Hidden Agendas: A Study of the Impact of Concealed Orders[1]

(Job Market Paper)

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November 2012

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Abstract

I find that as many as 20.37 percent of executions in NASDAQ are made against hidden orders. I show that hidden orders contain information on the intraday level: executed hidden orders can generate an average of a 13.4 basis points return compared with the closing price of the day (33 percent annualized return). On a two-day horizon, the portfolio of stocks with trades heavily executed against hidden buy orders outperforms the portfolio of stocks with trades heavily executed against hidden sell orders at an annualized 18-percent rate for small firms, but outperformance decreases with market capitalizations. On the monthly level, hidden order return predictability disappears. The evidence suggests that hidden order submitters do not have fundamental information, but have very short horizon information or superior order exposure and execution strategies. I also examine how the invisibility of hidden orders affects the way we observe different liquidity measures. I find that as much as 15.78 percent of depths are invisible. The true bid-ask spread is created by hidden orders 16.74 percent of the time, and the observable spread is 34 percent larger than the market true spread.

The option of hiding one's orders has become an important feature of equity markets. Virtually all of the exchanges now permit traders to choose the extent to which their orders are displayed in the system, allowing all, some or none of their orders to be visible. I use two proprietary datasets and find that hidden orders are important in NASDAQ. 20.37 percent of executions are made against hidden orders and 15.78 percent of overall depths are invisible[2]. Hidden orders contain information; on average they can generate 13 basis points of intraday return.

The natural question of whether or not hidden orders contain information has been examined in the theoretical literature. On one hand, people have concerns about whether or not insiders use hidden orders to conceal their private information. Boulatov and George (2011) have built a theoretical model which assumes that informed traders use undisplayed orders in order to hide their information. On the other hand, Moinas (2010) shows that both liquidity–motivated and information–motivated traders use hidden orders, and liquidity motivated traders use hidden orders in order to mitigate the price impact of large orders. The Buti and Rindi (2011) model assumes that there is no information asymmetry between traders, but hidden orders are still used to compete for the provision of liquidity.

My results about the information in hidden orders have important implications for our understanding of the role of hidden orders. The analyses are based on the first proprietary dataset. The sample period is from January 2010 to November 2011. I demonstrate that hidden orders can generate 13.4 basis points of intraday return compared with the actual closing price at the end of the day, and the returns are positive for any size stocks. On the annual level, the scale is as large as 33 percent. Trading firms commonly use the closing price as a benchmark for measuring traders' execution performance, and traders have a strong incentive to beat the daily

[2] Depth here refers to the level and breadth of all open orders.

closing price[3][4]. Traders who submit hidden orders are well informed in the sense that they have superior order exposure and execution strategies.

I apply the same methodology to examining the displayed order intraday returns, and find that for medium and large stocks, the returns for displayed orders are negative. Overall, the intraday return for displayed orders is 1.8 basis points, and only small stocks exhibit positive returns. The result has two implications: first, it confirms that there is intense competition to provide liquidity in the current market. For medium and large stocks, the revenue of displayed orders for providing liquidity is not enough to offset the adverse selection cost before liquidity rebate[5]. Second, the striking difference between the profit level of displayed and hidden orders suggest that hidden orders are significantly different from the regular liquidity providing provision. As a group, the submitters of hidden orders have better information than the submitters of displayed orders.

Given the fact that hidden orders contain information, it is natural to explore whether the information can be extended to a longer horizon. I approach the problem by constructing portfolios based on hidden order activities. On a two-day horizon, the portfolio of stocks with

[3]As regards NASDAQ stocks, the daily closing price is determined by a call auction mechanism. Hypothetically speaking, two types of traders are likely to use hidden orders. One type of trader is the sophisticated liquidity trader who chooses to provide liquidity using hidden orders. Such traders can choose to close their positions at the end of the day using daily closing prices, which results in a zero daily inventory. This type of trader opens positions when opportunities arise. There is with no obligation regarding the amount of orders they need to fill. The other type of trader is the order execution manager who needs to fill a pre-determined amount of orders specified by their clients. Ideologically, for the second type of trader, the profit made by using hidden orders is a convex combination of executed hidden orders and orders that are failed to get filled using hidden orders. In worst-case scenario, those orders can still be filled at the end of the day during the closing call auction.

[4]Sophisticated liquidity traders can close their position at any time before the end of the day when opportunities arise. Compared with closing the position by using the price determined by the call auction at the end of the day—which means no order management strategies—the time that is chosen to close the position initiated by hidden orders can also be well managed using sophisticated algorithms. If they do so, the returns are likely to exceed 16 basis points on average.

[5] The profit computed here has not taken liquidity rebate into account, and liquidity rebate may help liquidity providers to balance their costs.

trades heavily executed against hidden buy orders outperforms the portfolio of stocks with trades heavily executed against hidden sell orders at an annualized 18-percent rate for small firms, but outperformance decreases with market capitalizations. On the monthly level, hidden order return predictability disappears. The portfolios constructed based on the same methodology using displayed order are unable to generate abnormal returns on either the two-day horizon or the monthly level. Considering these results suggests that traders who submit hidden orders have information that is rapidly impounded in securities prices.

Although my paper does not provide answers concerning the market design when no hidden orders are allowed, my finding that hidden orders contain information develops a fundamental basis for future researchers in this area. Given that 20.37 percent of executions in NASDAQ are made against hidden orders and that hidden orders can generate as much as a 33 percent annualized return, the issue is severe and demands our attention.

Exchanges nowadays get virtually zero percent of retail orders, and virtually all marketable orders from retail brokerages (Schwab, e-trade, Scottrade, etc.) are filled off-exchange by market makers. The orders that remain on the exchange are non-marketable limit orders that are likely to have been submitted by sophisticated traders. Although hidden orders lose execution priority compared with displayed orders at a given price, the invisibility feature of such orders can be incorporated into sophisticated trading strategies. The *Wall Street Journal* reports that high-frequency traders sometimes use a special type of order known as "Hide Not Slide" to step in front of ordinary investors when buying and selling stocks. These maneuvers are executed in a fraction of second[6]. More specifically, there exists an algorithmic trading strategy

[6] This news was reported on September 19, 2012 in the *Wall Street Journal:* http://online.wsj.com/article/SB10000872396390443989204577599243693561670.html?mod=WSJ_hppMIDDLENexttoWhatsNewsSecond

known as "guerrilla" which involves submitting only hidden orders. The SEC is investigating computer-trading practices and the use of order types, but no reports have been released. This paper provides evidence regarding the informativeness of hidden orders, assisting SEC investigations.

This paper extends the empirical literature of hidden orders by examining a large number of cross-sectional and time-series stocks. The empirical literature on hidden orders is limited and has made use of small cross-sectional samples (e.g., De Winne and D'Hondt (2007), Frey and Sanda (2009) and Tuttle (2003)). The same as theoretical literature, empirical literature has not yet reached conclusive results regarding whether hidden orders contain information. Kumar, Thirumalai and Yadav (2010) use 3 months of Indian data and find that hidden orders have been used by informed traders. Harris (1996) uses 300 French stocks in Paris Bourse and argues that hidden orders are used primarily by uninformed traders, which is consistent with the line of reasoning that hidden orders mitigate the option value of standing limit orders. Bessembinder, Panayides and Venkataraman (2009) use 100 cross-sectional firms in Euronext-Paris, and state that their findings support the argument that hidden orders are more likely to be used by uninformed traders. Due to data constraints, Bloomfield, O'Hara and Saar (2011) examine the informativeness of hidden order in an experiment setting, and find that the ability to hide orders affects order strategies, but not market outcomes.

Most of the empirical literature regarding the transparency of the U.S. analyzes market quality after disclosure changes. Hendershott and Jones (2005) find that after Island stops displaying the limit order book in three ETFs, its share of trading activity and price discovery fell. Boehmer, Saar and Yu (2005) analyze the effect of pre-trade transparency by examining the

http://online.wsj.com/article/SB10000872396390444812704577605840263150860.html?mod=WSJ_hppMIDDLENexttoWhatsNewsSecond

introduction of the NYSE OpenBook, and conclude that an increase in pre-trade transparency affect trading strategies and can improve certain dimensions of market quality.

In the second part of the paper, I study how the invisibility of hidden orders affects the way we observe different market liquidity measures using the second proprietary dataset. In the case of hidden orders, the market we observe might not be the market's true state. This problem arises from the fact that we only observe displayed orders, and omit the information contained in hidden orders.

Market participants might observe only the incomplete depth at each price level. The bid-ask spread may be spurious due to the existence of hidden orders placed between displayed orders. I use one-second snap shots of the limit order book, which contains displayed and hidden depths at each price level for all common stocks listed in NASDAQ, and I find that as many as 15.78 percent of depths are invisible. 16.74 percent of time, the true bid-ask spread is created by hidden orders. This number is greater for small stocks (35.72 percent of time) than for large stocks (15.92 percent of time). In the aggregate, the spread we observe for the displayed orders is 34 percent larger than the market true spread.

The literature documents that the intraday minute-by-minute spread exhibits a reversed J-shaped pattern: liquidity is high in the morning and decreases as the day moves on (Chan, Christie, and Schultz (1995) and McInish and Wood (1992)). The trend of hidden order spread is the reserve: the spread is narrower in the morning and increases during the day, which implies the existence of a larger amount of hidden liquidity in the morning.

The paper is organized as follows: section I illustrates the institutional details of hidden orders and describes the data. Section II provides summary statistics for executions against hidden orders. Section III explores the information content of hidden orders. Section IV

documents how the invisibility of hidden orders affects how we observe the true state of the market. Section V concludes the paper.

I Institutional Details

A What is a hidden order?

This section illustrates the concept of hidden orders and provides examples of their execution sequences under different scenarios. As regards limit orders awaiting execution, NASDAQ's core matching engine determines their execution sequences based on a priority rule[7]. Orders at the best prices receive the highest priority[8]. As regards orders at the same prices, displayed orders have execution priority over hidden orders; display status trumps time as the third priority factor[9].

Figure 1 Panel A shows a limit order book snapshot which contains both displayed orders and hidden orders. Hidden order prices and depths are grey in color and displayed order prices, while depths are black in color. Market participants observe the best bid at $1.01 and the best ask at $1.06. Although the total depth of the best bid is 5500 shares, market participants can observe only the displayed 4000 shares. The same holds true for the depth of the best ask. In this example, best bid and ask prices are provided by hidden orders. The true best bid and true best

[7] NASDAQ's core matching engine accepts limit orders of only two types: displayed and hidden. Complex orders are pre-processed into these two order types before being sent to the core matching engine. For example, iceberg orders are broken into different types of orders based on their displayed and reserved sizes.

[8] The best prices here refer to the highest price for buy orders and the lowest ask price for sell orders.

[9] NASDAQ allows for additional order types other than displayed or hidden orders. Different NASDAQ order types can be found at:
http://www.NASDAQtrader.com/content/ProductsServices/Trading/Workstation/rash_strategy.pdf
NASDAQ does not allow market orders; all orders must come with intended prices. Orders that are intended to be executed immediately are made possible by marketable limit orders, for which buy orders are submitted at prices at least as good as the best ask prices, and sell orders are submitted at prices at least as good as the best bid prices in order to ensure executions.

ask prices, which take into account both displayed and hidden orders, are $1.03 for 850 shares and $1.04 for 900 shares, respectively.

[Insert Figure 1 Here]

Panel B, C, and D provides three examples which illustrate the execution priority of hidden orders. The execution priority has three levels: price, displayed status and time. Panel B illustrates the scenario following an arrival of a 300-share sell market order. The 300-share sell market order will be matched to hidden orders placed at $1.03 because $1.03 is the highest bid price. Market participants do not see any depths at $1.03 but are able to observe trades that occur at $1.03 for 300 shares once they are reported. Panel C illustrates the scenario following an arrival of a 1500-share sell market order. The order will initially be matched to hidden orders placed at $1.03 and will wipe out the 850-share depth, and then get matched to hidden orders placed at $1.02 and wipe out the 500-share depth. The remaining 150 shares will be matched to displayed orders placed at $1.01, because at the same price level, displayed orders have execution priority over hidden orders. Trades occurred at $1.03 with a total of 850 shares, at $1.04 with a total of 500 shares, and at $1.05 with a total of 150 shares being reported. Panel D illustrates the scenario following an arrival of a 6000-share sell market order. As in the previous example, the order will first wipe out all depths for hidden orders placed at $1.03 and $1.02. It will then be matched to displayed orders placed at $1.01, and will wipe out all displayed depths. The remaining 650 shares will be matched to buy hidden orders at $1.01. Market participants observe that trades occurred at $1.03 with a total of 850 shares, at $1.04 with a total of 500 shares, at $1.05 with a total of 4650 shares. Among the 4650 shares, 650 shares are executed against hidden orders.

B Data Description

The analyses in this paper are based on messages I find in two proprietary datasets, NASDAQ TotalView-ITCH and NASDAQ Model View. NASDAQ TotalView-ITCH consists of a series of messages that describe orders added to, removed from, and executed on NASDAQ. The data is in the form of daily binary files with order instructions. The first step is to separate the order instructions into different message types. This paper focuses on message P, which contains executions of hidden orders. A complete list of message types can be found in the NASDAQ TotalView-ITCH data manual[10]. The timestamps for all of the different types of messages have two parts: one concerns the number of seconds since midnight; the other concerns the number of nanoseconds (which is accurate to 10^{-9} second) since the most recent second message.

Table 1 presents a sample of the NASDAQ TotalView-ITCH message P, which includes executions against hidden orders. The dataset contains the trade prices, volume and timestamps for trades that occurred. It also indicates the signs for executed limit orders. The signs here are measured from the passive side. In this example, all of the trades were executed against the same limit order, which was assigned the unique order reference number 61224737 when the order was added to the book[11]. Sections II and III in this paper use all of the 2390 common stocks that were listed on NASDAQ from January 4, 2010 to November 18, 2011.

[Insert Table 1 Here]

Section IV uses the second source of proprietary data, the NASDAQ Model View dataset, which contains one-second snap shots of the limit order book for displayed and hidden order

[10] The NADAQ TotalView-ITCH data manual can be found at http://www.nasdaqtrader.com/content/technicalsupport/specifications/dataproducts/nqtv-itch-v4_1.pdf

[11] Effective December 6, 2010, NASDAQ OMX filled the order reference number field within the P message as zero.

depths at each price level. Section IV uses the same set of the 2390 common stocks as Section II and III. The sample period is from February 28, 2012 to March 16, 2012.

The CRSP dataset was used to retrieve the information on daily stock returns, market capitalizations, and volume. Section III uses three factors: MKT, SMB, and HML for the asset pricing tests. These are obtained from the Fama/French website data library.

II Summary Statistics

A How many executions are made against hidden orders?

This section presents both time series and well cross-sectional characteristics of trades executed against hidden orders. Figure 2 demonstrates the time series pattern. Panel A shows that the number of executions made against hidden orders over total trades in January 2008 is about 11.4 percent. This number remains relatively stable during 2010 and 2011. Panel B presents the executed shares made against hidden orders over total trading volume during the same time period. The general trend and its magnitude remain relatively stable as shown in both Panel A and Panel B.

[Insert Figure 2 Here]

Table 2 Panel A presents the cross sectional distributions for executed shares against hidden orders over the total trading volume. On average, 19.08 percent of trading volume comes from executions made against hidden orders. Small stocks have a significantly higher percentage of shares executed against hidden orders (32.00 percent) than large stocks (11.83 percent), and this number monotonically decreases in tandem with size quintiles. Panel B shows that on average, 20.37 percent of trades are executions against hidden orders. Panel B displays the same pattern as in Panel A, such that the small stocks have higher executions against hidden orders

over total trades, and this number decreases with market size quintiles. Panel C presents the cross-sectional distributions for the executed hidden order imbalances. The imbalance measure is calculated as the daily number of executions made against hidden buy orders minus the daily number of executions made against hidden sell orders over daily total trades. The mean of the imbalance measures is negative, which suggests that there are more executions made against sell hidden orders than against hidden buy orders. Small stocks have a higher order imbalance (-1.80%) than large stocks (-0.06%), and the mean decreases with the size quintiles.

[Insert Table 2 Here]

Stock size may be correlated with illiquidity. In order to disentangle the size effect from the illiquidity effect, Table 3 examines the cross-sectional distributions of hidden orders double sorted for size and illiquidity. The illiquidity measure follows Amihud (2002), for which the illiquidity is calculated as daily return over daily dollar volume. Stocks are sorted horizontally for size and vertically for illiquidity. Panel A shows that controlling for firm size, illiquid stocks have a higher percentage of shares that are executed against hidden orders than is the case for liquid stocks. The same pattern holds true for the percentage of executions against hidden orders in illiquidity quintiles, as Panel B indicates.

[Insert Table 3 Here]

B Which factors determine executions against hidden orders?

In this section, I examine the factors correlate with executions made against hidden orders. Variable *hidtrdpct* is the number of executions made against hidden orders over total trades. *logprc* is the log value of the price level, *range* is the daily highest price minus the lowest price over the closing price, and *illiquidity* is the Amihud (2002) illiquidity measure multiplied by 10^6. The results are in Table 4. High price stocks have a higher percentage of trades that come

from executions against hidden orders. High price stocks are likely to have large displayed bid-ask spreads, which provide more discrete price levels such that hidden orders can be placed at. Small stocks, and highly illiquid stocks have a larger percentage of executions against hidden orders, which is consistent with Table 4. The daily price range, which is used as a proxy for volatility, is positively correlated with the percentage of executions made against hidden orders. This finding is consistent with Hasbrouck and Saar (2001), which reflects that higher volatility is associated with a higher probability of limit order executions.

[Insert Table 4 Here]

III Are hidden orders informed?

The information content of stock prices is one of the fundamental questions in asset pricing studies, and this issue has been previously examined from several perspectives. For example, Boehmer, Jones and Zhang (2009) find that short sellers are well informed. Portfolios formed by short selling activities can predict returns. Pan and Poteshman (2006) find that evidence that option trading volume contains information about future stock prices. This section will focus on investigating the information that trading against hidden orders generates regarding future movements in stock prices.

A Intraday hidden order returns

I first examine whether hidden orders have information on the intraday level. The information content not only refers to the private knowledge that is used to forecast stocks' upward or the downward trends, but also traders' skills in managing their order exposures. Following Linnainmaa (2010), for each executed order, I compute its intraday log-return, measured from the transaction price to the bid-ask midpoint, and reverse the sign for executed

sell order. Then, for each stock on each day, I calculate the share weighted returns for both hidden and displayed orders. More specifically, let $R^h_{k,i,t}$ be the return for the kth execution of hidden orders on day *t* for stock *i*, which is computed as follows:

$$R^h_{i,t,k} = \begin{cases} log\left(\frac{midpoint_{i,t}}{prc^h_{i,t,k}}\right), for\ buyer\ initiated\ trade \\ log\left(\frac{prc^h_{i,t,k}}{midpoint_{i,t}}\right), for\ seller\ initiated\ trade \end{cases} \quad (1)$$

where $midpoint_{i,t}$ is the closing bid and the ask price midpoint; $prc^h_{i,t,k}$ is the execution price for the kth execution of hidden orders for stock *i* on day *t*. Then, I compute the share weighted return for executed hidden orders for stock *i* as

$$R^h_i = \frac{\sum_{t=1}^{T} \sum \omega^h_{i,t,k} R^h_{i,t,k}}{T} \quad (2)$$

where $\omega^h_{i,t,k}$ is the share weight for the kth execution of hidden orders, and *T* is the number of total trading days.

The return for displayed orders for stock *i* is computed as follows:

$$R^d_i = \frac{\sum_{t=1}^{T} \sum \omega^d_{i,t,k} R^d_{i,t,k}}{T} \text{ where}$$

$$R^d_{i,t,k} = \begin{cases} log\left(\frac{midpoint_{i,t}}{prc^d_{i,t,k}}\right), for\ buyer\ initiated\ trade \\ log\left(\frac{prc^d_{i,t,k}}{midpoint_{i,t}}\right), for\ seller\ initiated\ trade \end{cases} \quad (3)$$

$prc^d_{i,t,k}$ is the execution price for the kth execution of displayed orders for stock *i* on day *t*, and $\omega^d_{i,t,k}$ is the share weight for the kth execution of displayed orders.

Table 5 Panel A reports the share weighted intraday returns for executed hidden and displayed orders, as well as their return differences. Results show that hidden orders can generate 18 basis points intraday return on average. Hidden orders across all market size categories have significantly positive returns, and for small stocks the intraday return is as large

as 42.7 basis points. The return decreases with the market size categories, and it is 8.8 basis points for medium stocks and 2.4 basis points for large stocks. T-values are computed from stock-clustered residuals.

[Insert Table 5 Here]

There are two possible causes for the return differences for different-sized firms. First, as has been documented in the literature, small stocks have higher returns than large stocks due to their size effects. The second, small stocks tend to have wider spreads than large stocks. Sophisticated traders can undercut displayed orders by using hidden orders more frequently when spread is wide. In the extreme case, the advantage of hidden orders diminishes when the spread is one penny.

Panel A shows that on average displayed orders can generate 6.3 basis points of intraday return. However, only small stocks have positive returns. Both medium and large stocks have significantly negative intraday returns. The negative returns confirm the existence of intense competition to provide liquidity in the current market. For medium and large stocks, the revenue of displayed orders for providing liquidity is not enough to offset the adverse selection cost. Nevertheless, the profit computed here has not taken liquidity rebate into account, and the liquidity rebate for providing liquidity, which is typically around 0.295 cent per share in NASDAQ[12], may possibly balance their costs. The striking difference between the profit level of displayed and hidden orders suggest that hidden orders are significantly different from the regular liquidity providing provision. On average, hidden orders can generate 11.7 basis points return benchmarked to displayed orders. The return difference for small stocks is the largest, and

[12] The complete adding and removing liquidity rates are found in http://www.nasdaqtrader.com/content/ProductsServices/PriceList/pricesheet.pdf

the difference decreases with market size categories. As a group, the submitters of hidden orders have better information than the submitters of displayed orders.

As regards NASDAQ stocks, the daily closing price is determined by a call auction mechanism. Thus, the midpoint of bid and ask price may be different from the actual closing price of the day. Panel B, Table 5 repeats the analyses in Panel A, but uses the actual closing prices instead of the closing bid and ask midpoint to calculate intraday returns. The general return patterns for using the actual closing price stay the same. Though the magnitudes for hidden and displayed intraday returns are less than the ones presented in Panel A, their return differences stay at the same level. The same as Panel A, returns for hidden orders are positive across all market sizes, while returns for displayed orders are positive only for small stocks, and are negative for both medium and large stocks. On average, hidden orders have 13.4 basis points of return, displayed orders have 1.8 basis points of return, and their return difference is 11.5 basis points.

Trading firms commonly use closing price as a benchmark for measuring traders' execution performances, and traders have strong incentive to beat the daily closing price. Results in Table 5 suggest that traders who use hidden orders are informed about the intraday level in the sense that they have superior order exposure and execution strategies. Their strategies allow them to execute orders with profitable prices that beat the closing price. One natural strategy for them is to open positions using hidden orders (buy or short sell), and close the position (sell or buy back) at the end of day. The strategy generates a 13.4 basis points intraday return on average, and ends with a zero daily inventory[13].

[13] Although hidden orders can generate positive intraday returns, the trading strategy is hardly implementable by general investors. First, investors need access to direct data feeds, which provide instant updates for executions and message flows. Second, hidden orders do not have guaranteed executions; orders may not get filled and prices may drift away. Third, it is hard to define the time intervals upon which trading decisions and

B Asset pricing test

The following section examines whether hidden orders have information about longer horizons. If hidden orders are informed about stocks' fundamental values, stocks with heavy buy order imbalances should outperform stocks with heavily sell order imbalances. A portfolio approach is a natural way to examine these cross-sectional differences. This approach has two advantages: first, it is translated into an implementable trading strategy; second, aggregation into portfolios reduces the impact of outliers and relaxes the assumption of heteroskedasticity within portfolios compared to a regression approach. More specifically, I measure the aggregate imbalance of trades executed against hidden orders during the previous five trading days. I define $IBH_{i,t}$ for stock *i* on day *t* as

$$IBH_{i,t} = \frac{Imbalance\ of\ Trading\ Volume\ Exectued\ against\ Hidden\ Limit\ Orders_{i,t}}{\sum_{k=t}^{t-5} Trading\ Volume_{i,k}} \tag{4}$$

where

$$Imbalance\ of\ Trading\ Volume\ Exectued\ against\ Hidden\ Limit\ Orders_{i,t}$$
$$= \sum_{k=1}^{t-5} \big(Trades\ Executed\ against\ Buy\ Hidden\ Limit\ Orders_{i,k}$$
$$- Trades\ Executed\ against\ Sell\ Hidden\ Limit\ Orders_{i,k}\big)$$

In order to confirm that hidden order activities do not contain the same information set as market sizes, I conduct double sorts such that stocks are first sorted into three market capitalization categories. Then within each category, stocks are sorted for the second time into quintiles based on $IBH_{i,t}$. The result is a set of stocks that differ in hidden order activities but are of similar size. Stocks with the smallest $IBH_{i,t}$ are sorted into quintile 1, and stocks with the largest $IBH_{i,t}$ are sorted into quintile 5 within the same market capitalization category. In other

initiatives should be based. The benefits of hidden orders are mostly utilized by sophisticated traders with complicated algorithms.

words, quintile 1 contains stocks with trades executed most heavily against hidden sell orders. Quintile 5 contains stocks with trades executed most heavily against hidden buy orders. In order to reduce the effect of outliers, a stock was selected into a portfolio on the portfolio formation date only if it had at least 10 executions against hidden orders during at least one of the previous five trading days[14]. After stocks are sorted into 3x10 portfolios, I hold a value-weighted portfolio for 2 trading days. This process was repeated each day, so there are overlapping 2-day holding period returns. Each trading day's portfolio return is the simple average of 2 different daily portfolio returns, and one portfolio is rebalanced each day. I then roll forward one day and repeat the portfolio formation and return calculation process.

In order to ensure that portfolio returns are not driven by differences in risk and characteristics, I calculate abnormal returns using Fama and French's (1993) three-factor, Carhart (1997) momentum factor, and Pastor and Stambaugh (2003) liquidity factor model. The estimated abnormal returns are the constant alphas in the following regressions:

$$R_t = \alpha + \beta_1 MKT_t + \beta_2 SMB_t + \beta_3 HML_t + \epsilon_t \tag{5}$$

$$R_t = \alpha + \beta_1 MKT_t + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 MOM_t + \epsilon_t \tag{6}$$

$$R_t = \alpha + \beta_1 MKT_t + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 MOM_t + \beta_5 LIQ_t + \epsilon_t \tag{7}$$

where R_t is the excess return over the risk-free rate of a portfolio over time *t*, and MKT_t, SMB_t, HML_t, and MOM_t are the excess return on the market portfolio and the excess return on the long/short portfolios that captured size, book-to-market, momentum. LIQ_t is the Pastor and Stambaugh (2003) liquidity factor.

Table 6 Panel A presents abnormal returns for each of the double-sorted portfolios with the two-day holding horizon. The results are strongest for the small-sized firm category. For

[14] Highly illiquid stocks are likely to be filtered out using this selection criterion.

three-factor model, stocks with trades heavily executed against hidden buy orders (quintile 5) outperform stocks for which traders heavily executed against hidden sell orders (quintiles 1) by an annualized 17.7-percent rate (t-statistics 3.05). The outperformance of small stocks under four-factor model and five-factor model is at an annualized 17.4-percent and 17.8-percent respectively. Abnormal returns decrease with market sizes. As regards medium market size portfolios, stocks in quintile 5 outperform stocks in quintile 1 by 7.2 percent annually (t-statistics 1.83) under the three-factor model. Abnormal returns for medium stocks under the four-factor and the five-model are of similar magnitude as the three-factor model. As regards large market size portfolios, the return difference between quintile 5 and quintile 1 is insignificant across all model types.

[Insert Table 6 Here]

Although portfolios sorted on hidden order activities can generate excess returns, transaction costs are of considerable magnitude, given that half of the portfolios are rebalanced each day. The transaction cost is roughly estimated to be 12 percent annually, following the methodology in Boehmer, Jones and Zhang (2009). Without careful monitoring of the transaction costs, a large proportion of the abnormal returns will be wiped out. Trading strategies that are constructed based on observing hidden order executions without careful monitoring of transaction costs are less likely to generate profitable trading outcomes.

Table 6 Panel B repeats the analyses in Panel A, but instead uses the imbalance of trades executed against displayed orders during the previous five trading days as the portfolio sorting criterion. Portfolios are held for two trading days. Different from Panel A, the return predictability disappears across all market size categories.

I then examine whether hidden orders contain information on the monthly level by extending the portfolio holding period to 20 trading days. As is the case in previous analyses, I first sort stocks into three market capitalization categories, and then into five $IBH_{i,t}$ quintiles. This process is repeated each day, so there are overlapping 20-day holding period returns. Each trading day's portfolio return is the simple average of 20 different daily portfolio returns, and the 1/20 portfolio is rebalanced each day. I then roll forward one day and repeat the portfolio formation and the return calculation process. The results are presented in Table 7 Panel A. Abnormal returns are insignificant across all market size categories and under all model types. The results suggest that hidden orders do not contain information on the fundamental level.

[Insert Table 7 Here]

Panel B in Table 7 presents the abnormal returns for portfolios constructed with 20-day holding period using displayed order activities. Results show that there exist no return predictabilities. Taken together, this section suggests that submitters of hidden orders have information that is rapidly impounded into securities prices. Display orders do not have information either at the short term or on the monthly level.

IV The impact of omitting hidden orders on empirical measures

In the case of hidden orders, the market we observe might not be the market's true state. This problem arises because we observed only the displayed orders, while omitting the information contained in hidden orders. This section documents both the cross-sectional and intraday patterns of hidden liquidity, and provides one example of how this would affect the existing literature. The analyses in this section are based on the NASDAQ ModelView, which contains one-second snapshots of the limit order book for displayed and hidden order depths at

each price level. The sample contains all of the stocks listed on NASDAQ from February 28, 2012 to March 16, 2012.

A Where are hidden orders placed?

This section examines the traders' strategy in submitting hidden orders and documents the positions in which hidden orders are placed. First, I summarize the cross sectional distributions of hidden depths for each market size quintiles[15]. Table 8 shows that as much as 15.78 percent of depths are invisible. Small stocks have larger percentages of hidden depths (17.50 percent) than is the case for large stocks (13.37 percent). The pattern is less clear for medium size firms.

[Insert Table 8 Here]

Columns (1) and (2) of Table 9 show the observable quoted spread and true quoted spread for each market quintile. True quoted spread is the difference between the true best ask and the true best bid. It is calculated as follows:

$$true\ best\ ask = \min(\text{displayed best ask}, \text{hidden best ask})$$

$$true\ best\ bid = \max(\text{displayed best bid}, \text{hidden best bid})$$

$$true\ quoted\ spead = (\text{true best ask} - \text{true best bid})/(\text{true best ask} + \text{true best bid}) \quad (8)$$

[Insert Table 9 Here]

The table shows that the observable quoted spread is larger than the true quoted spread for each market size quintile. In the aggregate, the observable spread is 34 percent larger than the true market spread. Small stocks have larger observable quoted spreads as well as larger true quoted spreads than large stocks.

[15] Depth here refers to the aggregated depths at each price level.

Columns (3), (4) and (5) of Table 9 show the percentages of hidden time orders that are placed between, at, and away from observable spreads for each market capitalization quintile. The observable spread is calculated as the difference between the best bid and best ask prices for displayed orders, which are also the prevailing bid and ask prices that market participants observe. In the aggregate, hidden orders are placed between the observable spread 16.47 percent of the time. Hidden orders have lower execution priorities than displayed orders at the same price level, so one way to gain execution priorities is to place hidden orders between the observable bid and ask prices. If hidden orders improve the prevailing visible bid or ask prices, they will be executed ahead of displayed orders. Column (3) also shows that small stocks have a higher percentage of time (35.72 percent) than large stocks (15.92 percent) for hidden orders to be placed between the observable bid and ask prices. Column (4) shows that hidden orders are placed at the prevailing observable bid or ask prices 55.47 percent of time. Hidden orders are placed at the observable bid and ask prices at a lower percentage of time (31.13 percent) for small stocks than is the case for large stocks (56.86 percent). Column (5) shows that hidden orders are placed away from the observable spread 28.06 percent of time. Placing hidden orders at or away from observable bid or ask prices mitigates the cost of being picked-off by fast traders in the event of an asset value shock, or the cost of being adversely selected by informed traders. Hidden orders will not be executed when the counterpart submits a large size order equal to the displayed depth, and intend to wipe out the depth at certain price levels.

B Intraday spread patterns

It is well documented in the literature that the intraday minute-by-minute spread exhibits a reversed J-shaped pattern, and the liquidity is high in the morning and decreases as the day moves on. Figure 3 shows that the trend of the hidden order spread is the reserve. In other words,

the spread is narrower in the morning and increases during the day. The gradual increase of the hidden order spread suggests the possibility of high levels of hidden liquidity existing in the morning, and the traders switch to displayed orders when the hidden orders do not get filled as the day moves on. The results may also reflect the case that the hidden orders placed in the morning get filled. When no new hidden orders come in, the spread widens. Without order level information for hidden orders, it is not possible for this paper to distinguish between the two scenarios. The figure also shows that the hidden order spread experiences a sudden drop five minutes before the market closes. The sudden narrowing of bid and ask prices may be the result of the fact that orders that are intended to be executed, but are not filled, wind up getting sent to the closing call auction, where the closing prices, depending on the supply and demand schedule, are uncertain. Traders improve their bid and ask prices in order to obtain better chances of executions.

[Insert Figure 3 Here]

The figure shows that in the aggregate, the hidden order spread is larger than the displayed order spread. The result is consistent with Table 9 to the effect that the percentage of time that hidden orders are placed away from the observable spread is larger than the percentage of time that hidden orders are placed between the observable spread.

Given that the true ask is the minimum of the displayed ask and hidden ask prices, and the true bid is the maximum of displayed bid and hidden bid prices, the true spread is smaller than either the displayed order spread or the hidden order spread. The concentration of hidden liquidity in the morning is insufficiently strong to offset the low displayed liquidity. Therefore, the displayed liquidity and the true liquidity still exhibit the classical reversed J-shaped pattern.

C Misclassification of liquidity deciles and quintiles

This section provides one example regarding how the invisibility of hidden orders might affects existing academic research. As regards papers that analyze stocks' cross sectional patterns by sorting stocks into liquidity quintiles or deciles, spread is a common liquidity measure. Displayed spread can easily be calculated, for example, using the closing ask and bid prices in CRSP database. Nevertheless, the true spread is non-observable unless the observer knows the positions in which hidden orders are placed. As the previous sections suggested, the true spread is narrower than the displayed spread for all market size quintiles. Errors may occur when the displayed spread is used as a liquidity measure instead of the true spread. This problem is pertinent to academic research that examines the cross sectional properties of stocks by sorting them into liquidity classifications. This section documents the errors that arise from using the displayed spread instead of the true spread while sorting stocks into liquidity deciles or quintiles.

Table 10 shows that when stocks that are correctly sorted into their liquidity deciles using displayed spread 78.45 percent of the time, get sorted into deciles that are one decile above or below their correct liquidity deciles 20.72 percent of time, and get sorted into deciles that are two or more deciles above or below their correct deciles 0.83 percent of time. This problem is less severe when stocks are sorted into quintiles. Stocks get correctly sorted into their liquidity quintiles using the displayed spread 89.87 percent of time, get sorted into deciles that are one quintile above or below their correct liquidity quintiles 10.06 percent of time, and get sorted in deciles that are two or more quintiles above or below their correct quintiles 0.07 percent of time.

[Insert Table 10 Here]

The results suggest that the misclassification problem produces by using the observable spread instead of the true spread is relatively moderate. The true spreads are narrower than the observable spreads to relatively the same degree for all stocks, so rankings based on the true

spread and the observable spread remains rather similar. This section provides an example of how the problem of the invisibility of hidden orders affects academic research.

The invisibility of hidden orders can impact other areas of academic research, such as the midpoint of bid and ask prices, which is often considered to be the fundamental value of an asset. Given that the prevailing bid and ask prices may be spurious due to the existence of hidden orders, the midpoint measure based on the observable spread may also be unreliable. Furthermore, it would be interesting to determine how the intraday volatility calculated based on contaminated midpoint prices is affected. These are interesting topics for future research.

V Conclusion

This paper documents that a significant proportion of U.S. liquidity is hidden. By using cross-sectional data in NADSAQ, I show that hidden orders are informed on the intraday level. On average, executed hidden orders can generate 13.4 basis points of intraday return. I double sort stocks into portfolios based on their market sizes and hidden order activities, and show that in the context of a two-day holding horizon, the portfolio with trades that are heavily executed against hidden buy orders outperforms the portfolio that consists of trades heavily executed against hidden sell orders at an annualized 18-percent rate for small stocks, although the return predictability decreases with market capitalizations. This evidence suggests that submitters of hidden orders do not have fundamental information, but have very short-horizon information or superior order exposure and execution strategies.

This paper also documents how the invisibility feature of hidden orders affects how we observe market liquidity measures. I find that 16.74 percent of time, true bid-ask spread is non-observable since it is created by hidden orders, and this number is greater for small stocks (35.72

percent of time) than for large stocks (15.92 percent of time). In the aggregate, the spread we observe is 34 percent larger than the market true spread. On the intraday level, the spread of hidden orders is smaller than at the beginning of the day, which is the opposite of the established J shaped results for the displayed orders.

The measured liquidity improves while taking both hidden and displayed orders into account, but this does not imply that market liquidity improves with the existence of hidden orders, because they endogenously affect each other. Traders who use hidden orders can generate a large amount of intraday returns using sophisticated algorithms, and sometimes involve jumping ahead of less-sophisticated traders. It raises questions about whether hidden orders submitters obtain unfair advantages, and how this would might affect market liquidity remains unclear. These are important questions that can be answered by future research.

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Table 1: Sample Data This table presents a sample of the NASDAQ TotalView-ITCH message P, which includes all executions against hidden orders. It is possible to receive multiple trade messages for the same order if that order is executed in several parts. In this table, all transactions were executed against the same hidden order, which was assigned a unique order reference number 61224737 when the order was added to the book. As regards the *Time* variable, the digits that appear before the decimal point reflect the number of seconds past midnight; digits that appear after the decimal point reflect the number of nanoseconds since the most recent second timestamp. Buy/Sell indicates the direction of the limit order when it is added to the book.

Order Reference Number	Time (Nanoseconds)	Buy/Sell	Shares	Stock	Price
61224737	36888.426197129	S	1	DELL	14.57
61224737	36888.426524809	S	725	DELL	14.57
61224737	36888.426632973	S	400	DELL	14.57
61224737	36888.426697769	S	400	DELL	14.57
61224737	36888.426701583	S	100	DELL	14.57
61224737	36888.427005536	S	274	DELL	14.57

Table 2: Summary Statistics of Executed Hidden Orders. The sample of the stocks in this table consists of all of the common stocks listed on NASDAQ from January 4, 2010 to November 18, 2011, with records in NASDAQ TotalView-ITCH. There are 2390 stocks in the sample. In Panel A, I compute the time-series means of executed shares against hidden orders over the total trading volume for each stock. I then sort the stocks into five market capitalization quintiles, and present the cross-sectional summary statistics for five size quintiles. In Panel B, I compute the time-series means of number executions against hidden order over total trades for each stock during the sample period and present the cross-sectional summary statistics for five size quintiles. In Panel C, I compute the time-series means of executed hidden order imbalance for each stock and present the cross-sectional summary statistics for five size quintiles. The imbalance measure is calculated as the number of executions against hidden buy orders minus the number of executions against hidden sell orders on day *t* over the total trades on day *t*.

Panel A: Executed Shares Against Hidden orders / Total Trading Volume (%)							
Size	Mean	Std. Dev	Min	25%	Median	75%	Max
Q1 (small)	32.00%	12.41%	6.39%	21.37%	31.21%	43.11%	63.80%
Q2	21.40%	12.13%	6.27%	12.85%	17.21%	27.25%	77.11%
Q3	16.04%	8.51%	5.17%	10.90%	13.70%	18.10%	61.20%
Q4	14.13%	5.33%	5.31%	10.60%	13.50%	16.69%	49.85%
Q5 (large)	11.83%	6.42%	2.63%	6.66%	10.60%	15.05%	41.64%
All	19.08%	11.84%	2.63%	11.10%	15.33%	23.06%	77.11%
Panel B: Number of Executions Against Hidden orders / Total Trades (%)							
Size	Mean	Std. Dev	Min	25%	Median	75%	Max
Q1 (small)	29.34%	11.23%	6.15%	19.94%	28.71%	37.59%	64.39%
Q2	23.36%	10.26%	5.72%	16.63%	20.66%	27.29%	79.06%
Q3	18.50%	6.55%	5.92%	14.29%	17.52%	21.06%	50.49%
Q4	16.67%	4.75%	5.16%	13.47%	16.26%	19.26%	42.12%
Q5 (large)	13.97%	6.16%	4.78%	9.12%	13.21%	17.27%	39.41%
All	20.37%	9.82%	4.78%	13.91%	17.82%	24.05%	79.06%
Panel C: Executed Hidden Order Imbalance (%)							
Size	Mean	Std. Dev	Min	25%	Median	75%	Max
Q1 (small)	-1.80%	4.38%	-37.25%	-3.82%	-1.60%	0.49%	16.03%
Q2	-0.58%	3.22%	-9.72%	-1.55%	-0.41%	0.26%	46.01%
Q3	-0.45%	1.60%	-12.92%	-0.91%	-0.19%	0.31%	3.23%
Q4	-0.08%	0.90%	-5.38%	-0.36%	0.01%	0.36%	3.83%
Q5 (large)	-0.06%	0.63%	-4.26%	-0.25%	0.00%	0.19%	4.80%
All	-0.60%	2.66%	-37.25%	-1.06%	-0.15%	0.27%	46.01%

Table 3: Executed Hidden Orders over Size and Illiquidity. The sample of the stocks in this table consists of all of the common stocks listed on NASDAQ from January 4, 2010 to November 18, 2011, with the records in NASDAQ TotalView-ITCH. There are 2390 stocks in the sample. In Panel A, I compute the time-series means of executed shares against hidden orders over total trading volume for each stock. I sort the stocks into five market capitalization quintiles, and among each market capitalization quintile, I sort the stock into five Amihud (2002) illiquidity quintiles. I then present the cross-sectional averages for five size quintiles over five Amihud (2002) illiquidity quintiles. In Panel B, I compute the time-series means of number executions against hidden orders over total trades for each stock over the sample period and present the cross-sectional average for five size quintiles over five Amihud (2002) illiquidity quintiles.

Panel A: Executed Shares Against Hidden orders/Total Trading Volume by Size and Illiquidity					
	Q1(small)	Q2	Q3	Q4	Q5(Large)
Q1(Low)	19.17%	17.13%	16.11%	16.43%	11.88%
Q2	26.11%	19.79%	17.37%	15.80%	12.53%
Q3	30.73%	21.14%	17.88%	17.12%	14.01%
Q4	34.79%	24.86%	18.79%	15.93%	14.95%
Q5(High)	35.96%	33.99%	22.37%	18.11%	16.49%
Panel B: Number of Executions Hidden Orders / Total Trades by Size and Illiquidity					
	Q1(small)	Q2	Q3	Q4	Q5(Large)
Q1(Low)	19.73%	13.66%	12.90%	13.47%	9.64%
Q2	26.30%	16.80%	14.25%	13.24%	10.65%
Q3	32.76%	18.99%	14.83%	14.35%	11.50%
Q4	39.22%	23.57%	16.68%	13.38%	12.83%
Q5(High)	42.10%	34.10%	21.61%	16.23%	14.54%

Table 4: Factors Correlated with Executions Against Hidden Orders. This table provides factors that correlate with executions against hidden orders. The sample of the stocks in this table consists of all of the common stocks listed in NASDAQ from January 4, 2010 to November 18, 2011, with records in NASDAQ TotalView-ITCH. *hidtrdpct* is the number of executions against hidden orders over total trades and *hidvolpct* is the executed shares against hidden orders. *logprc* is the log value of the price level; *range* is the daily highest price minus the lowest price over the closing price, *illiquidity* is the Amihud (2002) illiquidity measure multiplied by 10^6. *** indicates significance at the 1% level and p-values appear in parentheses.

hidtrdpct	1				
logprc	0.036***	1			
	(<.0001)				
logmktcap	-0.300***	0.672***			
	(<.0001)	(<.0001)			
range	0.130***	-0.362***	0.044***	1	
	(<.0001)	(<.0001)	(<.0001)		
illiquildity	0.009***	-0.018***	-0.017***	0.016***	1
	(<.0001)	(<.0001)	(<.0001)	(<.0001)	

Table 5: Intraday Returns for Executed Hidden and Displayed Orders in Percentage. This table reports intraday returns in percentage for executed hidden and displayed orders. The sample of the stocks in this table consists of all common stocks listed on NASDAQ from January 4, 2010 to November 18, 2011, with records in NASDAQ TotalView-ITCH. In Panel A, each intraday executed buy order return is computed as the log-return measured from the transaction price to the closing bid-ask midpoint, and the signs are reversed for each sell order return, as suggested by Linnainmaa (2010). In Panel B, each intraday executed buy order return is computed as the log-return measured from the transaction price to the actual closing price of the day, and the signs reverse for each sell order return. For each stock on each day, I compute the share weighted average returns for all executions based on their order types, then I average hidden and displayed order returns across all days for each stock. *** indicates significance at the 1% level and t-statistics appear in parentheses.

MktCap	Hidden	Displayed	Difference
Panel A (closing price: midpoint of closing bid and ask prices)			
Small	0.427***	0.217***	0.210***
N = 797	(24.84)	(18.63)	(17.96)
Medium	0.088***	-0.017***	0.104***
N = 797	(21.44)	(-4.95)	(23.69)
Large	0.024***	-0.011***	0.035***
N = 796	(13.77)	(-6.8)	(17.55)
All	0.180***	0.063***	0.117***
N = 2390	(25.9)	(13.62)	(26.06)
Panel B (closing price: actual closing price of the day)			
Small	0.298***	0.088***	0.210***
N = 797	(27.8)	(10.87)	(21.15)
Medium	0.081***	-0.02***	0.102***
N = 797	(20.62)	(-3.44)	(16.16)
Large	0.021***	-0.013***	0.034***
N = 796	(12.37)	(-6.99)	(16.59)
All	0.134***	0.018***	0.115***
N = 2390	(29.31)	(5.22)	(27.14)

Table 6: Portfolio Based on Size and Executed Trade Imbalances with Two-Day Holding Period. The sample of the stocks in this table consists of all of the common stocks listed on NASDAQ from January 4, 2010 to November 18, 2011, with records in NASDAQ TotalView-ITCH. In Panel A, firms are sorted into quintile based on executed hidden order imbalances during the previous five trading days. In Panel B, firms are sorted into quintile based on executed displayed order imbalances during the previous five trading days. Value-weighted portfolios are held for two trading days. This process is repeated each trading day, so that trading day's portfolio return is an average of two different portfolios with one portfolio rebalanced each day. Fama and French (1993) three-factor alphas, Carhart (1997) momentum factor alphas, and Pastor and Stamabaugh (2003) liquidity factor alphas multiplied by 250 are reported to reflect an appropriate yearly return. *** indicates significance at the 1% level and t-statistics appear in parentheses.

Panel A: Abnormal Returns for Portfolios with 2 Holding Days (Sorted by Hidden Order Activities)									
	Three-Factor			Four-Factor			Five-Factor		
	P1	P5	P5-P1	P1	P5	P5-P1	P1	P5	P5-P1
Small	-0.033	0.144	0.177***	-0.035	0.140	0.174***	-0.068	0.110	0.178***
			(3.05)			(3.01)			(2.86)
Medium	-0.037	0.035	0.072	-0.030	0.045	0.074	-0.034	0.041	0.075
			(1.83)			(1.90)			(1.76)
Large	-0.015	0.007	0.021	-0.021	0.005	0.025	-0.036	-0.005	0.029
			(0.41)			(0.48)			(0.53)

Panel B: Abnormal Returns for Portfolios with 2 Holding Days (Sorted by Displayed Order Activities)									
	Three-Factor			Four-Factor			Five-Factor		
	P1	P5	P5-P1	P1	P5	P5-P1	P1	P5	P5-P1
Small	0.005	0.135	0.128	0.009	0.127	0.117	-0.013	0.080	0.092
			(1.79)			(1.68)			(1.23)
Medium	0.003	0.042	0.038	0.013	0.049	0.035	0.016	0.040	0.023
			(0.88)			(0.81)			(0.49)
Large	-0.036	0.026	0.063	-0.036	0.024	0.061	-0.037	0.007	0.044
			(1.32)			(1.27)			(0.86)

Table 7: Portfolio Based on Size and Executed Trade Order Imbalances with Twenty-Day Holding Period. The sample of the stocks in this table consists of all of the common stocks listed on NASDAQ from January 4, 2010 to November 18, 2011, with records in NASDAQ TotalView-ITCH. In Panel A, firms are sorted into quintile based on executed hidden order imbalances during the previous five trading days. In Panel B, firms are sorted into quintile based on executed displayed order imbalances during the previous five trading days. Value-weighted portfolios are held for twenty trading days. This process is repeated each trading day, so that trading day's portfolio return is an average of twenty different portfolios with 1/20 of the portfolio rebalanced each day. Fama and French (1993) three-factor alphas, Carhart (1997) momentum factor alphas, and Pastor and Stamabaugh (2003) liquidity factor alphas multiplied by 250 are reported to reflect an appropriate yearly return . *** indicates significance at the 1% level and t-statistics appear in parentheses.

Panel A: Abnormal Returns for Portfolios with 20 Holding Days (Sorted by Hidden Order Activities)									
	Three-Factor			Four-Factor			Five-Factor		
	P1	P5	P5-P1	P1	P5	P5-P1	P1	P5	P5-P1
Small	0.023	0.036	0.012	0.021	0.034	0.012	-0.011	0.007	0.017
			(0.33)			(-0.49)			(0.45)
Medium	-0.004	-0.014	-0.011	0.004	-0.005	-0.010	0.006	-0.016	-0.023
			(-0.49)			(-0.45)			(-0.92)
Large	0.017	-0.004	-0.014	0.010	-0.006	-0.010	-0.011	-0.016	-0.003
			(-0.53)			(-0.37)			(-0.12)

Panel B:Abnormal Returns for Portfolios with 20 Holding Days (Sorted by Displayed Order Activities)									
	Three-Factor			Four-Factor			Five-Factor		
	P1	P5	P5-P1	P1	P5	P5-P1	P1	P5	P5-P1
Small	0.021	0.047	0.025	0.023	0.045	0.021	-0.015	-0.006	0.009
			(0.61)			(0.52)			(0.2)
Medium	-0.041	0.009	0.049	-0.032	0.019	0.049	-0.030	0.003	0.032
			(1.77)			(1.79)			(1.08)
Large	-0.023	0.032	0.054	-0.025	0.030	0.053	-0.040	0.011	0.051
			(1.85)			(1.82)			(1.63)

Table 8: Cross Sectional Distribution of Hidden Depth. The sample of the stocks in this table consists of all of the common stocks listed on NASDAQ between February 28, 2012 to March 16, 2011, using records in NASDAQ ModelView. There are 2390 stocks in the sample. I computed the time-series means of hidden depth over total depth for each stock. Depth here refers to the aggregated depths at each price level. I then sort the stocks into five market capitalization quintiles, and present the cross-sectional summary statistics for five size quintiles.

Cross-Sectional Distribution of Percentage of Hidden Depth							
Size	Mean	Std. Dev	Min	25%	Median	75%	Max
Q1 (small)	17.50%	15.58%	0.44%	6.37%	13.81%	22.46%	85.65%
Q2	16.49%	14.54%	0.42%	6.35%	12.00%	21.36%	81.96%
Q3	14.64%	11.23%	0.80%	6.73%	11.96%	20.00%	77.66%
Q4	16.88%	10.36%	0.44%	10.09%	15.44%	20.71%	74.99%
Q5 (large)	13.37%	8.05%	1.13%	7.35%	12.17%	17.72%	59.94%
All	15.78%	12.35%	0.42%	7.30%	13.06%	20.29%	85.65%

Table 9: Positions' Hidden Orders Are Placed for Market Size Quintiles. Column (1) calculates the displayed quoted spread, which is the difference between the best bid and ask for displayed orders, and column (2) shows the true quoted spread, which is the difference between the true bid and true ask. Column (3) shows the percentage of time that hidden orders place between the displayed spread; column (4) shows the percentage of time that hidden orders place at the displayed bid for buy orders and the displayed ask for sell orders; column (5) show the percentage of time that hidden orders are placed away from the observable spread.

$$true\ best\ ask = \min(\text{displayed best ask}, \text{hidden best ask})$$

$$true\ best\ bid = \max(\text{displayed best bid}, \text{hidden best bid})$$

$$true\ quoted\ spead = (\text{true best ask} - \text{true best bid})/(\text{true best ask} + \text{true best bid})$$

Size	(1) Observable quoted spread	(2) True quoted spread	(3) Between	(4) At	(5) Away
Q1 (small)	0.0375	0.0274	35.72%	31.13%	33.15%
Q2	0.0144	0.0110	23.78%	40.89%	35.33%
Q3	0.0067	0.0052	20.03%	44.51%	35.46%
Q4	0.0029	0.0023	19.24%	47.11%	33.65%
Q5 (large)	0.0012	0.0009	15.92%	56.86%	27.22%
All	0.0126	0.0094	16.47%	55.47%	28.06%

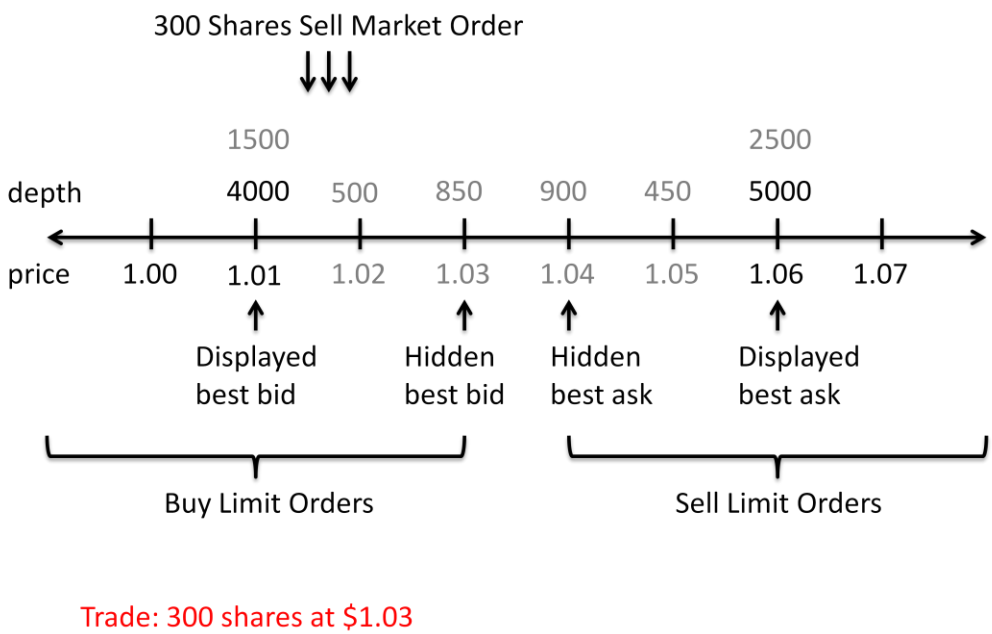
Table 10: Misclassification of Liquidity Deciles and Quintiles Using Displayed Spread. This table documents misclassification errors that arise from sorting stocks into liquidity deciles and quintiles using the displayed, instead of the true spread as a liquidity measure. Stocks are sorted into quintiles and deciles for each day. *Correct* corresponds to the percentage of stocks sorted into their correct deciles or quintiles though the displayed spread is used as a sorting criterion. The entries listed under *Misclassified* stand for the percentages that stocks are sorted into either *n* deciles (quintiles) above or below their correct classifications.

	Deciles	Quintiles
Correct	78.45%	89.87%
Misclassified		
+- 1	20.72%	10.06%
+- 2	0.70%	0.07%
+- 3	0.08%	0.00%
+- 4	0.04%	0.00%
+- 5	0.01%	
+- 6	0.00%	
+- 7	0.00%	
+- 8	0.00%	
+- 9	0.00%	
	100%	100%

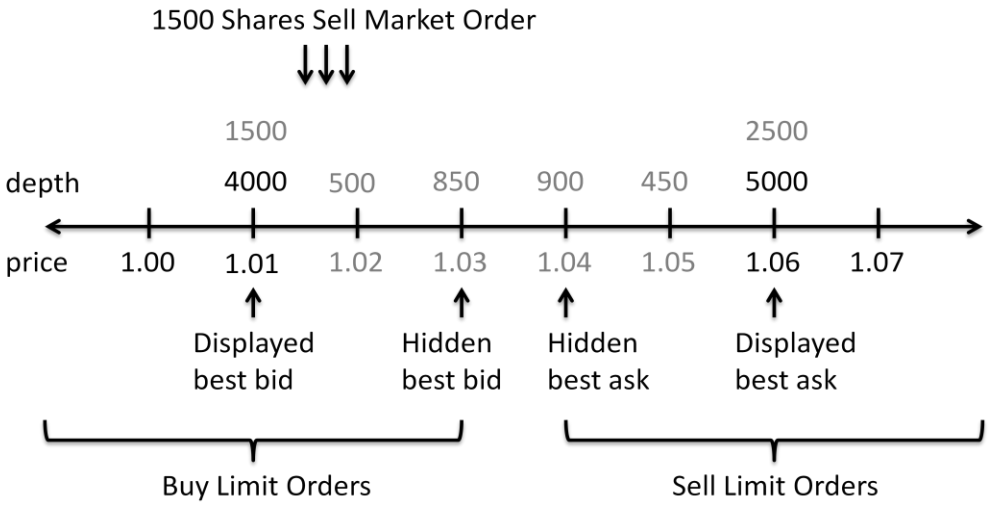
Figure 1: Example of Hidden orders and their executions. This diagram provides an example of hidden orders which are invisible to market participants. Hidden order prices and depths appear in grey and displayed order prices and depths appear in black. Market participants observe that the best bid is $1.01 and the best ask is $1.06. Although the total depths for the best displayed bid are 5500 shares, market participants can only observe the displayed 4000 shares. The same holds for the total depths at the best displayed ask. In this example, the best bid and ask prices are provided by hidden orders. The true best bid is $1.03 for 850 shares, and the true best ask is $1.04 for 900 shares.

Panel A: Diagram of a limit order book

Panel B: A 300-share sell market order comes to the market

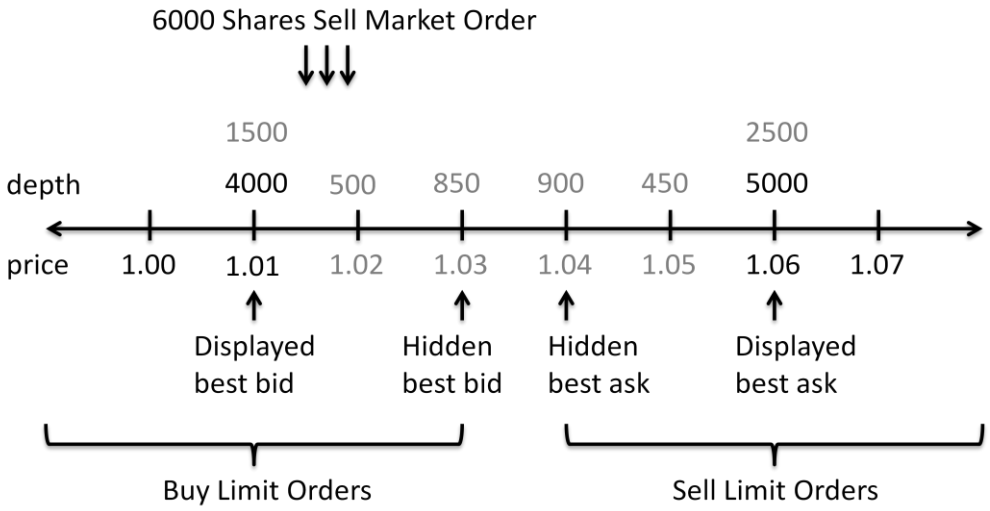


Panel C: A 1500-share sell market order comes to the market



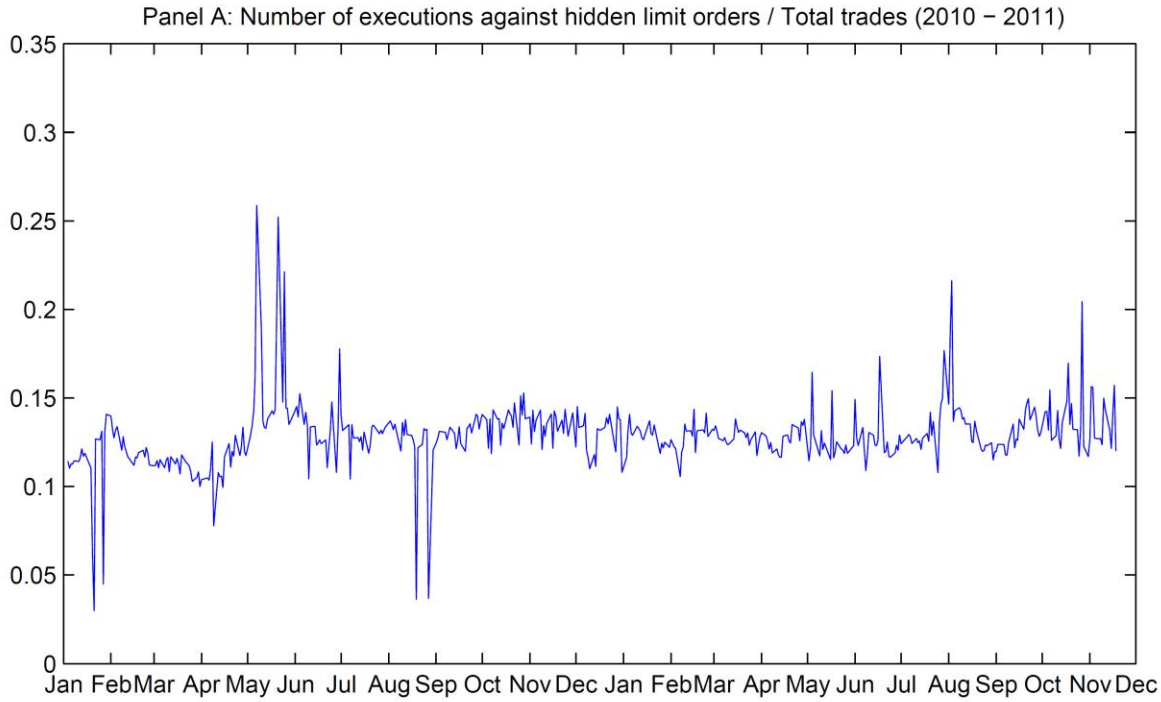
Trade: 850 shares at $1.03
500 shares at $1.02
150 shares at $1.01 (displayed limit orders are executed first)

Panel D: A 6000-share sell market order comes to the market



Trade: 850 shares at $1.03
500 shares at $1.02
4000 shares at $1.01 (displayed limit orders)
650 shares at $1.01 (hidden limit orders)

Figure 2: Time Series Variation of Hidden Trades. This figure illustrates the total level of hidden trades and volume from 2010 to 2011. Panel A shows the number of executions against hidden orders over total trades. Panel B shows the shares executed against hidden orders over total trading volume.



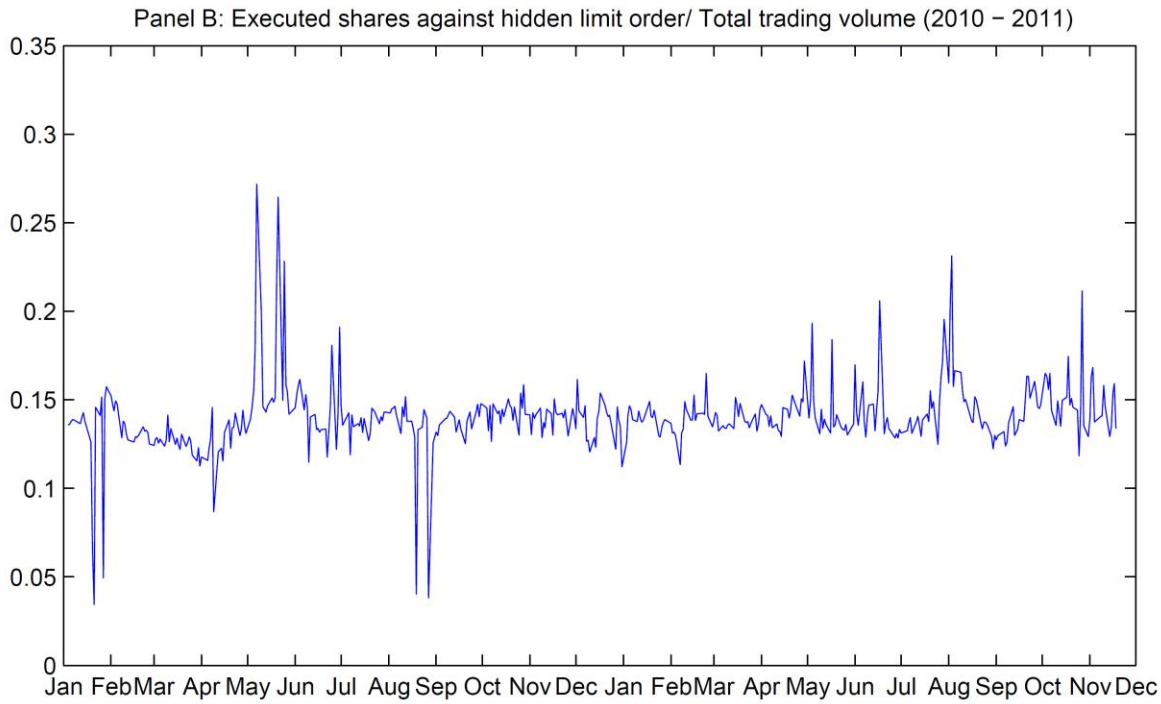


Figure 3: Intraday Spread in Percentage. The solid line displays the intraday spread for hidden orders, the dashed line shows the intraday spread for displayed orders, and the dotted lines exhibit the true spread, for which the true ask is the minimum of all of the hidden and displayed sell order prices, and the true bid is the maximum of all of the hidden and displayed buy order prices.