Intraday Liquidity Dynamics and Price Movements

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Abstract

This study aims at analyzing whether intraday price movements help better characterize liquidity in real time. We generate 15-minute price movement configurations based on Japanese candlesticks and measure liquidity in terms of spread, depth, order imbalance, dispersion and slope. We also consider trading activity and volatility measures. We find that Dojis and some Hammer-like configurations are associated with higher liquidity in the limit order book. The effects are short-lived but could enable traders to benefit from temporary higher liquidity. These results are robust to changes in the interval lengths. Our results suggest that the execution of trades could be improved when these particular structures appear on a price chart.

JEL Classification: G14

Keywords: Liquidity, Microstructure, Price Dynamics, Japanese Candlesticks

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1 Introduction

Liquidity has become of paramount importance in finance. The recent emergence of liquidity dark pools, algorithmic trading and, more generally, high frequency trading has drawn the attention of an increasing number of researchers and practitioners. The flash crash of May 6th, 2010 is the best example of the implications of algorithmic trading, on the one hand, and the absence of liquidity, on the other hand. In such a trading environment and given the multidimensionality of liquidity, finding and estimating intraday liquidity in a fast and accurate way is a tough challenge.

One solution to overcome this hurdle has been proposed by Kavajecz and Odders-White (2004) who reveal some unexpected features of technical analysis. These authors examine similarities between support and resistance levels and the daily prices for which they observed high depth in the limit order book. They also study moving average indicators and check their information content in the order book. Based on NYSE stocks, their results show that signals in price charts are significantly related to the state of liquidity in the order book. They find that support and resistance levels and moving averages are strongly correlated with liquidity measured with customized indicators. The authors also conduct Granger causality tests, which reveal that technical analysis helps discover depth already present in the book.

In this paper, we extend their analysis to High-Low-Open-Close price dynamics that practitioners typically represent by drawing Japanese candlesticks. This method is an Eastern charting technique that is in essence very similar to bar charts. When looking at candlestick charts, traders have a quick snapshot of buying and selling pressures, as well as turning points. Using market data on a sample of European stocks of three national indexes, we study the relationship between liquidity and price movements by applying an event study methodology on 15-minute time intervals for the best-known candlesticks structures. As outlined by Kavajecz and Odders-White (2004), price dynamics are expected to be linked with modifications in the state of the limit order book and with the supply of liquidity. For this purpose, we analyze different liquidity proxies: the relative spread, one-sided displayed and hidden depth measures (at the best bid and offer, at the five best limits, and for the whole book), order imbalances, dispersion measures, and the slope of the book. We also analyze the following trading activity measures: number and size of buyer and seller-initiated trades, as well as trade imbalances for number of trades and volumes. We first focus our analysis on the Doji structures which are the most influential single lines of the literature on Japanese candlesticks. The Dojis are also
expected to have a direct impact on liquidity given the succession of price pressures that drive these signals. We then extend our analysis to other types of configurations.

When a Doji appears on screen, our results suggest that liquidity is higher for all proxies although there is less trading activity at that particular moment. The duration of the liquidity changes depends on the proxy but the patterns are always short-lived. This reinforces the hypothesis of an agreement on a price for the security, as exposed in the literature on Japanese candlesticks. This consensus implies a narrower spread, higher depth and less dispersion due to higher competition that liquidity suppliers face. The position of opening and closing prices on the candle is also related to different changes on bid and ask sides: bodies near the highest price of the interval are linked to changes at the ask while bodies near the lowest are related to changes at the bid. Using these dynamics might improve the execution of buy and sell decisions. Liquidity seems also to be higher when a Hammer or a Hanging Man occurs. In this respect, Japanese candlesticks may be used to have a quick idea on the state of liquidity in the limit order book. In a typical asset management firm, the decision to trade comes from the portfolio management team which then ask a broker to get the order executed in the best way. Japanese candlesticks may be used to have a quick idea on the state of liquidity in the limit order book. Trade execution could be improved by looking at these candlestick structures at the trade execution time. The magnitude of the potential gains on transaction costs is beyond the scope of this analysis and is left for further research.

The remainder of the paper is organized as follows. Section 2 provides a brief review of the literature on price dynamics, technical analysis and liquidity. Section 3 describes the dataset and the different liquidity measures that are used. Section 4 presents the methodology that we apply. Section 5 reports the findings of the event study and section 6 contains the robustness checks that are performed. The final section concludes.

2 Literature review

2.1 Liquidity and price dynamics

Liquidity and order book dynamics have been at the core of several researches during the last decade. It is nevertheless still difficult to find a unique definition of liquidity in the literature. Demsetz (1968) first outlines the immediacy characteristic of liquidity, i.e. the immediate conversion of an asset into cash at the best available price. Campbell et al. (1997) define
liquidity as "the ability to buy or sell significant quantities of a security quickly, anonymously, and with relatively little price impact". They also attribute four dimensions to liquidity: trading time (time between trades), depth (volume), tightness (spread) and resiliency (recovery from a liquidity shock).

Blume et al. (1989) study the interactions between liquidity and price dynamics by investigating the impact of order imbalances on stock price movements during the stock market crisis of October 19 and 20, 1987. The authors identify strong and positive correlation between order imbalances and price movements. The paper also enlightens a cascade effect of order imbalance on stock prices. The authors conclude that their results are consistent with the hypothesis that the stock decline was due to the incapacity of the market structure to absorb large selling orders. Using data from the Paris Bourse, Biais et al. (1995) investigate the supply and demand of liquidity as well as traders’ aggressiveness. They find that traders place orders inside the quotes when the spread or the depth (at the best quotes) is large. Chordia et al. (2001) empirically find that liquidity and trading activity are influenced by market returns and volatility. They also find that effective and quoted spreads increase dramatically in down markets. This effect is asymmetric because spreads do not decrease much in up markets. Chordia et al. (2002) reach the same results and identify a significant impact of daily order imbalance on both market returns and volatility. They also state that it is unwise to trade when the order book is highly imbalanced if waiting costs are low. Chordia and Subrahmanyam (2004) present a theoretical framework for Chordia et al. (2001) and obtain the same results at the individual stock level. Harris and Panchapagesan (2005) also outline a relationship between the limit order book and future price movements using the TORQ database. Chan (2005) find evidence that order placement strategies depend on previous returns, i.e. traders are more aggressive in buying and place fewer sell orders after positive returns and conversely, a decrease in price cause sellers to be more aggressive by placing more orders at the best quotes, larger orders, or by reducing the spread. More recently, Chordia et al. (2008) find that short-term return predictability is lower when liquidity (as measured by the bid-ask spread) is higher. They also pointed out that prices have been more efficient after the change to decimal tick size, supporting the positive relationship between liquidity and market efficiency. Cao et al. (2009) analyze the predictive power of limit order book information for 100 stocks quoted on the Australian Stock Exchange. They find evidence that it facilitates price discovery and is associated with future short-term returns. Boudt et al. (2012) also consider the dynamics of liquidity around price jumps and the information content of window formation in intraday price charts with an
event study. They find that liquidity drops sharply and is particularly low at the time and in
the following thirty minutes of a price jump.

2.2 Market efficiency, price dynamics and Japanese candlesticks

Papers on price dynamics abound in the literature. They are mainly related to the efficient-
market hypothesis (EMH) developed in Fama (1970). There exists no consensus on efficiency:
some argue that markets are sufficiently efficient while others find that there are punctual
inefficiencies that allow traders to generate abnormal returns using information contained in
past prices. Grossman and Stiglitz (1980) also argue that markets can be efficient if both
informed and uninformed traders exist and if information is costly. So, the lack of consensus
between proponents and opponents of efficiency contributes to market efficiency.

The debates on the efficiency of financial markets have led to empirical research on stock
return predictability. One of the fields investigated is the so-called technical analysis, i.e.
the study of past prices and their potential predictive power of future prices and returns.
This concept is in contradiction with the weak-form efficiency of Fama (1970). Even here,
the studies provide conflicting results. For instance, Brock et al. (1992) (henceforth BLL)
find that moving averages and trading-range breaks generate statistically significant abnormal
returns compared to four benchmark models, using a bootstrap methodology with the Dow
Jones Industrial Average index. Bessembinder and Chan (1995), who test the profitability of
technical analysis in Asian markets, also find evidence that their rules lead to abnormal returns
and make the distinction between emerging and developed Asian markets, pointing out that
returns are higher in emerging markets than in developed countries. Nevertheless, higher
returns do not compensate for higher transaction costs incurred in both studies. Bessembinder
and Chan (1998) also confirm the results of BLL but argue that market efficiency cannot be
rejected due to return measurement errors arising from nonsynchronous trading, among other
things. Sullivan et al. (1999) go beyond the analysis of BLL by testing 7846 trading rules with
White’s Reality Check bootstrap methodology\(^1\) which offers a better control for data-snooping
biases. The authors find that some of their trading rules perform even better than those of
BLL. These studies are the best examples of stock return predictability research on technical
analysis.

During the last decade, the attention of some researchers has been drawn to Japanese

\(^1\)White (2000).
candlesticks, another technical analysis charting method. Japanese candlesticks are a technical analysis charting technique based on High-Low-Open-Close prices. In that sense, they are similar to bar charts but they are easier to interpret. Indeed, the body is black for negative days (yin day) and white for positive days (yang day). Bar charts do not contain this information.

The formation process of candlesticks appears in figure 1. There exist plenty of structures, formed by one to five candles, depending on the length of the shadows and the size and color of the bodies. These candlesticks emphasize what happened in the market at that particular moment. Each configuration can be translated into traders’ behaviors through price dynamics implied by buying and selling pressures.

Figure 1: Candlestick formation process

Japanese candlesticks are interesting because they summarize a lot of information in one single chart: the closing price, the opening price as well as the lowest and highest prices. With the raising interest in high frequency trading and the narrowing of trading intervals, they have been increasingly used by practitioners to capture short term price dynamics. As for technical analysis, papers addressing candlesticks enter in the "stock return predictability" method to the west in the nineties. Japanese candlesticks have been first used by Munehisa Homma who traded in the rice market during the seventieth century. The original names of the candlestick structures come from the war atmosphere reigning in Japan at that time. At the beginning, there were only basic structures from one to three candles but more complex configurations have been identified since then. The predictive power of these configurations is still discussed. Nison (1991), Nison (1994), Morris (1995) and Bigalow (2001) are the best known and used handbooks of candlestick charting.

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2Even if they have been used for centuries in eastern countries, Steve Nison was the first to bring this method to the west in the nineties. Japanese candlesticks have been first used by Munehisa Homma who traded in the rice market during the seventieth century. The original names of the candlestick structures come from the war atmosphere reigning in Japan at that time. At the beginning, there were only basic structures from one to three candles but more complex configurations have been identified since then. The predictive power of these configurations is still discussed. Nison (1991), Nison (1994), Morris (1995) and Bigalow (2001) are the best known and used handbooks of candlestick charting.
category. Marshall et al. (2006) and Marshall et al. (2008) find no evidence that candlesticks have predictive value for the Dow Jones Industrial Average stocks and for the Japanese equity market, respectively. They replicate daily data with a bootstrap methodology similar to the one used in Brock et al. (1992). However, intraday data is more relevant as traders do not typically wait for the closing of the day to place an order. Using intraday candlesticks charts on two future contracts (the DAX stock index contract and the Bund interest rate future), Fock et al. (2005) still find no evidence which suggests that candlesticks, alone or in combination with other methods, have a predictive ability. However, none of these papers looks at the relationships between candlestick configurations and order book dynamics.

Previous research has outlined strong relationships between price movements and trade measures (e.g. Blume et al. (1989)). As candlesticks are good proxies for representing High-Low-Open-Close prices dynamics, we also expect a relationship between the occurrence of particular structures and trading activity measures. Fiess and MacDonald (2002) also argue in favor of that point. A relation between candlestick configurations and liquidity measures is also expected as trading activity measures are linked to the state of the order book, i.e. a trade occurs when supply meets demand and this matching is realized through the limit order book. The occurrence of some particular single lines should also be related to direct modifications in the book. This is the case of the Doji structures.

The Doji is one of the core structures of Japanese candlesticks. A Doji appears when the closing price is (almost) equal to the opening price. Candlestick books\textsuperscript{3} refer to it as the magic Doji. We observe different types of Dojis.\textsuperscript{4} The most frequent Doji is a "plus", i.e. no real body and almost equal shadows. If both closing and opening prices are also the highest price of the interval, the Doji becomes a Dragonfly Doji. By contrast, it becomes a Gravestone Doji when both closing and opening prices are equal to the lowest price of the interval. Another characteristic of the Doji is the position. A Doji may appear in a star position which means that a gap exists between the Doji and the previous candle. These Dojis are mostly part of the abandoned babies structures. A Doji may also occur in a Harami position when it appears within the previous body.

The Doji denotes moments where markets are on a rest and where there exists an agreement on the price of the stock. In this situation, traders are likely to situate the price of the stock inside the spread, leading to competition among traders which reduces the spread and the

\textsuperscript{3}Nison (1991), Nison (1994) and Morris (1995).
\textsuperscript{4}A description of the presented structures is available in appendix.
dispersion while increasing the slope and best quotes quantities. As a consequence, we expect liquidity to be higher and trading activity to be lower. We expect our results to be short-lived and the dynamics to appear in the window [-1;+1]. We also expect different outcomes between Gravestone and Dragonfly Dojis as they come from different succession of price pressures: the Gravestone (Dragonfly) is made with a previous bullish (bearish) rally and ends up with a strong selling (buying) pressure.

3 Data

3.1 Data and Sample

We use Euronext market data on 81 stocks belonging to three national indexes: BEL20, AEX or CAC40. We have tick-by-tick data for 61 trading days from February 1, 2006 to April 30, 2006. This database enables us to compute different measures from the order book and from trades. We also dispose on undisclosed data on hidden orders.\footnote{Hidden orders are orders that gradually display part of their total amount. For instance, a hidden order of 500 may appear on the book with a quantity of 100 and will automatically be refilled when 100 shares have been consumed.}

We have rebuilt High-Low-Open-Close prices from this database for the 81 stocks over the whole sample period. As tick data are not adapted for candlesticks analysis, we built 15-minute-intervals which leads to 34 intervals a day. This interval length is the best trade-off which allows to include intraday trends and to avoid noisy candlesticks patterns resulting from non-trading intervals. We use the HLOC prices calculated above in order to identify candlestick configurations with the help of the TA-Lib.\footnote{The TA-lib library is compatible with the MATLAB Software and returns, for each type of configuration and for each record, "1" if the bullish part of the structure is identified, "-1" for the bearish part and "0" otherwise. As the structures are bullish, bearish or both, for each event type, the values that may appear are [0 ; 1], [-1 ; 0] or [-1 ; 0 ; 1]. The TA-lib allows some flexibility in the recognition of the configurations. As it is an open source library, we have been able to check the parametrization of the structures. Events are recognized according to the flexibility rules presented in Nison (1991) and Morris (1995). The TA-lib contains 61 pre-programmed structures. We however dropped 17 of them due to a lack of intraday significance. The list of these configurations is available upon request.}

We have a total of 167068 records (81 firms, 61 days, 34 intervals/day) in our dataset.

We filter the sample as follows. First, we remove Four Prices Dojis because they are associated with non-trading patterns.\footnote{A Four Prices Doji occurs when all the prices are equal. When they occur in daily, weekly or monthly charts, they are a strong clue of a potential reversal. However, in intraday price charts, they represent non-trading intervals.} Second, we only keep the events for which we do not
observe any other structure in the previous and next three intervals in order to avoid any
contagion effect in our measures. Therefore, there is only one event by analyzed window. As we study a moving window of [-3;+3], we do not consider events in the first and last three intervals for each day. Finally, we only keep events types for which we have at least 30 event occurrences.

After the removal of all the possible contagious data, we have a total of 2959 Dojis, among which 653 are Dragonfly Dojis and 614 are Gravestone Dojis. Table 1 shows event occurrences.

<table>
<thead>
<tr>
<th>Name</th>
<th>Bull/Bear</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doji</td>
<td>1</td>
<td>2959</td>
</tr>
<tr>
<td>Bearish Dojistar</td>
<td>-1</td>
<td>111</td>
</tr>
<tr>
<td>Bullish Dojistar</td>
<td>1</td>
<td>121</td>
</tr>
<tr>
<td>Dragonfly Doji</td>
<td>1</td>
<td>653</td>
</tr>
<tr>
<td>Gravestone Doji</td>
<td>1</td>
<td>614</td>
</tr>
</tbody>
</table>

We look at the occurrences of the identified structures and check whether some configurations appear at a particular moment during the day. Figure 2 displays the intraday pattern of our events. The distribution seems to peak at both the first and last moments of the day. Figure 3 shows that these results come from many Dojis occurring at these particular moments.

Figure 2: Events by Interval

This figure displays the number of events in each time interval.

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8 We keep the 44 configurations from the TA-lib for this filter.
3.2 Liquidity Measures

We measure liquidity at the end of each trading interval which enables us to measure the direct impact of the event on liquidity. We first calculate the traditional liquidity proxies such as relative spread, depths (displayed and hidden, in number of shares) and order imbalances (at different order book levels). We also use dispersion and slope measures which are respectively presented in Kang and Yeo (2008) and Næs and Skjeltorp (2006). Then, we compute trading activity measures as buyer and seller-initiated volumes and imbalances, in number of trades and quantities. Finally, we evaluate volatility using the High-Low measure for each time interval. Table 2 presents the different measures.

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9 These measures are computed with the sum over each interval.
10 We also study the squared return as a volatility measure but the results are very similar.
<table>
<thead>
<tr>
<th>Name</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantities at the Best Bid</td>
<td>1978.00</td>
</tr>
<tr>
<td>Quantities at the Best Ask</td>
<td>1953.00</td>
</tr>
<tr>
<td>Quantities at the Best Bid (Hidden)</td>
<td>0.00</td>
</tr>
<tr>
<td>Quantities at the Best Ask (Hidden)</td>
<td>0.00</td>
</tr>
<tr>
<td>Displayed Depth 5 Best Bid</td>
<td>13409.00</td>
</tr>
<tr>
<td>Displayed Depth 5 Best Ask</td>
<td>13612.00</td>
</tr>
<tr>
<td>Hidden Depth 5 Best Bid</td>
<td>1559.00</td>
</tr>
<tr>
<td>Hidden Depth 5 Best Ask</td>
<td>1800.00</td>
</tr>
<tr>
<td>displayed Depth 5 Best Bid (Ask)</td>
<td>312453.50</td>
</tr>
<tr>
<td>displayed Depth Ask</td>
<td>361465.00</td>
</tr>
<tr>
<td>Hidden Depth Bid</td>
<td>130558.50</td>
</tr>
<tr>
<td>Hidden Depth Ask</td>
<td>143938.00</td>
</tr>
<tr>
<td>Total Depth Bid</td>
<td>169410.00</td>
</tr>
<tr>
<td>Total Depth Ask</td>
<td>212337.00</td>
</tr>
<tr>
<td>Hidden Depth First Limits (Bid+Ask)</td>
<td>4514.50</td>
</tr>
<tr>
<td>Hidden Depth First Limits (Bid+Ask) Hidden</td>
<td>453.00</td>
</tr>
<tr>
<td>Depth 5 First Limits (Bid+ask)</td>
<td>27908.00</td>
</tr>
<tr>
<td>Hidden Depth 5 First Limits (Bid+ask)</td>
<td>8410.50</td>
</tr>
<tr>
<td>Total depth (Bid+ask)</td>
<td>387121.50</td>
</tr>
<tr>
<td>Hidden Total depth (Bid+ask)</td>
<td>280698.00</td>
</tr>
<tr>
<td>First Limits Imbalance</td>
<td>0.00</td>
</tr>
<tr>
<td>First limits Hidden Imbalance</td>
<td>-0.04</td>
</tr>
<tr>
<td>5 Best Limits Imbalance</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Quadrants at the best bid (ask) denotes the amount of shares displayed at the best bid (ask) limit. Hidden indicates the quantities that are not displayed. Displayed Depth 5 Best Bid (Ask) represents the total amount displayed at the five best bid (ask) limits. Hidden Depth 5 Best Bid denotes the total hidden amount at the five best bid (ask) limits. Displayed Depth Bid (ask) stands for the total amount of shares that is displayed on the bid (ask) side of the order book. Hidden Depth Bid (ask) only includes hidden quantities at the bid (ask) while Total Depth Bid (ask) is the sum of both displayed and hidden total depths at the bid (ask). Depth 5 First Limits (Bid+ask) is the sum of displayed best bid and offer quantities. Hidden Depth First Limits (Bid+ask) only takes into account hidden quantities. Depth 5 First Limits (Bid+ask) and Hidden Depth 5 First Limits (Bid+ask) are computed across the five best price limits while Total depth (Bid+ask) and Hidden Total depth (Bid+ask) consider the whole book. First limits Imbalance is the best limits displayed imbalance ($\text{Imbalance}_{i,t} = \frac{\text{Depth}_{\text{Bid},i,t} - \text{Depth}_{\text{Ask},i,t}}{\text{Depth}_{\text{Bid},i,t} + \text{Depth}_{\text{Ask},i,t}}$, where $i$ denotes a given security and $t$ a given interval). First limits Hidden Imbalance only considers hidden quantities. The same measures are computed for the five best limits (5 Best Limits Imbalance and 5 Best Limits Hidden Imbalance) as well as for the whole book (Imbalance Displayed and Imbalance Hidden). Imbalance Total is the total imbalance, summing displayed and hidden quantities.
Dispersion  Kang and Yeo (2008) present two measures to quantify the density of the limit order book, i.e. how limits are far from each other or from the quoted midpoint. One of these two measures is the dispersion:

\[
\text{Dispersion}_{i,t} = \frac{1}{2} \left( \frac{\sum_{j=1}^{n} w_{i,j \mid t} Dst_{i,j \mid t}^{\text{Bid}}}{\sum_{j=1}^{n} w_{i,j \mid t}} + \frac{\sum_{j=1}^{n} w_{i,j \mid t} Dst_{i,j \mid t}^{\text{Ask}}}{\sum_{j=1}^{n} w_{i,j \mid t}} \right),
\]

(3.1)

where, for security \(i\) and interval \(t\), \(w_{i,j \mid t}\) are the weights which are equal to quantities, offer and bid sizes, at the \(j\)th price limit normalized by the total depth of the five best limits, \(Dst_{i,j \mid t}^{\text{Bid}} = (PB_{i,j-1 \mid t} - PB_{i,j \mid t})\) and, \(Dst_{i,j \mid t}^{\text{Ask}} = (PA_{i,j \mid t} - PA_{i,j-1 \mid t})\). The midquote is used for the distance of the first best limits.

As Kang and Yeo (2008) outline, dispersion is small under fierce competition as each trader wants to gain price priority.

Slope  The slope is computed by averaging the price elasticity of quantities over the five best quotes. We calculate the slope of the book following Næs and Skjeltorp (2006), that is:

\[
\text{Slope}_{i,t} = \frac{DE_{i,t} + SE_{i,t}}{2},
\]

(3.2)

where \(DE_{i,t}\) and \(SE_{i,t}\) are the slope of the bid and ask side respectively and are computed as:

\[
DE_{i,t} = \frac{1}{5} \left( \frac{v_{1}^{B}}{p_{1}^{B}/p_0 - 1} + \sum_{\tau = 1}^{N_B} \frac{v_{\tau+1}^{B}/p_{\tau+1}^{B} - 1}{p_{\tau+1}^{B}/p_0 - 1} \right),
\]

(3.3)

\[
SE_{i,t} = \frac{1}{5} \left( \frac{v_{1}^{A}}{p_{1}^{A}/p_0 - 1} + \sum_{\tau = 1}^{N_A} \frac{v_{\tau+1}^{A}/p_{\tau+1}^{A} - 1}{p_{\tau+1}^{A}/p_0 - 1} \right).
\]

(3.4)

\(p_{\tau}^{B}\) and \(p_{\tau}^{A}\) are the prices, respectively at the bid and at the ask, appearing at the quote \(\tau\). \(p_0\) denotes the quoted midpoint. Finally, \(v_{\tau}^{B}\) and \(v_{\tau}^{A}\) are the natural logarithm of accumulated total share volume at the limit \(\tau\) respectively for the bid and the ask\(^{11}\).

A steep slope represents an order book where volumes are concentrated at a given limit (low elasticity) while a gentle slope denotes an order book where volumes are not aggregated.

\(^{11}\)By accumulated, we mean the sum of the quantities outstanding at that limit and the sum of all quantities outstanding at each better quote.
at a given limit (high elasticity). A steep slope also means that traders agree about the value
of the security while a more gentle slope indicates that traders have different estimations of
the fair price of the security.

**Trade Imbalance**  In order to calculate trade imbalance, we first have to sign transactions.
Most empirical studies use Lee and Ready (1991)'s algorithm, which categorizes buyer and
seller-initiated trades based on the position of the transaction price relative to the bid-ask
spread. With our database, we are able to match for each transaction the orders that generate
a given trade. Then, the sign of the transaction is found by comparing the submission time
of the orders, i.e. the last order being the determinant of the transaction. After that, we
compute the total number of trades and quantities respectively for buyer and seller-initiated
trades. With these variables, we compute two trade imbalance measures:

\[
ImbalanceN_{i,t} = \frac{N_{\text{Trades}^\text{Buy}}_{i,t} - N_{\text{Trades}^\text{Sell}}_{i,t}}{N_{\text{Trades}^\text{Buy}}_{i,t} + N_{\text{Trades}^\text{Sell}}_{i,t}}
\]  

(3.5)

where \(N_{\text{Trades}^\text{Buy}}_{i,t}\) is the number of buyer-initiated trades occurring at the \(t^{th}\) interval for
stock \(i\) and \(N_{\text{Trades}^\text{Sell}}_{i,t}\) is the number of seller-initiated trades occurring at the \(t^{th}\) interval
for stock \(i\).

\[
ImbalanceQ_{i,t} = \frac{Q^\text{Buy}_{i,t} - Q^\text{Sell}_{i,t}}{Q^\text{Buy}_{i,t} + Q^\text{Sell}_{i,t}}
\]  

(3.6)

where \(Q^\text{Buy}_{i,t}\) is the sum of the volume of all buyer-initiated trades occurring at the \(t^{th}\) interval
for stock \(i\) and \(Q^\text{Sell}_{i,t}\) is the sum of the volume of all seller-initiated trades occurring at the \(t^{th}\)
interval for stock \(i\).

These measures are computed separately for each interval and for each security. As we also
dispose on the buyer and seller-initiated quantities and number of trades, we also include them
in the analysis.

**Aggressiveness**  We compute our aggressiveness measure separately for bid and ask sides.
Our measure captures the number of aggressive orders, i.e. orders that consume liquidity and
generate a trade, compared to the total of orders that occurs during a given time interval:
\[
Aggressiveness_{i,t} = \frac{Nb^{Aggressive}_{i,t} - Nb^{Passive}_{i,t}}{Nb^{Aggressive}_{i,t} + Nb^{Passive}_{i,t}}
\]

where \( Nb^{Aggressive}_{i,t} \) is the total number of marketable buy orders occurring at the \( t^{th} \) interval for stock \( i \) and \( Nb^{Passive}_{i,t} \) is the total number of non-marketable buy orders occurring at the \( t^{th} \) interval for stock \( i \). A similar process is applied to sell orders.

4 Methodology

With our extended dataset containing HLOC prices, candlestick identification variables and liquidity measures, we conduct an event study of liquidity behavior around candlestick structures. We focus on a time window of \([-3,+3]\) containing seven observations: three observations before the signal, the time of the signal and three observations after the signal. This leads us to consider liquidity behavior 45 minutes before and after our events. As we have different types of measures, we compute our abnormal liquidity measures depending upon the nature of the variables, as suggested by Boudt et al. (2012).

For spreads, imbalances and aggressiveness measures, we compute the abnormal measure as follows:

\[
Abnormal_{i,t,m} = \frac{Measure_{i,t,m} - Median^{NE}_{i,t,m}}{Median^{NE}_{i,t,m}},
\]

where \( Measure_{i,t,m} \) is the analyzed liquidity measure \( m \) for stock \( i \) for the time interval \( t \) and \( Median^{NE}_{i,t,m} \) is the median of the measure \( m \) for stock \( i \) across all non-events\(^{12} \) occurring during the time interval \( t \).

For the other measures, the calculation method is:

\[
Abnormal_{i,t,m} = \frac{Measure_{i,t,m} - Median^{NE}_{i,t,m}}{Median^{NE}_{i,t,m}},
\]

where \( Measure_{i,t,m} \) is the analyzed liquidity measure for stock \( i \) for the time interval \( t \) and \( Median^{NE}_{i,t,m} \) is the median of the measure \( m \) for stock \( i \) across all non-events occurring during the time interval \( t \).

\(^{12}\)The 17 dropped pre-programmed structures have been included in the non-event sample as they are too frequent on intraday data and are not linked to any particular signal.
We apply these processes separately for each liquidity measure. We then aggregate the results obtained on a stock basis to form median patterns of liquidity behavior around each event and for each measure. We analyze these patterns to check whether the abnormal measures are significantly different from zero. For this purpose, we use a standard non parametric sign test on the controlled measures. Our null hypothesis postulates that the median of the abnormal measure equals zero. The statistic $M$ is computed as follows:

$$M = \frac{N_+ - N_-}{2},$$

(4.3)

where $M$ follows a binomial distribution, $N_+$ is the number of positive values and $N_-$ is the number of negative values. Values equal to zero are discarded.

We then analyze the p-values of each time interval of the window and check whether the differences are significant or not. If the p-value at the signal interval is significant, the structure is associated to a particular state of (il)liquidity. This signal may thus lead to a given configuration of the limit order book. If p-values are significant before the signal, the signal may be a response to a particular state of liquidity. If p-values are significant after the signal, a change of liquidity may correspond to a response to the signal.

5 Results

5.1 Doji

5.1.1 Overall picture

In a nutshell, the results show that liquidity is higher when a Doji appears, confirming our hypotheses. A higher liquidity and fewer trades mean that a consensus exists on the price of the stock and that buyers and sellers are not willing to trade at a different price. They do not want to hit the best opposite quote. A Doji is an indication of the presence of liquidity on each side of the book. Placing liquidity-taking orders at that moment will thus cost less in terms of implicit costs. Liquidity providers are also numerous and, as a consequence, face more competition to supply liquidity.

However, these results are valid only without the presence of jumps. Boudt et al. (2012) argue that jumps are linked to illiquid states of the book. We may thus consider that candles in
Harami position are linked to liquidity while star positions, i.e. jumps, are linked to illiquidity. We tested this hypothesis by comparing Harami Dojis and Doji Stars.\textsuperscript{13} We confirm that the Doji in star position are linked to less liquid states of the book than for Harami Dojis.\textsuperscript{14}

Furthermore, identifying the type of Doji also brings interesting information about the heaviness of one side of the book. The Dragonfly Doji seems to be associated to more changes at the ask and the Gravestone Doji seems to be linked to changes at the bid. These movements occur about 15 minutes before the occurrence of these Dojis, implying that the Doji itself is the consequence of depth dynamics. This result is confirmed by imbalances which show that the order book is imbalanced before these Dojis and returns to more normal values after the occurrence of the Dojis. We also observe disparities regarding trades. While buyer-initiated trades are less frequent and smaller in size when there is a Gravestone Doji, seller-initiated trades are less frequent and smaller in size when a Dragonfly Doji occurs. Buy orders are also more aggressive after a Dragonfly Doji and sell orders are more aggressive when a Gravestone Doji appears.

Our analysis finally shows that liquidity is negatively correlated with volatility as the High-Low is significantly lower while liquidity seems to be higher when a Doji appears. This result contributes to the literature on the liquidity-volatility relationship.

\textsuperscript{13}We disentangle Bullish and Bearish parts of the configurations as they may have a totally different impact. \textsuperscript{14}The drop in liquidity is effective in terms of spread, depth, dispersion and slope. These results are not reported here but are available upon request.
5.1.2 Details

Figure 4: Abnormal spread around Doji

Full, dotted and dashed lines represent the intra-window median pattern for the abnormal spread respectively for the Doji, the Dragonfly Doji and the Gravestone Doji. Triangles (△), squares (□), and circles (○) indicate a rejection of the null hypothesis respectively at the 99%, 95% and 90% confidence levels.

The spread significantly drops when a Doji appears. The recovery is fast after the trough in all cases. This is perfectly in line with what we expected as a Doji occurs when there is a consensus on the price. Traders seem to agree on a price for the stock and situate it inside the spread. A reduction of the spread confirms this consensus.
Figure 5: Abnormal depth around Doji

(a) Best bid
(b) Best Ask
(c) First quote (Both sides)
(d) Five quotes (Both sides)

Full, dotted and dashed lines represent the intra-window median pattern for each of the abnormal depth measures mentioned respectively for the Doji, the Dragonfly Doji and the Gravestone Doji. Triangles (△), squares (□), and circles (○) indicate a rejection of the null hypothesis respectively at the 99%, 95% and 90% confidence levels.

The quantities at the best bid are significantly higher, at a 1% confidence level, at the time of the signal. Quantities at the best bid are also significantly higher just before the apparition of a Gravestone Doji. The pattern at the ask is more noisy but indicates that the Dragonfly Doji presents a significantly higher best ask depth just before its occurrence.

These Dojis seem to be the consequences of a particular state of liquidity in the limit order book as the pattern starts in $t-1$. The Gravestone Doji is likely to occur just after an accumulation of depth at the bid that does not translate into more trades. The Dragonfly Doji seems to appear when depth at the ask is higher and when there are less trades. The results of the bid side are confirmed if we consider the five best quotes. However, it is not the case for the ask side. If we look at the sum of both sides, we also observe a peaking depth for the first quote and for the five best quotes. This is interesting as the reduction of the spread does not take place at the cost of a lower depth. Liquidity is higher over these two dimensions.
Figure 6: Abnormal Hidden Depth (Sum)

(a) Five best bid limits

(b) Five best ask limits

Full, dotted and dashed lines represent the intra-window median pattern for each of the abnormal hidden depth measures mentioned respectively for the Doji, the Dragonfly Doji and the Gravestone Doji. Triangles (△), squares (□), and circles (◦) indicate a rejection of the null hypothesis respectively at the 99%, 95% and 90% confidence levels.

The Gravestone Doji presents a peak in hidden depth at the bid just before its apparition while depth at the ask peaks just before the Dragonfly Doji. These findings indicate that the position of the real body (near the highest or lowest price of the time interval) on the candle has a one-sided impact on depth, hidden or not.
Figure 7: Abnormal imbalance around Doji

Full, dotted and dashed lines represent the intra-window median pattern for each of the abnormal imbalances respectively for the Doji, the Dragonfly Doji and the Gravestone Doji. Triangles (△), squares (□), and circles (○) indicate a rejection of the null hypothesis respectively at the 99%, 95% and 90% confidence levels.

We observe opposite patterns for the Dragonfly and Gravestone Dojis. Order book imbalance is significantly higher just before and when a Gravestone Doji appears while it is significantly lower before and when a Dragonfly Doji occurs. The simple Doji does not exhibit any particular pattern.
Full, dotted and dashed lines represent the intra-window median pattern for each of the abnormal dispersion respectively for the Doji, the Dragonfly Doji and the Gravestone Doji. Triangles (△), squares (□), and circles (○) indicate a rejection of the null hypothesis respectively at the 99%, 95% and 90% confidence levels.

The dispersion drops when a Doji appears, meaning that the competition in the book is higher at that particular moment and that the limits are closer from each other. This is consistent with the idea of consensus. Traders are also competing to gain price priority implying a narrower spread. If we disentangle ask and bid sides, we observe that dispersion is significantly lower at the bid for the Dragonfly Doji and at the ask for the Gravestone Doji while it remains unchanged on the other side. These findings are also coherent with the philosophy behind these two Dojis: a strong buying pressure creates the Dragonfly Doji while the Gravestone Doji appears after a selling rally. This is also in line with the one-sided impact that occurs for depth.
Figure 9: Abnormal slope around Doji

Full, dotted and dashed lines represent the intra-window median pattern for each of the abnormal slope respectively for the Doji, the Dragonfly Doji and the Gravestone Doji. Triangles (△), squares (□), and circles (○) indicate a rejection of the null hypothesis respectively at the 99%, 95% and 90% confidence levels.

The slope significantly peaks at the moment of the Doji, on both supply and demand sides. These outcomes are consistent with the agreement on the price and with dispersion measures which show an increase in order book density when these signals appear.
The number of trades is lower when the signal appears, whatever the direction of the trade. After the signal, there is a quicker return to normal values for buy trades than for sell trades which remain low 15 minutes after the signal. Traders seem to delay buying and selling activities when these signals occur, even if liquidity is higher. As depth does not fall and even increase, there are more pending orders in the book. If we investigate the pattern for the Gravestone and the Dragonfly Doji and keeping in mind the philosophy behind these structures, we observe that buy trades are less numerous and less big for the Gravestone Doji compared to sell trades while we observe the opposite pattern for the Dragonfly Doji. Since, the Gravestone Doji appears when a selling rally follows a strong buying pressure, our results suggest that the selling rally does not come from an increased sell volume but from a decrease in buy volume. The opposite interpretation may be done for the Dragonfly Doji. Trade imbalances confirm these findings with a sharp drop for the Gravestone Doji and a significant peak for the Dragonfly Doji.
Figure 11: Abnormal aggressiveness around Doji

Full, dotted and dashed lines represent the intra-window median pattern for these aggressiveness measures respectively for the Doji, the Dragonfly Doji and the Gravestone Doji. Triangles (△), squares (□), and circles (○) indicate a rejection of the null hypothesis respectively at the 99%, 95% and 90% confidence levels.

Sell orders are more aggressive when a Doji appears while buy orders are more aggressive only 15 minutes after the apparition of the Doji. Traders seem to place more marketable orders than they usually do, even if trading activity is lower. This suggests that buy traders become aggressive after the apparition of the Doji. Sellers react quicker than buyers do. The results also suggest that sellers are even more aggressive when the Doji is a Gravestone Doji and buyers seem to be even more aggressive in the case of a Dragonfly Doji. These results are at first sight not consistent with the lower trading activity around these structures. Yet, even if traders are less numerous, they are more aggressive but their aggressiveness does not erode depth at the opposite side.
Figure 12: Abnormal High-Low around Doji

Full, dotted and dashed lines represent the intra-window median pattern for the volatility measured with the high-low range respectively for the Doji, the Dragonfly Doji and the Gravestone Doji. Triangles (△), squares (□), and circles (○) indicate a rejection of the null hypothesis respectively at the 99%, 95% and 90% confidence levels. Whatever the Doji structure, the High-Low volatility measure sharply falls when the signal appears. The level is significant at 1%. A Doji is thus linked to lower volatility, which is consistent with the consensus on the price implied by the Doji. This also indicates that high volatility Dojis, Doji with very long shadows, are very rare in our dataset.

6 Robustness checks

In this section, we first investigate other types of dynamics by looking at Hammer-like configurations. Among Hammer-like structures, there are four structures that are characterized by a long shadow and a small real body.\textsuperscript{15} The Hammer appears at the end of a downtrend and is made of a very small real body with (almost) no upper shadow and a very long lower shadow. The same structure may appear at the end of an uptrend but, in that case, it is called a Hanging Man. Inverting the shadows, i.e. the upper shadow becomes the lower shadow and vice-versa, we obtain an Inverted Hammer at the end of a downtrend or a Shooting Star at the end of an uptrend. This group of figures is interesting for many purposes. First, as these figures are said to be strong reversal structures, we expect a high correlation between changes in trade imbalances and the occurrence of these structures. Regarding liquidity, the results should be linked to previous findings on the Gravestone and Dragonfly Dojis if the size of the real body has little impact. Indeed, a Dragonfly Doji may be a particular Hammer or Hanging Man while a Gravestone Doji may be a particular Inverted Hammer or Shooting Star, depending on their position on the price chart. If we observe differences between these structures, the size

\textsuperscript{15}A description of the presented structures is available in appendix.
of the real body has an influence on liquidity behavior. We also expect a difference between
bullish and bearish signals. Hammers and Inverted Hammers should present some similarities
in their results as well as Hanging Men and Shooting Stars.

Then, we conduct the same analysis on candlesticks generated from 30-minutes and 60-
minutes price series. By doing this, we create two new sets of events. This enables us to check
whether our findings are the consequence of the choice of the time interval.\footnote{All the graphs of this analysis are not presented here but are available upon request.}

6.1 The Hammer, the Hanging Man, the Inverted Hammer and the Shooting Star

In a nutshell, our results confirm the literature on Japanese candlesticks which states that
Hammer-like configurations are strong reversal structures as they really break the intra-window
pattern. We observe a higher liquidity just before the formation of the Hammer but this
liquidity is not provided by more depth: the book is more dense and the spread is lower. The
Hanging Man also shows similar outcomes but only after it has fully appeared on the chart.
The results we discuss here may come from the configuration type, i.e. the size of the shadows.
This is confirmed by the order imbalance results which show that the order imbalance is more
in favor of the ask when the lower shadow is longer. Trading activity and aggressiveness
measures are totally in line with the bearish or bullish reversal potential of the structure. We
also observe lower volatility when these structures appear. The results are summarized in
Table 3.


<table>
<thead>
<tr>
<th></th>
<th>Hammer (625)</th>
<th>Inverted Hammer (175)</th>
<th>Hanging Man (469)</th>
<th>Shooting Star (91)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>-1</td>
</tr>
<tr>
<td>Spread</td>
<td>- 3</td>
<td>- 2</td>
<td>+ + + 3</td>
<td>- 2</td>
</tr>
<tr>
<td>Bid depth</td>
<td>- 3</td>
<td>- - 3</td>
<td>+ + + 3</td>
<td>- 2</td>
</tr>
<tr>
<td>Ask depth</td>
<td>+ + + 3</td>
<td></td>
<td>+ + + 3</td>
<td>+ + 3</td>
</tr>
<tr>
<td>Imbalance</td>
<td>- - 3</td>
<td></td>
<td>+ + + 2</td>
<td>- 2</td>
</tr>
<tr>
<td>Dispersion - Bid</td>
<td>- - 3</td>
<td></td>
<td>+ + 1</td>
<td>- 2</td>
</tr>
<tr>
<td>Dispersion - Ask</td>
<td>- - 3</td>
<td></td>
<td>+ + + 3</td>
<td>+ + 3</td>
</tr>
<tr>
<td>Slope - Bid</td>
<td>+ + + 3</td>
<td></td>
<td>+ - 3</td>
<td>+ + 3</td>
</tr>
<tr>
<td>Slope - Ask</td>
<td>+ + + 3</td>
<td></td>
<td>- - 3</td>
<td>+ + + 3</td>
</tr>
</tbody>
</table>

This table presents the results obtained for the four Hammer-like structures for each liquidity measure. Each panel represents a [-1;+1] time window around the occurrence of the event. "+" and "+" signs denote positive and negative values for the abnormal measure. "+" and "-" signs denote bigger positive and negative variations. "++" and "-" signs denote peaks and trough over the time window. The exponents denote the significance: 1 for 10% significance, 2 for 5% significance and 3 for 1% significance.

The results clearly indicate that liquidity is higher before the apparition of the Hammer and when the Hanging Man occurs. Liquidity seems also to be lower for the Inverted Hammer and the Shooting Star. Depth results suggest that changes in liquidity around these structures are only one-sided. These outcomes are similar to those of the Doji structures for which bid and ask quantities evolve differently depending on the position of the price on the candle (near the highest or lowest of the interval). The imbalance significantly drops just before a Hammer or a Hanging Man. The book seems to be imbalanced in favor of the ask side when these configurations appear, confirming previous results. Regarding dispersion, we observe that the Hammer present a sharp drop in dispersion at the ask just before its occurrence. This may suggest that the length of the shadows has also an impact on dispersion. A Hammer is likely to occur when the density of the ask side increases, i.e. price limits are closer from each other. This is consistent with an agreement on the minimum price and the end of the bearish rally. As expected, these structures exhibit changes in dispersion given their high reversal potential. Slope results are totally in line with dispersion results. Number of buy and sell trades, trade imbalance, aggressiveness and volatility measures are consistent with the literature on Japanese candles and with the price pressures that drive these signals. There are thus not reported here.
6.2 Changing the time interval

Table 4 presents the number of occurrences for each structure for both 30-minutes and 60-minutes price series.

<table>
<thead>
<tr>
<th>Name</th>
<th>Bull/Bear</th>
<th>Count 30 minutes</th>
<th>Count 60 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doji</td>
<td>1</td>
<td>1511</td>
<td>1103</td>
</tr>
<tr>
<td>Bearish Dojistar</td>
<td>-1</td>
<td>34</td>
<td>34</td>
</tr>
<tr>
<td>Bullish Dojistar</td>
<td>1</td>
<td>43</td>
<td>36</td>
</tr>
<tr>
<td>Dragonfly Doji</td>
<td>1</td>
<td>254</td>
<td>198</td>
</tr>
<tr>
<td>Gravestone Doji</td>
<td>1</td>
<td>283</td>
<td>197</td>
</tr>
<tr>
<td>Hammer</td>
<td>1</td>
<td>268</td>
<td>225</td>
</tr>
<tr>
<td>Hanging Man</td>
<td>-1</td>
<td>209</td>
<td>159</td>
</tr>
<tr>
<td>Inverted Hammer</td>
<td>1</td>
<td>73</td>
<td>47</td>
</tr>
<tr>
<td>Shooting Star</td>
<td>-1</td>
<td>42</td>
<td>27</td>
</tr>
</tbody>
</table>

If we consider 30-minutes intervals, Doji structures display very similar liquidity, trading activity and volatility patterns over the whole window. The conclusions of 15-minutes price series are also applicable. This is also true for 60-minutes intervals even if the patterns are more noisy. The results support all our findings. This indicates that the relationships between price dynamics and liquidity are still significant for longer periods.

While looking at Hammer-like configurations, the conclusions of 30-minutes and 60-minutes intervals are very similar. Liquidity measures outcomes are much less significant for all measures, except for the dispersion and the slope whose conclusions remain unchanged. The spread still drops in case of a Hammer or a Hanging Man. We however observe fluctuations in the time window but without significance. Trading activity, aggressiveness and volatility measures display similar patterns as for 15-minutes price series but with much more noisy results. When intervals are longer, buying and selling pressures are always struggling, leading to more noise in the results.

To sum up, robustness checks results confirm the outcomes of our core study. The relationships between liquidity and price movements outlined in our study are thus applicable to time intervals up to 60 minutes. The Doji structures do not present different results. This confirms that the consensus on the price that appears on the chart also appears in the order book whatever the time interval from 15 to 60 minutes. These checks also confirms the "one-
sided” impact that has been previously outlined. However, we also observe that Hammer-like configurations patterns are not as significant for longer intervals as for smaller ones.

7 Conclusion

In this paper, we investigate the relationships between some well-characterized price movements and liquidity in order to check whether it is possible to improve transaction cost monitoring, order placing and execution by extracting information out of price dynamics. We focus on HLOC prices and the best known Japanese candlesticks charting method to characterize price dynamics. We use an event study methodology on 15-minute intervals in order to check how liquidity is affected by the occurrence of a given candlestick structure. After filtering for contagious effects and non-relevant events, we focus the core analysis on traditionnal, Dragonfly and Gravestone Dojis which are the most influential single lines of the literature on Japanese candlesticks. These structures imply a consensus between buyers and sellers on the price of the security.

We look at several liquidity and trading activity measures: spread, depth, order imbalance, dispersion, slope, trade imbalance, aggressiveness and volatility. We disentangle bid and ask sides as we expect the book to be affected differently on each side. Liquidity seems to be higher over all dimensions when a Doji appears. We also find that there is less trading activity at that moment. Traders seem to agree on the price of the security and only a few of them is willing to hit the best opposite quote. A liquidity-taking order placed at that particular moment may thus incur a lower market impact, implying lower implicit costs.

We also outline that the position of the real body on the candle seems to have an impact on the behavior of liquidity. A Dragonfly Doji is likely to be linked to a bigger depth variation on the ask side and a Gravestone Doji to a bigger depth variation on the bid side just before their occurrences. This also enables us to argue on causality, as in Kavajecz and Odders-White (2004). These Dojis seem to be the answer to particular liquidity and trading activity dynamics. These results have to be further discussed as these structure may appear at the end of either an uptrend or a downtrend. It would be interesting to analyze how valid is this pattern if we disentangle bullish signals from bearish signals. Our results also show that Dojis appearing in star positions are linked to less liquid states of the order book than for traditional Dojis.
We perform two types of robustness checks. We first look at other influential candlesticks configurations among the Hammer-like family. We observe interesting results on Hammers and Hanging Men which indicates that liquidity is higher before the occurrence of a Hammer and when a Hanging Man appears. However this increase in liquidity is not provided by more depth. Placing a large liquidity-taking order at the time of the Hammer may thus not necessarily cost less as a higher density does not provide lower market impact, if quantities do not increase.

The Hanging Man, which looks like to the Hammer, i.e. small real body, no upper shadow and a very long lower shadow, presents similar outcomes but it only displays higher liquidity at the time of occurrence. Moreover, the Hanging Man appears after an uptrend, in opposition to the Hammer. This may suggest that the trend has little impact on liquidity. We do not investigate further trading activity and aggressiveness measures as they are totally in line with the buying and selling price pressures that drive the signals. Finally, our results confirm previous findings on Doji structures which suggest that the position of the real body in comparison to the highest and lowest price of the interval has a one-sided influence on liquidity. When the body is near the highest, there seem to be more liquidity at the ask and conversely, liquidity is higher at the bid when the real body is near the lowest price of the time interval. This is even more true when the real body is short, i.e. in case of Dojis.

We then change our interval length in order to validate our results for longer time intervals. With 30-minutes and 60-minutes price series, the results are very similar for Doji structures. Hammer-like configurations do not present very different patterns but display much less significance, except for dispersion and slope measures. The patterns are not as significant for this second category. As expected, all the patterns contain more noise, given the longer period taken into consideration, but still outline a relationship between price dynamics and our measures.

All our results suggest that traders might benefit from candlesticks analysis as a way to better time their order submissions in order to improve their transaction costs management. All things being equal, placing a marketable order when a Doji appears involves a better execution than at another moment.

References


The Doji presents a closing price (almost) equal to the opening price. It occurs when there is an agreement on the fair value of the asset and where markets are 'on a rest'. The Doji indicates the end of the previous trend. The most traditional Doji is a 'plus' sign but Dragonfly and Gravestone Dojis are also frequent. A Dragonfly Doji appears when a strong selling pressure directly follows a strong buying pressure implying an upper shadow almost equal to zero. The Gravestone Doji occurs when the buyers have dominated the first part of the session and the sellers, the second one. The Hammer and the Hanging Man appear when sellers dominate the first part of the session and buyers, the second part. By construction, they present a long lower shadow and almost no upper shadow. The Hammer occurs at the end of a downtrend while the Hanging Man puts an end to an uptrend. The Inverted Hammer and the Shooting Star are made with a small real body, a very long upper shadow and almost no lower shadow. The Inverted Hammer appears at the end of a downtrend and the Shooting Star occurs at the end of an uptrend. These structures are said to be strong reversal ones.