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Intraday stealth trading. Evidence from the Warsaw Stock Exchange[1]

Abstract: The intraday volatility and volume U-shaped pattern is well documented in literature. It describes the common pattern of investor's behaviour on the stock markets: investors trade in the beginning and the end of the day more intensively than at the lunch time. However that pattern does not differentiate between the trades' size and investor characteristics. The stealth trading hypothesis states that informed traders tend to hide their information. There is a need for such behaviour at the time of low volatility and they may achieve this by breaking up their trades into smaller parts. At a time of high volatility informed traders are willing to place large orders because high volatility provides a sufficient camouflage of their information. We examine volatility patterns for small, medium and large trades and consider how the duration between trades and spreads differs between trade-size categories. Our sample consists of data from the Warsaw Stock Exchange, which is organized as an order-driven market. We show that medium-size trades are associated with relatively large cumulative stock price changes, however these results are not robust when liquidity measures and the duration between the consecutive trades are taken into account.
Keywords: stealth trading, informed traders, price changes.
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Introduction

The literature provides evidence of a U-shape pattern observed in intraday returns and volume. Since the works of Wood et al. [1985] and McInish and

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Wood [1990] the characteristic intraday patterns of absolute returns and volume are widely recognized on different stock markets [Wood, McInish & Ord 1985; Andersen, Bollerslev & Cai 2000; Harju & Hussain 2006; Będowska-Sójka 2010]. Few possible explanations for these phenomena exist. The intraday pattern of price variability (price changes) as well as the intraday pattern of volume are influenced by the impact of two different types of investors: informed and liquidity investors. Informed traders are perceived as those who trade on the basis of private information that is not yet publicly released. Liquidity traders trade for some other reasons, which usually reflect the liquidity needs [Admati & Pfleiderer 1988]. Admati and Pfleiderer [1988] show that informed traders are more active during periods of concentrated trading by liquidity traders, that is in the high volume periods. Barclay, Litzenberger and Warner [1990] state that stock price movements are driven mainly by informed trading. In the theoretical work of Kyle [1985] informed traders, in order to camouflage their information, divide their orders into smaller parts and spread them over time. Karpoff [1987] finds a positive relation between price changes and volume.

Barclay and Warner [1993] introduced the stealth trading hypothesis, according to which informed traders are likely to hide their information by breaking up their trades into smaller parts. They expect that trades based on private information executed in a low volatility period are rather medium-sized. In time of high volatility there is no need to camouflage the information and informed traders can execute their trades without unwanted price impact. Therefore the behaviour of informed investors in times of high and low volatility differs.

The literature presented in next section is focused mainly on price-driven markets. We investigate the stealth trading hypothesis on the Warsaw Stock Exchange which is a purely order driven market. We follow the methodology used in earlier works of Barclay and Warner [1993], Chakravarty [2001] and Ascioglu et al. [2011] but change and develop the approach to adapt it to the conditions of the Polish stock market. We examine if the stealth trading hypothesis applies to the Polish stock market by focusing on blue chip stocks. We consider the measures of price changes and activity used in earlier studies and additionally include also the levels of trading intensity as well as the market's depth to examine the robustness of the results.

The rest of the paper is organized as follows: In Section 1 we present the previous literature. In Section 2 the data and methodology are described. In Section 3 the results are presented, whereas in Section 4 the additional measures of trading intensity and market's depth are included in the study. The last section concludes.

1. Previous literature

Barclay and Warner [1993] introduce the stealth trading hypothesis by asking how much cumulative changes in prices are related to trades divided into different size categories: small, medium or large. If informed investors try to hide their information, they should avoid large orders that may be perceived by other traders as a signal of changing stock valuation. Therefore they will camouflage their information by spreading trades over time or by trading when volatility is high. However executing portioned trades over longer time period causes possible additional costs of acquiring the desired position in the longer term and possibly at a worse price. It may also increase the transaction costs. Therefore according to the stealth trading hypothesis the magnitude of cumulative price changes should occur in medium-sized trades, which neither reveal information nor increase transaction costs.

Barclay and Warner [1993] use a sample of NYSE tender-offer target stocks to test the stealth trading hypothesis and two additional hypotheses: the public information hypothesis and the trading volume hypothesis. The public information hypothesis asserts that stock price changes are due to the public information releases. Therefore stock price changes in a given trade-size category are proportional to the percentage of trades in that category. In other words, the reaction of cumulative price changes should be positively related to the number of transactions. Alternatively, the trading volume hypothesis states that cumulative price changes in each trade-size category are directly related to trading volume in that category. According to this hypothesis large trades should move prices more than small trades do. Barclay and Warner [1993] find that most of the cumulative stock price changes are attributable to medium-sized trades and therefore conclude that informed traders execute their transaction in the medium-size category which supports the stealth trading. Simultaneously they find no support for both the public information and trading volume hypothesis.

Chakravarty [2001] uses a sample of NYSE stocks for a three month period and three different years and shows that medium-sized trades cause disproportionately large cumulative price changes. By differentiating between type of investors Chakravarty [2001] shows that individuals make up very little of the cumulative price change, whereas nearly 80% of the cumulative price change occurs from the medium-sized institutional trades. He finds support for the stealth trading hypothesis, but rejects both the public information and the trading volume hypothesis.

Blau, van Ness and van Ness [2009] using a sample of NYSE stocks show that small trades move prices at the time of low volatility and low volume. During the periods of high volatility (and high volume as well), that means at the time of opening and closing of the trading day, informed traders are able to increase their trade sizes. They find that price changes from larger trades exhibit the well-known U-shaped pattern whereas price changes from smaller trades show a reverse U-shaped pattern. It is in agreement with the stealth trading hypothesis where informed traders do not want to reveal their information to the market and in times of low volatility look for sufficient disguise for their information. In the time of high volatility larger trades move prices more than smaller trades because at that time informed traders chooose larger orders. It is in line with the strategic trading literature where informed traders focus their trading in times of higher volatility [Wang 1998]. The shift from medium [Barcaly & Warner 1993] to small [Blau, Van Ness & Van Ness 2009] transaction volume comes from the decimalization of quotations in the NYSE and a decrease in transaction costs on the stock market.

Alexander and Peterson [2007] show that trades tend to cluster on round amounts (e.g. multiples of 500, 1000, etc.). They argue that the rounded trades move prices more than the unrounded trades because informed traders tend to use the former in order to hide their information.

According to our knowledge only few papers focus on testing the stealth trading hypothesis on financial markets other than NYSE. Ascioglu et al. [2011] find support for the stealth trading hypothesis on the Tokyo Stock Exchange. They find that both small and medium trades contribute to the cumulative price changes more than large trades. They also find that on high volatility days the volume of large and medium-size trades increases. This is in accordance with the hypothesis that informed traders are willing to trade at the time of high volatility when they can execute their orders in a shorter time.

Abad and Pascual [2011] test the stealth trading on 35 stocks from IBEX35 quoted on the Spanish Stock Exchange and find that when controlling for bid-ask bounce, time duration between trades and measures of depth the role of medium trades in generating cumulative price changes diminishes. According to our knowledge there is no paper considering the stealth trading hypothesis on the emerging markets in Eastern Europe. This paper tries to shed some light on this issue.

2. Data and methodology

2.1. Data

The analysis is based on a sample of the most actively traded stocks on the Warsaw Stock Exchange (WSE) included in WIG20 index. All stocks considered in the study were traded in the fully electronic order-driven platform called WARSET with the usual price-time priority (since April 2013 Warsaw Stock Exchange has changed the trading system to the Universal Trading Platform). The market is transparent offering transaction information that consists of the number and the price of stocks traded together with five top bid and ask offers. We do not base the sample on any particular information event as do Barclay and Warner [1993]. Chakravarty [2001] assumes that informed trading is more likely to occur under conditions of price increase than decrease and restrict his sample to stocks that had at least 5% price increase in the sample period. We assume that stealth trading may occur on both sides of the order book. According to Polish stock market regulations insiders report their transactions both when buying or selling stocks within few days after transaction. Therefore we include all 20 stocks independently of the price move direction observed within the sample period.

Our sample consists of tick-by-tick price and volume data of stocks quoted within the period 01–10–2012 till 28–12–2012 which is 62 days. The data is obtained from www.gpw.com. The prices used in the study are transaction prices. The number of transactions within those three months fluctuate from 17,514 transactions (for Kernel stocks) to 93,790 (for KGHM stocks). In the Section 5 we also use bid and ask prices. Stocks are quoted in continuous auctions from 9:00 a.m. till 5:20 p.m. The tick-by-tick data is prepared in the way that all transactions which were attached to the system at the same time (in seconds) and with the same price are replaced by one transaction with the cumulated volume. Transactions with different prices executed at the same time (in seconds) are replaced by a new price weighted by the volume.

The transaction costs for trading on the market depend on the brokerage and are either proportional to the value of an order or are lowered together with the increasing volume of transaction within the given period. The orders could be divided into parts usually with no impact on the transaction costs.

2.2. Cumulative price change and average price change

In order to determine which trades move prices, we consider different trade-size categories in which cumulative and average price changes are examined. Following Barclay and Warner [1993], Chakravarty [2001], Blau et al. [2009], Lu et al. [2009] and Ascioglu et al. [2011] first we obtain the price change (PCH) of a stock as a difference between the trade's price and the previous transaction price, $PCH = P_t - P_{t-1}$, in a given trade-size category. Next we define cumulative price change (CPCH) as a sum of all stock price changes within one stock in the given period and given trade size and additionally calculate the change in price over the full sample for each firm (FPCH) over all trade-size categories. We divide the cumulative price change (CPCH) obtained in each category by FPCH to obtain a proportion of price changes in a given trade-size category in the overall price change (PCPCH). These proportions are expected to add in 1 for each stock. The cumulative price change accounts for 199.38 in our sample, which seems to provide good verification of the stealth trading hypothesis.

2.3. Trade-size cutoffs and activity measures

In earlier papers that examined the stealth trading hypothesis on NYSE [Barclay & Warner 1993; Chakravarty 2001; Blau et al. 2009] the volume categorization is consistent and depends on the number of shares traded. Trades are classified as small with 100–500 shares, medium with 500–9,999 shares and large trades over 10,000 shares. In Ascioglu, Comerton-Forde and McInish [2011] trades are divided into categories dependent on the number of shares and lots. Alternatively Abad and Pascual [2011] use individual size categories based on the distribution of observed volume of traded shares and this approach is the most appropriate in our case.

The prices of stocks included in our sample ranges from 0.5 PLN to 400 PLN, so the average volume differs substantially between the stocks traded. Therefore in our case trade-size cut-offs are based on the individual distribution of trading volume for each stock. We separate trades into trade-size categories, defined individually for each stock dependently on the empirical distribution of traded volume within the sample period. The small volume is related to the fifth decile of the empirical distribution of volume over the whole sample period of a given stock (0; 50%), medium trades are from over fifth decile till ninety fifth percentile (50%; 95%), whereas large trades are over 95 decile.

As an activity measure we calculate the percentage of volume (VOL) which is obtained as the sum of the trading volume of a given stock in a given trade-size category by total trading volume. Another measure representative of trade activity is the average number of transactions (TRA) measured in the given size categories and within different time intervals. We obtain the cross-sectional mean of percentage volume and percentage of trades within the given time periods for the whole sample.

3. Results

In order to test the stealth trading hypothesis we compare the cumulative price changes and trading activity in different size categories. If informed traders hide their information by breaking up trades, we would expect that small or medium-size trades will have a disproportionately stronger impact on cumulative price changes than large-size trades. In order to capture the relative impact of price changes of each stock in the whole sample we calculate the weighted cumulative price change in different size categories for the cross-section of securities. The weighted cumulative price change (WCP) introduced by Barclay and Warner [1993] is obtained as the weighted cross sectional mean of the cumulative price changes (CPCH) of each stock in the sample with weights obtained as an absolute value of the cumulative price change of each stock in the sample over the whole sample period [Barclay and Warner 1993; Blau et al. 2009].

Table 1 presents weighted cumulative price changes, average price changes, the proportion of volume and proportion of trades for the cross-section of 20 stocks in each of the three main size categories. The results in Table 1 show that most of the cumulative price changes are observed in the medium-size trade category. Small trades constitute an average decrease of about 5% of the weighted cumulative price change and comprise about 5% of total volume and almost 50% of all trades. Medium-size trades cause more than 91% of the cumulative price change and comprise about 44% of the total volume and 45% of all trades, whereas large trades cause almost 14% of the cumulative price change with over 51% of the volume and 5% of all trades. Relative to their proportion of trades and volume, medium-size trades seem to play a disproportionately important role in cumulative price changes. It is consistent with the stealth trading hypothesis.

Table 1. Cumulative price change, volume and trades by different size categories (%)

Trade size	Weighted cumulative price change WPC	Percentage of volume VOL	Percentage of trades TRA
Small	–6.68	5.23	49.38
Medium	93.02	43.87	45.49
Large	13.86	50.90	5.13

Note: Mean percentage of the weighted cumulative stock price change, mean percentage of volume and mean percentage of trades for stocks in the sample with three main size categories (small, medium and large). For each stock the cumulative price change in a given size category is obtained. The weighted cross-sectional mean with weights equal to absolute value of the full change of each stock's price in the sample is reported. The proportion of total volume and proportion of total trades are calculated by the usual means in the sample.

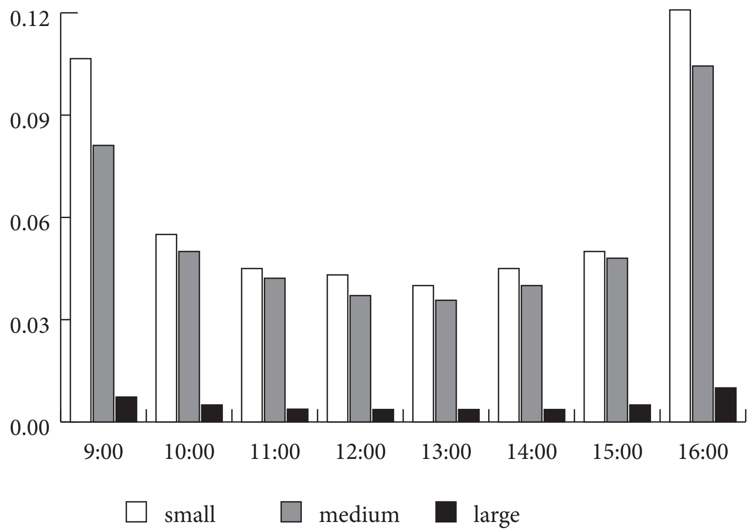
Trade-size category classification is based on the empirical distribution of trading volume calculated individually for each stock.

The alternative hypotheses, the public information and the trading volume hypothesis, find no support in the data. The public information hypothesis states that investors trade in the presence of public information and therefore that the percentage of cumulative price changes should be equal to the percentage of trades. In case of small trades, the weighted cumulative price change equals -5% and comprises 49% of trades, for large trades the weighted cumulative price change accounts for almost 14% with 5% of trades. The hypothesis that the percentage of cumulative price change is equal to percentage of trades is therefore rejected.

According to the trading volume hypothesis large trades have a stronger impact on price changes than small trades. We test if the percentage cumulative price changes in a given trade size category are proportional to the percentage proportion of volume in this category. We find that whereas for medium-size trades the cumulative price change account for 92% and 44% of the volume, large-size trades account for 14% of cumulative price changes and almost 51% of the volume. We reject the trading volume hypothesis – changes in prices are not proportional to the volume traded.

We further examine the cumulative price changes as well as trading activity measures at separate intervals during the day in order to study if the price changes depend on the volatility. In the intraday data the U-shape pattern in volatility is observed which means that on average volatility is higher at the beginning and the end of the day. Blau et al. [2009] examine if this pattern is similar across all trade-size categories. They claim that if stealth trading exists, informed traders may trade more heavily in the periods of high volatility without the anxiety of releasing information. In other words there is no need to disguise the information at the beginning and the end of the day. We test if changes in prices from the smaller trades would be greater than from large trades in the middle of the day when volatility is low. Additionally the price changes from large trades should be more substantial than from small trades at the beginning and end of the day when volatility is higher and there is no need to disguise information. In order to examine the pattern of the cumulative price changes in times of high and low volatility, the trading day is divided into seven hourly intervals and one 80-minute interval. Figure shows the intraday price changes' pattern of different trade-size categories, small, medium and large, separated into given time intervals.

As is presented in Figure, for each size category we obtain the U-shape pattern in absolute values of the cumulative price changes For our sample a standard U-shaped pattern exists in all trade size categories. These results are in contradiction to Blau et al. [2009] as they find different patterns for small (inverted U-shape) and large trades (standard U-shaped).



Intraday pattern of the cumulative price changes for individual trade-size categories

Note: The absolute values of the proportion of cumulative price changes are calculated in different trade-size categories

We examine also the weighted cumulative price changes of different trade sizes within different time intervals. Results presented in Table 2 show that weighted cumulative price changes for medium trades in the middle of the day (11:00 – 14:00) are higher than the weighted cumulative price changes of small and large trades. The weighted price changes are the most substantial at the beginning of the day for small and medium trades and at end of the day for medium and large trades. Contrary to the stealth trading hypothesis the cumulative price changes of small trades are not substantially different from these of large trades in the middle of the day. However the cumulative price changes of large and medium trades are higher at the last part of the trading day than during any other interval of the day. These results suggest that informed traders can trade at the time of high volatility and high volume without revealing information to other market participants.

Table 2. Intraday percentage of the weighted cumulative price change

Time	Trade-size category (%)		
	small	medium	large
9:00–10:00	29.65	34.88	2.42
10:00–11:00	–5.50	7.89	3.16
11:00–12:00	0.19	9.44	4.20
12:00–13:00	–4.43	15.69	–3.81
13:00–14:00	3.24	0.45	–1.16
14:00–15:00	13.19	–1.36	–0.46
15:00–16:00	40.60	–41.03	–4.18
16:00–17:20	–83.80	67.05	13.70

Note: The percentage of the weighted cumulative price change is calculated as in Barclay and Warner [1993]. The trade-size categories are based on the empirical distribution of volume of each stock individually.

We also conduct the analysis of the volume pattern for different trade size categories. Table 3 presents the intraday percentage of volume during the trading day. The U-shape pattern in activity is recognized in each trade size category.

Table 3. Intraday percentage of total volume in different time intervals

Hour	Trade size categories (%)		
	small	medium	large
9:00–10:00	0.82	6.291	6.99
10:00–11:00	0.60	5.12	6.31
11:00–12:00	0.51	4.40	5.19
12:00–13:00	0.51	4.06	4.82
13:00–14:00	0.47	3.97	4.57
14:00–15:00	0.55	4.65	5.27
15:00–16:00	0.61	5.55	7.22
16:00–17:20	1.16	9.85	10.53

Note: The intraday percentage of total volume is calculated as an average of percentage of volume in a given trade-size category for all stocks in the sample. The size categories are based on the empirical distribution of volume.

4. The impact of intensity and liquidity on price changes

The presence of informed traders may be signaled by an increase of trading intensity and liquidity. Trading intensity is defined as the volume of a security during a specific given interval. Liquidity is treated as the possibility of buying or selling stocks without affecting the asset's price. As liquidity is characterized by a high level of trading activity, it is strongly related to trading intensity. There are a number of papers examining the relationship between intensity or liquidity of trading and the price formation process. Engle [2000] describes the relationship between intensity of trade and volatility, where the former is proxied by duration, measured as the time between two consecutive trades. He finds that the longer the duration, the lower volatility. As informed traders are likely to trade at the time of high volatility to stealth information, we expect trades with short durations to have a disproportionate role in the cumulative price changes. As far as liquidity is concerned a wide range of the literature is related to the bid-ask spread as a measure of liquidity [e.g. Hasbrouck 2007]. Not only trades that occur when the spread is wide increase transactions costs, but also the wider the bid-ask spread is, the higher the probability of the trading based on information [Hautsch 2004]. Therefore we expect that cumulative price changes for trades with wide spreads would be higher than those for narrow spreads.

We assume that additional measures of these variables can shed a light on our discussion. We include, duration as a proxy of trading intensity and spread calculated as the difference between bid and ask price for a share at one moment is a proxy for liquidity in our study. Durations are calculated as time in seconds between consecutive trades. Three different durations based on the empirical distribution of the duration of the individual stock are concerned: short (0; 0.25), medium (0.25; 0.75) and long (0.75; 1). Three spread categories based on the empirical distribution of individual stock spreads are defined: narrow (0; 0.25), medium (0.25; 0.75) and wide (0.75; 1).

The results of calculations for different spread categories are presented in Table 4. Generally wide spreads are related to higher weighted cumulative price changes than narrow spreads for which the weighted cumulative price change is negative across all trade size categories. When spreads are wide, medium or small size trades obtain a higher weighted price change than large trades. It is consistent with the stealth trading hypothesis where informed traders are supposed to divide blocks of shares into tiny trades. The small transactions with medium spreads account for 3% of total volume and 25% of all trades, whereas the medium transactions with medium spreads account for 23% of total volume and 23% of all trades.

Table 4. Weighted cumulative price changes, volume and trades when different spreads are considered

Trade size	**Small**			**Medium**			**Large**		
spreads	**narrow**	**medium**	**wide**	**narrow**	**medium**	**wide**	**narrow**	**medium**	**wide**
WPCH	–3.04	2.78	0.18	–0.83	1.47	0.29	–0.12	0.19	0.08
Percent of volume	0.01	0.03	0.01	0.10	0.23	0.11	0.11	0.28	0.12
Percent of trades	0.12	0.25	0.13	0.11	0.23	0.11	0.01	0.03	0.01

Note: WPCH stands for weighted cumulative price change obtained as in Barclay and Warner [1993].

The results of calculations considering trade intensity proxied by durations are presented in Table 5. The highest weighted price changes are obtained for short durations in small and medium trade size categories. These transactions account altogether for 6% of all trades and 3% of total volume.

It is in line with our expectations because informed traders are supposed to trade at the time of high volatility when durations are short. Only for the large trade size category in case of long duration is the weighted cumulative price change positive. However these transactions account for only 2% of all trades but as their proportion of volume accounts for 18% they can be classified as big block trades.

Table 5. Weighted cumulative price changes, volume and trades when different durations are considered

Trade size	Small			Medium			Large		
duration	short	medium	long	short	medium	long	short	medium	long
WPCH	0.32	0.02	–0.41	0.25	–0.73	–0.06	0.02	0.03	0.09
Percent of volume	0.00	0.03	0.02	0.03	0.28	0.13	0.02	0.31	0.18
Percent of trades	0.03	0.30	0.17	0.03	0.29	0.14	0.00	0.03	0.02

Note: WPCH stands for weighted cumulative price change obtained as in Barclay and Warner [1993].

The additional measures included in the study shows that the highest weighted price changes are obtained for small and medium trades with either medium spreads or characterized by short durations. These results are consistent with the stealth trading hypothesis, but may also signal the presence of algorithmic trading on the Warsaw Stock Exchange. In algorithmic trading high frequency traders can divide blocks of shares into hundreds of small trades without affecting prices in the market.

Conclusions

In the paper we examine the stealth trading hypothesis according to which informed traders either break up their trades into smaller parts or trade at the time of high volatility in order to hide their information. We find that medium-size trades play a relatively disproportionately important role in the cumulative price changes. We show that the well-known intraday volatility U-shape pattern is common for all trade size categories. The small trades are on average related to negative price changes, whereas medium and large trades comprise positive price changes, mainly in the first and last hour of trading. Only medium-size trades executed in the middle of the trading day are associated with relative large cumulative stock price changes. It is in line with the stealth trading hypothesis.

When activity measures are examined both volume and average number of transactions produce a U-shape pattern. The informed traders prefer to execute large trades at the time of high volatility and high volume without revealing information to other market participants. However we do not find any significant relationship between price changes and volume in our sample.

We show that the highest cumulative price change is obtained for small trades with medium spreads. When durations are considered the highest cumulative price change is observed for small and medium trades with short durations. Both conclusions are in line with the stealth trading hypothesis according to which informed traders are active at the time of high volatility and moderate liquidity. Future research will focus on the issue as to what extent the observed behavior of traders is caused by high frequency trading.

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