed at bringing together both the buyers and the sellers wanting to settle a transaction at a determined price – of course, at a price where demand meets supply. The presence of better informed market participants leads to the existence of spread.[1] Spread is the difference between the price at which liquidity suppliers are keen to purchase financial instruments and the price at which those same participants are interested in selling them (bid-ask). At the time when many analyses focus on the optimisation of inventory costs,[2] others concentrate on information asymmetry aspects – also affecting the spread size (Glosten, Milgrom 1985). The problem of matching market participants and of establishing a fair spread (prices) is especially more exposed in markets where liquidity is not very evident. In such conditions, it is difficult to specify how exactly prices are affected by information asymmetry and how well they reflect the information advantage some traders have against other traders. The analysis of the order book is a key step in order to establish the information asymmetry level at a certain moment and to determine the direction of traders reactions in response to the continuous information dissemination. Order books allow observation of the trading activity through market orders and limit orders. The presence of continuously faster order submission techniques or mechanisms, for example as a result of the presence of HFT, gives a significant advantage in the additional and eventual revision of previously submitted orders. More than that, the presence of high frequency traders or similar mechanisms brings them to a significantly leveraged position in reducing adverse selection risk exposure, which may lead to a decrease in transaction costs in terms of the spread of a financial instrument.

The main aim of this paper is to formalise the knowledge, as far as possible, basing in a rather limited number of available publications, focused in answering the question of how the selection and submission of market and limit orders affect the price discovery process. It is worth mentioning that regardless of how advanced financial markets are, it is very difficult to obtain precise order submission and execution data from the order books. For this reason, the number of existing empirical analyses is limited. In addition to the abovementioned goal, preliminary conclusions of studies will be shown, presenting how high-frequency trading participants, a branch of algorithmic trading, influence the price discovery process, and eventually lead to a decrease in information asymmetry. This is of such importance because according to estimations, HFT may be responsible for as much as 50% of all transactions in the capital market in the US. The share and influence of algorithmic trading in the

[1] It is important to underline that the mechanisms determining the spread, both the minimal and maximum values, are different and dependent on financial instruments and the markets where they are traded.

[2] The term 'inventory costs' includes both the costs of keeping an open position and trading activity understood as trading volume (Galati 2000).

transaction process is the focus of many academic studies that bring, not rarely, contradictory results. Some studies lead to the opinion that the presence of algorithmic trading increases market efficiency and improves the efficiency of the price discovery process. The results of other studies show that such traders, or some strategies used by them, may have a destabilizing character in the financial market as a result of achieving profits at the expense of other market participants.

This paper focuses on the literature analysis of a limited number of papers concentrated most often on the US financial market, where liquidity is significantly high, leading to a more precise analysis of the influence of both market and limit orders in the price discovery process. Taking the above into account, this paper shows that:

a) motivations behind traders decisions on the moment for order submission or their withdrawal are strategic, or even tactical;

b) although market orders have the most price impact in a short time period, in the long-run price impact is higher when using limit orders due to (among others) the amount of submitted orders;

c) one of the main reasons informed traders prefer to submit limit orders is due to the fact that in this way they reduce adverse selection exposure and because of the long-term effect on prices in comparison to market orders;

d) high-frequency traders prefer to use limit orders, which limit adverse selection exposure, decrease transaction costs, and finally increase transaction profits.

2 Market orders, limit orders and the order book

In most of the financial markets, trades amongst participants are performed electronically. Independently, if the financial instruments are stocks, currencies, or derivatives, traders participating in such markets may submit tender offers, or declarations that they are keen to make transactions in a specified instrument. These declarations are submitted though orders. Independently of their function or size, market participants have basically two types of orders available: market orders and limit orders. Although market orders are one of a kind, limit orders may be submitted in many variations, including completely hidden orders or partially hidden orders – known as iceberg orders. Market orders have the substantial advantage of a high probability of execution, because the execution price is the best available price (bid-ask) for immediate execution at a given moment. Limit orders, on the contrary, are submitted at any desired price and wait for execution until the price reaches the earlier defined level. As it will be shown further in this paper, sell limit orders are most often submitted above the ask price, while buy limit orders are most often submitted below the bid price – nevertheless the reasons for defining the execution price for limit orders are very complex. Before going into detail on issues related to the mechanisms behind order-type decisions and their potential impact on the price discovery process, it seems important to firstly describe the most important features of the order book (OB), where these orders are recorded.

On most of the electronic markets, regardless of whether they are regulated venues or alternative trading systems – dark pools, the submitted limit orders are recorded in an order book. This applies not only to stocks or currencies, but also to derivatives, for which the Chicago Mercantile Exchange (CME) and EURONEXT life, are good examples of derivatives exchanges using complex order books. Currently, many institutional investors trading in the most liquid markets make decisions based on

information retrieved from order books. Although, the informational value included was, and still is, the focus of several studies, it seems difficult to find an analysis from which empirical results show their factual informational value. One of the rare studies is the one performed by Cao, Hansch and Wang in 2009 showing that the informational value for the price discovery process deriving from the order book (excluding the bid-ask prices) is close to 22% (Cao, Hansch, Wang 2009). The remainder of this informational value (78%) results from the best bid-ask prices and the price of the last transaction. Currently, for a certain fee electronic exchanges may make public order books, therefore making visible not only the best bid-ask prices (known as Level I), but also the total number of financial instruments (volume) laying in the order book resulting from limit orders for the 5 price levels above the ask price and 5 price levels below the bid price (Level II). For an even higher fee, some electronic exchanges may release data for the next 5 price levels above the ask and 5 price levels below the bid. In the end, this provides investors with the informational power on the volume of standing orders for the 10 price levels above the ask level and 10 price levels below the bid level (Level III). However, it is questionable whether obtaining more information related to the order book yields any actual gains. A study by Hautsch and Huang on the Euronext in Amsterdam shows that the most important fragment of information for the bid-ask price discovery process is the first 3 price levels on the order book (Hautsch, Huang 2012). This does not necessarily mean that the same applies to all markets and instruments, and so further analysis is required, but in many papers researchers most often refer to the first 5 price levels of both sides of the order book, or in other words, the Level II of the order book.

Table 1
Example of Level II order book

	Price	Volume
Ask	106	250
	105	500
	104	700
	103	1000
	102	750
Bid	**98**	700
	97	1000
	96	800
	95	650
	94	500

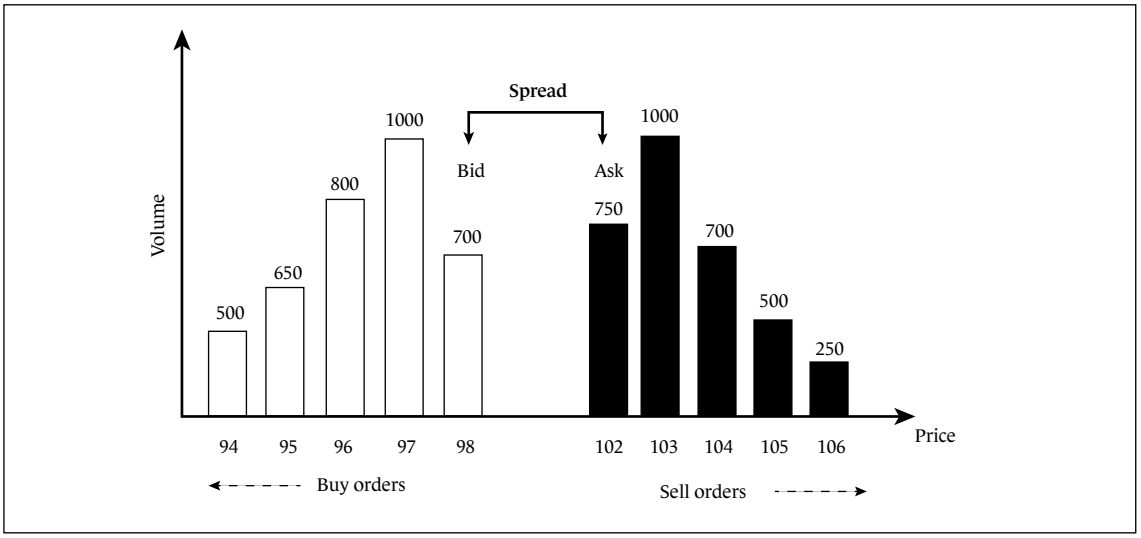
Source: own work.

Because investors may at any time submit and withdraw limit orders as a result of, for example, market conditions, order books may provide important information in the short-term. The first and most obvious information resulting from the order book is the current level of activity from investors interested in buying and selling instruments at the different price levels, which can be observed

through the volume levels at each price level. For example, a significantly high volume at certain price levels may indicate the support or resistance level. This would mean that at these levels there is a low probability for prices to fall below the support price level or rise further than the resistance level. Order books are most often presented in the format of a table, like the one provided for illustrative purposes in Table 1, for the first 5 price levels (Level II).

Figure 1 further presents an illustration of the order book resulting from Table 1 for the Level II order book, which combines the first 5 price levels including the best bid-ask prices.

Figure 1
Illustration of Level II order book (Table 1)



Source: own work.

It is worth mentioning that the shape of the order book in Figure 1 is not arbitrary. In practice, under ideal conditions, when there is an equilibrium in the order book, these may have a shape similar to the one presented in Figure 1 (Chiarella, He, Wei 2013; Gould et al. 2013; Lallouache, Abergel 2014). Although the shape of the order book in Figure 1 is treated as a representative one and is presented as so in many papers, in practice the order book may present any shape depending on the market,[3] financial instrument or even the time in the session (Cartea, Jaimungal, Ricci 2014). In a classical order book, on the first price level above the ask and on the first price level below the bid, is where there is an accumulation of limit orders and with them volume. On the next price levels, the volume and number of orders decreases. For this reason, the most common shape of the order book presented in the literature is the one resembling Figure 1. Of course, as mentioned before, this shape of the order book does not need to occur, as there is not always market equilibrium. An important parameter of the order book worth presenting, which is often analysed and mentioned in many studies or even used

[3] A study by Charoenwong, Visaltanachoti and Ding shows, for example, that the difference in the shape (curvature) of the order book of the Paris Bourse and the that of the Stock Exchange of Thailand results from the different sizes of the minimal spread and the information asymmetry present at the Stock Exchange of Thailand (Charoenwong, Visaltanachoti, Ding 2014).

for the construction of transaction strategies, is market depth. Market depth is a concept that may be understood as the existent volume individually at each and single price level. Even though market depth and liquidity are related, it is important not to associate market depth with liquidity – by claiming, for example, that the higher (lower) is market depth, the higher (lower) is liquidity on a certain financial instrument. Liquidity may be interpreted as the possibility for rather quick order executions – even for significant nominal values, at low transaction costs and with limited price impact (Brandão-Marques, González-Hermosillo 2015).

It is also worth mentioning, that market depth and together with it, the shape of the order book on both sides (bid-ask), do not need to be, and are often not, symmetrical. This means that the volume of all limit orders standing for execution on the ask side, does not need to be the same as the volume of limit orders on the bid side. This situation shows an asymmetry in the order book on the sell side (orders above ask level) and on the buy side (orders below the bid). Each submitted order, regardless of whether they are market orders or limit orders, changes the shape of the order book and its eventual movement relative to the market price. Even though market orders, as the name implies, affect market depth at the best market bid-ask prices, limit orders diversely affect the market depth and the order book depending on the types of limit orders used.

There are three categories of limit orders which differ depending on the price that is specified on those limit orders (Hautsch, Huang 2012): limit orders outside the market (limit orders submitted outside the best market prices), limit orders at the market (submitted at the best market prices), and limit orders inside the bid-ask spread (inside the spread). The results of some studies show that the types of limit orders submitted most often, even though without any significant superiority, are the ones submitted outside the market, that is, submitted above and below the bid-ask prices (Wee, Yang 2015). Below the bid, limit orders are submitted at successively lower prices. In comparison, above the ask, limit orders are submitted at successively higher prices. Limit orders at the market, as the name implies, are submitted at the current best market prices, and it should be mentioned that two types of limit orders at the market may be distinguished – aggressive limit orders and passive limit orders (Said et al. 2018). Aggressive sell limit orders are submitted at the bid for aggressive sell limit orders, or at the ask in the case of aggressive buy limit orders, and as one may notice, they constitute an alternative to market orders. These types of orders are most often called crossing the spread[4] and are intended to be immediately executed. They may even sometimes be considered market orders in the literature (Said et al. 2018). It is should be pointed out that in the case of limit orders crossing the spread, the execution prices are always the best market prices available at a specific moment, and there is no possibility for these orders to be executed at unfavourable prices, e.g. higher or lower prices due to price shocks, as it is possible with market orders. Contrary to aggressive limit orders that remove liquidity from the market, one may mention passive limit orders which are aimed to rather increase this liquidity. This means that buy limit orders submitted at the bid and sell limit orders submitted at the ask increase this way the market depth at the specified price levels instead of diminishing it as in the case of aggressive limit orders. Another type of limit order mentioned previously, is the limit order inside the spread. The mechanism behind these orders is the same as in the previous limit orders, but the main difference is that these orders lead to changes (improvement) of the current best bid-ask prices. This is known as the price improvement process. Instead of submitting limit orders, for example,

[4] The term crossing the spread results from the fact that instead of submitting, for example, a buy limit order at or below the bid, they are submitted at the ask for immediate execution.

at prices below the bid, traders submit them above the bid, potentially reducing the spread – in this example the ask price remains unchanged while at the same time only the bid price increases. A similar mechanism will function for sell limit orders below the ask – here, the price improvement effect takes place but on the ask side.

3 The role of market and limit orders in the price discovery process

The main determinants having a significant influence on the level of order aggressiveness that may be mentioned (Charoenwong, Visaltanachoti, Ding 2014) are as follows: bid-ask spread, market depth, spread, market depth of other financial instruments correlated in a higher or lower degree, or even market sentiment. Taking into account the different types of limit orders and market orders, it is important to understand how they affect the limit order book, and so, the price discovery process. Market orders and aggressive at the market limit orders are executed without delay at the bid-ask prices. For both of these types of orders, in the case where there is a buy order, these will be executed at the ask, while a sell order will be executed at the bid. In such cases, these orders will simply remove liquidity from the market – liquidity that is provided by typical limit orders or passive limit orders, making this a simple mechanism for price changes. When the volume standing for execution at the bid-ask levels is consumed (e.g. through market orders), a price increase or decrease will succeed. For example, if at the bid-ask price level of 98/102 in Figure 1, where the available standing volume is 700/750 units and next, the volume at the bid level becomes depleted say, through sell market orders, then the bid price level drops to 97, and the spread increases to 5 units (97–102). It should be noted that when there is a difference between order volume and market depth, market orders do not need to be executed in full at the current market bid-ask prices. If it is planned to submit a buy order at the market price 102 (ask) with a volume of 1000 units, but only 750 units are available (as in Figure 1), this order will only be partially filled at that price. First, 750 units will be executed at the ask, and the next 250 units will be filled at the next closest and higher price above the ask – in this case the 103 price level. In consequence, market depth at 103 level drops from 1000 units to 750 units, and the new ask will be at 103 price level. If the order volume was even higher and the market depth at 102 and 103 price levels were not sufficient to fill the order, the remainder of the order would be executed at sequentially higher prices until full execution. This of course implies that at the time that the standing volume becomes depleted at the different price levels through this market order, the (in this case) ask will rise until there is a price level where there are standing limit orders which fulfil the current liquidity needs.

The next type of limit orders are the ones submitted inside the spread which lead to a price improvement. In Figure 1 one may see that the best market prices are the ones at 98 (bid) and 102 (ask). This implies that an investor willing to use market orders will buy at 102 and sell at 98. Now, limit orders inside the spread lead to different consequences in the order book. When investors decide to use limit orders inside the spread, they will ultimately be decreasing the spread, simply because they are generating a new price level which is more competitive (better/cheaper) than the previous bid-ask price levels. For this example, an investor could, for example, submit a buy limit order with a volume of 800 units at the price of 99 – higher than the current bid, raising this way the current best market price bid to 99 from the previous 98 price level. The spread will finally be reduced from 4 units (102–98) to 3 units (102–99). As it is observed in the above example, the price improvement process will therefore consist

in providing better trading conditions – it is now possible to sell at a higher price (99) in comparison to the previous price of 98. Some studies show that the long-term effect resulting from limit orders inside the spread will be determined by the size of these orders (Hautsch, Huang 2012). If orders are submitted with significantly large nominal values, then price changes are more likely to be long-term and according to the planned direction (price increase or decrease). Orders with smaller nominal values will only lead to other faster traders taking advantage of the temporary price improvement without any long-term price improvements.

According to studies on the S&P and ASX (Wee, Yang 2015), both limit orders submitted outside the best prices, i.e. outside the market, and passive (which increase liquidity) at the market limit orders are the most often submitted types of limit orders for liquidity provision. While using Figure 1 as an example, if a sell limit order is submitted at 103 (outside the market price) with the volume of 250 units and the market depth at this price is 1000 units, then after including the limit order market depth at 103 price level, there will be 1250 standing units. The market depth has increased and so too has the amount of units necessary to be bought at that price level to lead to a subsequent price change. An equivalent mechanism will take place with buy limit orders below the bid – market depth will also be larger, and so will the necessary amount of units necessary to be sold until there is a price change. Passive limit orders submitted at the market are definitely more aggressive types of orders than those submitted outside the market (Hautsch, Huang 2012), although the same mechanism applies as before. The reason why these orders are more aggressive than limit orders outside the market is that they have a larger impact on the bid-ask prices by increasing or decreasing (if orders are cancelled) market depth at the bid or ask. This will ultimately mean that the necessary volume to change prices will be higher (lower) depending on higher (lower) market depth at the bid-ask levels. It is worth mentioning that for passive orders, unlike market orders or aggressive limit orders, the only method to decrease the standing volume lying in the limit order book, is by withdrawing earlier submitted orders. Liquidity will decrease not because of the increase in "consumption", i.e. an increase in demand while having a constant supply for the financial instrument, but due to a decrease in supply for that instrument. For example, based on Figure 1, if there is a sell limit order at the ask (102) with a volume of 250 units, while at the same time the order book shows 750 standing units waiting for execution, the necessary amount of units leading to a change in price to 103 is at least 1000 units, i.e. 750 + 250 units. The withdrawal of earlier submitted orders at the ask with the same total nominal value (250) will, in turn, mean that the necessary orders total value for a price change will now be 500 units (less than the 1000 units as before). It is interesting to note that studies show that the order book activity at the bid and ask levels is not symmetrical after at the market limit orders are submitted. In other words, when limit orders are submitted at the bid, there will be a visible increase in activity, either of orders submission and/or withdrawal on the same side of the order book (bid side). When, in turn, there are limit orders submitted at the ask, there will also be an increase in the order book activity on the ask side, but this time it will be smaller than it was on the bid side. A study by Hautsch and Huang shows that the number of quotes at the bid side increases considerably faster than the number of quotes at the ask side (Hautsch, Huang 2012), which leads to a temporary narrower spread. The increase in the order book activity may result from the fact that traders will want to submit additional orders, but in a more aggressive fashion, if they observe an increase in the number of limit order submissions on the same side of the order book for which their limit orders have also been submitted. What results from Hautsch and Huang's study mentioned above is that traders will finally submit limit orders inside the

spread (from the bid side), reducing its size and ultimately leading to a price increase. The mechanism described above related to at the market limit orders, and consequently the submission of limit orders inside the spread driving to long-term price changes leads to a very important conclusion: limit orders contain private information related to a financial instrument (Hautsch, Huang 2012). This conclusion is of such importance that it brings down some opinions related with the topic (eg. Harris 1998) that claim that informed traders are liquidity takers (they remove liquidity through market orders) and are not liquidity suppliers. Similarly, Kaniel and Liu (2006) arrive at the conclusion that informed traders may prefer to use limit orders instead of market orders. The reason for such behaviour can be related to the fact that market orders may provide too much information to other investors (Kaniel, Liu 2006) – even when taking into account the price impact, the probability of submitting limit orders may be so high that it will indicate a high level of informational value (Kaniel, Liu 2006). One extremely interesting conclusion put forward by the above-mentioned authors and contradictory to what the literature mentions is the one stating that the higher the number of uninformed traders, the lower the probability that informed traders will submit limit orders – regardless of the fact that the profitability of such orders increases with the number of uninformed traders (Kaniel, Liu 2006). The authors explain such evidence by indicating that when there is an increase in the number of uninformed traders, the profitability of market orders increases at an even higher rate than the profitability of limit orders. Studies by Hautsch and Huang present additional important conclusions. The results of these studies show that there is a negative correlation between the price impact and the distance of submitted limit orders from the market prices. Even though at the market limit orders lead to the most abrupt market reactions (in comparison to other limit orders), orders submitted at larger distances from the market prices have the most long-term price impact, and not those submitted at the bid-ask (Hautsch, Huang 2012). Cao, Hansch and Wang reach somewhat equivalent conclusions for short-term periods by stating that the accumulation of limit orders in the top part of the order book (closer to bid or ask) brings a larger submission scale of aggressive orders (e.g. market orders) for them to be executed in the first place – which may in the end mean that such a portion of the order book may contribute to a better price forecast in the short term (Cao, Hansch, Wang 2009). Mentioning long periods of time, Kaniel and Liu show that there are no significant differences for the time periods of one-hour or one-day in the level of informativeness between large limit orders and market orders (Kaniel, Liu 2006). Mentioning the price impact resulting only from limit orders, when theory (eg. Glosten, Milgrom 1985) indicates that limit orders have a long-term price impact, empirical studies are more modest and even contradictory to these indications, despite the fact that several studies, e.g. Dufour and Engle (2000) or Engle and Patton (2004), were dedicated to modelling trading impact on prices (although without order segregation). One such study that has, however, segregated individual types of orders, is the one by Rosu, which reaches the conclusion that the price impact attributed to limit orders is only 25% in comparison to the impact of market orders (Rosu 2015). Divergent conclusions may be taken from a different study by Wee and Yang, which shows that limit orders have a larger price impact than market orders, which would mean that they convey information and are therefore submitted by informed traders (Wee, Yang 2015). Such an observation seems to be similar to the market practice in which more liquidity suppliers submit hidden or partial hidden (iceberg) orders in order to reduce the potential price impact that is generated by other traders considered to be less informed traders (Hautsch, Huang 2012). When mentioning hidden orders, it is important to notice that the earlier mentioned large market depth near the top of the order book (close to the bid-ask) may result from

orders submitted only to lead to the execution of hidden orders. Already in 2002, Hasbrouk and Saar showed the presence of limit orders in the order book for which the only reason for being submitted was to lead to the execution of hidden orders that demonstrated better execution prices – as such, orders were submitted not because of higher informational value, or as an action in response to such information as, for example, the submission of buy orders in response to positive general economic information (Hasbrouck, Saar 2001). For example (based on Figure 1), a trader may submit a sell limit order just above the bid (at 98) in order to search for hidden inside the spread limit orders, submitted previously at, for example, 99. In the case that such hidden orders do indeed exist in the order book, that trader would take advantage of the fact that his orders would be executed at a better price (99) than the market price. Otherwise, if there are no hidden orders, these "searching" orders are immediately cancelled.

3.1 Hidden limit orders

Hidden orders are already very popular in the financial markets, and studies show their surprising high share in the total volume of some stock exchanges, as for example the share of over 44% in the total market volume of the Euronext, or 28% of the Australian Stock Exchange total volume. Nevertheless, permitting the submission of hidden orders by stock exchanges and regulators diminishes not only market transparency, but also the available liquidity, simply because even when hidden orders increase real liquidity, they also decrease the competition among the suppliers of the visible liquidity, which leads to a widening of the spread. Thereafter, on the one hand, a wider spread may be less favourable for the retail traders, i.e. liquidity takers, but on the other hand more advantageous for institutional traders acting as liquidity providers, which again may lead to an increase in competition among them. What remains questionable is whether the decrease in general competition as a result of the presence of hidden orders occurs at a greater extent than the increase in competition among liquidity providers around the spread. The research subject related to the effects of hidden orders (fully and partially visible) is not only broad, but also complicated, and as such it is the reason for a separate paper. Nevertheless, while mentioning the types of orders and their eventual impact on the price discovery process, an important topic is also the order execution priority.

For market participants and for the price discovery process, a very important factor is order execution rules in the order book, which make this knowledge meaningful when studying orders impact and order strategies. As a general rule, two primary principles may be distinguished prevailing in regulated markets or also in alternative trading systems (Moallemi, Yuan 2014): price priority and time priority. There is one other rule, which opposed to the previous two rules may not be commonly followed, e.g. due to national regulations – that is, public order precedence. The basic principle behind this rule is that in the order execution mechanism, public orders, i.e. not submitted by exchange members, have priority over the orders submitted by exchange members (Harris, Namvar 2016). This rule is of no less importance than previous rules, but not necessarily followed by all exchanges – for example, the New York Stock Exchange (NYSE) has resigned from this rule, giving the same order priority to all market participants (Clark-Joseph, Ye, Zi 2017). Whether this third principle is in force or not in a country or exchange, it does not change the importance of the other order execution rules, meaning that orders will be filled according to the following sequence: price priority, time priority and in last place, public order precedence.

The price priority rule gives execution priority to submitted orders which will have an influence on the best market price. What this rule implies is that in the first place orders submitted inside and at the bid or ask will be executed in the first place and next, orders submitted at prices closer to the bid or ask will follow successively. The fundamental assumption arriving from this rule is to prevent making price jumps over the order book, and to present the current fair price resulting from supply and demand for a financial instrument. The next rule, time priority gives priority to orders arriving to the order book in the first place, and these will be executed first. One may compare this to the FIFO (first in first out) rule. This rule is of such significance that it is probably one of the most analyzed rules in research papers and when building trading models. With the current technological progress on the financial markets, the presence of traders using algorithmic trading and especially high frequency trading, the order by which orders arrive to the order book and especially, the order by which they will be filled, becomes extremely important for the trading process. Certainly, the execution sequence is very important in order to take advantage of the best given prices at a certain moment. This, in turn, may be a secondary goal because in the first place investors will want to limit adverse selection exposure. Since adverse selection derives from the informational advantage that some traders may have, these may secure better trading conditions than other traders who don't have such information or simply obtain it with delay. Adverse selection is therefore of such importance that practically every market participant wants to avoid it. When retail traders have few possibilities regarding adverse selection, institutional traders put significant effort in order to reduce adverse selection. One of such example is high-frequency traders, who dedicate significant time, human resources and especially a significant amount of capital in order to achieve the best order queue in the order book (Martin 2017 or Stockstotrade 2018). It is very important to notice that queue optimization in the order book is not the same as pursuing the opportunity to submit orders just to achieve first (fastest) execution. It should be mentioned that the fastest order execution is not always the most beneficial. If traders submit numerous and sizeable orders, it could mean that their execution leads to an immediate (instead of a desired delayed) price change, something that may not be favourable for some trading strategies. Since the order queue optimization in the order book is of such importance, many research studies (e.g. Avellaneda, Stoikov 2008; Chiarella, He, Wei 2013; Cont, Kukanov, Stoikov 2014; Harris 1998; Hörschler 2011) have been dedicated to its analysis and optimization. In addition, to complicate things a bit further, the order queue optimization becomes more complex when a trader wishes to modify an existing order. The moment an existing order is modified, depending on the regulation of the exchange or the alternative trading system,[5] it may mean that the modified order will fall back to the end of the queue and therefore lose the priority previously achieved. For example, on the Warsaw Stock Exchange a modification of an order for which the volume is reduced does not lead to a time priority impairment. Nevertheless, as a general rule, if an order loses priority it may in fact mean the order is cancelled, modified, and next submitted once more into the order book (Nasdaq 2016). This may finally mean that the trader may lose the potential advantage it had in the order execution priority, which in turn will have a key influence on the strategy efficiency and its profitability.

As order types are constantly being expanded and the use of fully hidden orders – or even their derivatives such as the iceberg orders – seems to be rising, it is imperative to fully understand and grasp the priority rules that give typical orders an advantage (or not) over hidden orders. Partially hidden

[5] For the Warsaw Stock Exchange (WSE), the policies for cancelling and modifying orders may be found in Division 4, chapter 4, section 9, art. 37 – WSE detailed exchange trading rules in UTP system (WSE 2019).

orders, available as well at the Warsaw Stock Exchange, known internationally as iceberg orders,[6] give the possibility of specifying only a predefined portion of the order which will be seen in the order book.[7] At the moment, when the visible portion of the order is filled, the next portion of that same amount will become visible, and this process will repeat itself until the full execution of the iceberg order. As a general rule, orders that are fully visible have priority over iceberg orders, and these will have priority over fully hidden orders (Nasdaq 2016). It is important to remember when planning order submission and execution that the previously mentioned time rule also applies – each of the next orders will be executed according to the exact time they reached the order book. This means that if two orders have reached the order book at the same price level and at the same time, the priority will be attributed to the order type. Independently of the order, the price rule will have priority over other rules, meaning that if a hidden limit order is submitted at the ask and in the next price level of the order book a "plain" limit order arrives, priority is given to the price priority rule, which in this case means that the hidden order will be first filled and only then the "plain" limit order. At this time, one of the reasons for which traders may be interested in submitting hidden orders may be brought forward. By submitting orders inside the spread, not only will traders be reducing the real (hidden) spread – the hidden bid is higher that the visible bid or the hidden ask is lower than the visible ask – but they are also increasing the probability of the orders being filled because of the order priority mentioned before. As shown, the knowledge of order priority rules is very important and may be meaningful not only for the price discovery process and for the profitability of strategies, but may also be of systemic importance for a market as it may (although not necessarily must) decrease market and price transparency.

4 The influence of high-frequency traders on the price discovery process

The presence of high-frequency traders in the financial markets is still considered somewhat controversial as their influence on the markets is not known, even though their share in the market volume is not insignificant. Other reasons for this uncertainty also derives from, firstly, difficulty finding an appropriate definition of high-frequency trading, and secondly, the fact that they are often blamed for market irregularities, e.g. leading to a significant increase of market volatility, or for introducing toxic liquidity (Lenczewski 2018). The effort onus to find an appropriate definition for HFT is not only on regulators, but also on (academic) researchers trying to make an appropriate segmentation of market participants in order, for example, to perform analysis of the price impact according to the types of traders. An appropriate categorisation of high-frequency traders is additionally difficult, because as time goes by together with technological progress, the speed associated with the order submission, modification or order cancellation is increasing significantly fast. In certain research papers, it is possible to find criteria for defining HFT as one of modifying or cancelling orders within 100 milliseconds (Bouveret et al. 2014). In other papers this time period is shortened to 50 milliseconds from the moment an order is submitted until it is executed, modified, or cancelled (Gao 2015; Gai, Yao, Ye 2012 or Hasbrouck 2014); nevertheless, these criteria change and evolve with time, making it difficult to find one general and stable definition.

[6] In Polish it is defined as *zlecenia z warunkiem wielkości ujawnianej* (WUJ).

[7] Detailed information on the mechanisms of the iceberg orders for WSE may be found in Division 4 chapter 4, section 5, art. 30 and Division 5 chapter 5, section 4, art. 26 of WSE detailed exchange trading rules in UTP system (WSE 2019).

Given that high-frequency traders generate 15 times more messages and hold 6 times more trades than other traders (Brogaard, Hendershott, Riordan 2019), then it should be concluded that the share of such traders in the price discovery process can be rather significant. The newest research lead by Brogaard, Hendershott and Riordan confirm such a statement as the results of their studies show the influence in the price discovery process of limit orders submitted by high-frequency traders to be twice as much as the influence of the same orders submitted by non-HFT (Brogaard, Hendershott, Riordan 2019). It is worth mentioning that the same study shows that the number of limit orders submitted by high-frequency traders and their price impact decreases when the price volatility of financial instruments increases (Brogaard, Hendershott, Riordan 2019). Such an observation is in line with other findings that discard opinions stating that high-frequency trading is responsible for inducing price volatility. Going further, the fact is that high-frequency traders lead to a decrease in volatility because HFTs are liquidity providers and often engage in providing such liquidity when other participants withdraw from such actions (Kamarei 2011) – a perfect example of such behavior is the Flash Crash from 6 May 2010.

When referring to high-frequency traders and the previously mentioned order priority, it is worth noticing that they may in fact have a significant advantage over other non-HFT traders. Due to the speeds available to HFTs, it is possible to reach the conclusion that these traders try in the first place to make their orders arrive into the order book before other orders, and in such way as to have order execution priority over other traders. Such an opinion may lead to further reflections on the positive effects that high-frequency trading may have on the price discovery process. First, such traders may react to published information (e.g. economic news) much faster than other traders and therefore ensure that their orders will be executed in the first place, then HFTs are in fact increasing market efficiency (Hoffmann 2013). Second, high-frequency traders lead to price synchronization of financial instruments across markets – something that may only be achieved through high (frequency) speeds. Studies performed by Austin Gerig on the NASDAQ show that high-frequency traders lead to the parallel price synchronization of related, or even correlated, financial instruments (Gerig 2012). This will finally lead to a decrease in transaction costs, prices will become more precise, and as mentioned earlier, market efficiency increases.

There are still not many studies dedicated, not only to an analysis of the influence on the price discovery process that order may have, but also, on the influence of HFTs in such a process. Some results of such studies carried out in different countries have been presented in Annex. Regardless of the number of available studies, these topics are important issues in the market microstructure research field, which will not only help in the future to understand the price discovery process, but will also help understand the process of increasing market efficiency and market structure, i.e. how trading between regulated exchanges and alternative trading systems is structured, or even how this structure adapts to different circumstances.

5 Summary

The subject related to information asymmetry is a key topic for a better understanding of processes taking place between participants of regulated markets and those in (alternative) unregulated markets. Traders submit orders for many reasons, including the above-mentioned information asymmetry, and

by performing studies in such an area it may help to better understand the structure of transaction costs (spreads) and mechanisms behind how, not only liquidity, but also prices of financial instruments, are structured. In order to reach such goals, it is important to perform analysis of how both market and limit orders affect the price discovery process. More precisely, such studies should not only examine the level of influence of such orders on future prices, but also identify mechanisms based on which traders reduce adverse selection exposure. These are important topics, not only for markets with a low level of market liquidity, but also in more mature markets and with a high level of liquidity.

Research papers that study the influence of limit and market orders on the price discovery process are in comparatively scarce numbers. There are, of course, many theoretical papers which introduce hypotheses on who uses the many different types of orders and for what goal, but the conclusions of some empirical works show there are situations where market practice does not always follow theory. An example of such a situation is the hypothesis stating that market participants that are in possession of information not yet available to other participants are liquidity takers and use market orders to achieve the fastest execution possible, therefore having an immediate impact on prices of financial instruments. Although market orders may indeed have the largest instantaneous price impact, empirical studies show that they may not have the highest informational value and have a low importance for the price discovery process. The evolution of the order book is also a very significant factor for this process. Even if we do not take into account aggressive limit orders, passive limit orders at the top of the order book may encourage other traders to submit market orders, which finally may have a long-term influence on prices.

One other important topic brought forward in this paper is the influence of high-frequency trading and orders submitted by these traders on the price discovery process. Research shows that not only are high-frequency traders liquidity providers (not liquidity takers), but in addition they are not responsible for generating price volatility, since they reduce their trading activity at times when price volatility is relatively high. An important conclusion is the one that high-frequency traders may lead to higher market efficiency and a decrease in trading costs as a result of a larger price synchronization among financial instruments that are related to each other or may be reasonably correlated.

Even though the research topic related to the influence of the different types of orders on the prices of financial instruments is challenging due to problems related, for example, with acquiring data, and as such is not very often studied, it is worth trying to carry out further analysis. The aim of this paper is to underline the research topic of order influence on the price discovery process through an analysis of the literature on this subject and related to the influence of HFTs on that same process. As a short summary of selected positions in the literature dedicated to an analysis of the influence of limit and market orders on the price discovery process, Annex presents some of the conclusions brought forward in these research papers for the period of 2000–2019.

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Annex

Table 1
List of conclusions from selected studies dedicated to the analysis of the influence of limit and market orders on the price discovery process, carried out in the period of 2000–2019

Author	Year	Title	Orders	Market(s)	Conclusions
Dufour, Engle	2000	Time and the price impact of a trade	Time relationship between trades in the capital market and the information level included in those trades	United States (NYSE)	The higher the trading activity, the higher also the influence of trades on prices due to the large informational level leading to a faster price update The moment when informed traders make transactions, liquidity providers demand larger spreads, and liquidity takers temporarily stop making trades, leading to a temporary lack of liquidity
Bloomfield, O'Hara, Saar	2005	The "make or take" decision in an electronic market: evidence on the evolution of liquidity	Limit and market orders	United States	Informed traders submit a greater amount of limit orders in comparison to market orders
Kaniel, Liu	2006	So what orders do informed traders use?	Limit and market orders	United States	Informed traders prefer to submit limit orders – if information they possess may have a long-term price impact In equilibrium conditions, limit orders have higher informational value than market orders
Buti	2009	Hidden orders and optimal submission strategies in a dynamic limit order market	Limit orders	United States	The higher the price volatility, the lower the limit order aggressiveness
Cao, Hansch, Wang	2009	The information content of an open limit-order book	Order book	Australia (ASX)	Limit orders submitted outside the market (bid-ask) present a low informational level, and the authors estimate their influence on the price discovery process to be close to 22% The remaining 78% results from orders being submitted at the market (bid-ask) and the last trading

Table 1, cont'd

Author	Year	Title	Orders	Market(s)	Conclusions
Hautsch, Huang	2012	The market impact of a limit order	Influence of limit orders on stock prices	Euronext Amsterdam	Limit orders have a long-term stock price impact – also orders submitted further away from market prices The higher the nominal value of limit orders, the higher the probability that other traders will submit orders in the opposite direction due to the signalling effect
Chiarella, He, Wei	2013	Learning and evolution of trading strategies in limit order markets	Order book	The use of a genetic algorithm as a learning model in an artificial limit order market	The use of a genetic learning algorithm on uninformed traders may increase informational efficiency on a certain market and lead market prices to follow intrinsic values It is the use of such an algorithm in uninformed traders, instead of informed traders, that influences the order submission process of both traders
Hoffman	2013	A dynamic limit order market with fast and slow traders	Analysis of advantages and disadvantages of limit orders submitted by high-frequency traders	Theoretical model of the order book	Limit order submission by HFTs leads to higher trade profits due to a lower adverse selection exposure Because of the lower exposure to adverse selection, HFT traders don't need to limit the number and value of limit orders, at the same time when non-HFTs have a higher probability of order non--execution
Charoenwong, Visaltanachoti, Ding	2014	Analysis of limit order book and order flow	Order book	Thailand	Order submission aggressiveness is higher when the spread is relatively narrow Limit order submission probability is higher when the spread is wider Order book in the Stock Exchange of Thailand (SET) shows a relatively weak convexity on the bid side and is uniformly distributed on the ask side

Table 1, cont'd

Author	Year	Title	Orders	Market(s)	Conclusions
Wee, Yang	2015	The evolution of informed liquidity provision: evidence from an order--driven market	Influence of limit and market orders on the liquidity of stocks in ASX in the period 2006–2012	Australia (ASX)	Informed traders are more inclined to provide liquidity than uninformed traders since the later are exposed to adverse selection Limit orders submitted by institutional traders have a larger price impact in comparison to those submitted by retail traders
Brogaard, Hendershot, Riordan	2019	Price discovery without trading: evidence from limit orders	Limit and market orders	United States	Market orders submitted by HFTs have smaller price impact than those submitted by non--HFTs Limit orders submitted by HFTs have as much as twice the price impact in comparison with the impact of the same orders submitted by non-HFTs More aggressive orders have a significant price impact, in the following order: market orders, limit orders submitted at the market (bid-ask), limit orders submitted outside the market (bid-ask) Although, the individual price impact of HFTs limit orders is smaller, in general these orders have the largest price impact due to the number of submitted orders

Source: own compilation.