Unrecognized Odd Lot Liquidity Supply: A Hidden Trading Cost for High Priced Stocks

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Abstract: Current National Market System rules do not recognize odd lots in the protected intermarket quote. Thus, liquidity demanders can receive worse prices than they would receive if odd lots were protected. The effect of ignoring odd lots is magnified because off-exchange trades (over one-third of total volume) benchmark executions against the protected quote. We identify time intervals with an unprotected odd lot limit order at a price better than the protected quote and examine trades during those intervals for ten high-priced stocks during one week in 2015. We find over 406,000 intervals representing 37% of sample stock trading time where an odd lot order betters the protected quote. Examining trades within these intervals, we find nearly 55,000 cases in which the trade price is worse than the odd lot price. In total, the price disimprovement in our ten stocks is $554,675 for the week examined. This is a previously undocumented trading cost associated with the corporate decision to not split a stock's price in a market in which odd lot orders are excluded from the protected quote.

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One corporate action notably missing during the rise in equity prices since the financial crisis is the stock split. For the six years ending December 31, 2014, there were 50 stock splits among S&P500 firms. This represents 1.7% of the 500 stocks per year. From 1996 to 1999, when the index experienced a similar aggregate return, there were 412 S&P500 firm stock splits, representing 20.6% of the index stocks per year. As a result, the average price of an S&P 500 stock stood at about $85 per share at the end of 2014 compared to $45 at the end of 1999 and $55 at the 2007 market peak.[1]

Academic studies of stock splits address costs and benefits associated with signaling, liquidity, and/or share ownership. Copeland [1979] argues that a lower stock price increases the base of traders and increases the volume of trade. Brennan and Copeland [1988] posit that managers convey positive private information about firm prospects by splitting the stock price and temporarily increasing the percentage bid-ask spread. Angel [1997] hypothesizes that the wider percentage spread after a split induces traders to use more limit orders thereby increasing liquidity. Grinblatt, Masulis and Titman [1984] document positive abnormal returns around split announcement dates, consistent with a signaling story, and around the split's effective data, which might be consistent with liquidity effects. Easley, O'Hara and Saar [2001] find that splits are associated with more executed limit orders, increases in both informed and uninformed trading volume, and larger trading costs. Muscarella and Vetsuypens [1996] find increases in liquidity around splits in ADR prices. We examine a trading cost not studied in the extant work – a cost exacerbated by management's decision to not split the firm's stock and the Securities

[1] See the Credit Suisse Market Structure report "Is the Price Right? Implications of Rising Stock Prices," 15 April 2015. The Bloomberg News story "Since Nobody Else Wants to Split Their Shares, An Exchange Will" notes that this trend has continued – only 11 S&P500 companies split their shares in 2015 and five in the first seven months of 2016.

and Exchange Commission's decision to not include odd lot limit orders in the protected intermarket stock price quotes.

As stock prices rise in the absence of stock splits, traders more frequently use odd lots (orders for fewer than 100 shares) to represent their trading interests. To date, academic research on odd lots investigates instances where matching liquidity suppliers and liquidity demanders produces odd lot *trades*. O'Hara, Yao, and Ye [2014] document that odd lot trades represent nearly 25% of all trades in their sample stocks and that the proportion of odd lot trades is greater for high-priced stocks. Johnson, Van Ness, and Van Ness [2015] distinguish between odd lot trades resulting from odd lot liquidity demanding orders and odd lot trades resulting from larger liquidity demanding orders interacting with odd lot liquidity supply orders. Their focus, however, continues to be on trades of less than a round lot.

Virtually nothing is known about *potential* liquidity supply from odd lot limit orders. This is at least partly because current equity market structure excludes odd lot orders from the displayed National Best Bid and Offer (NBBO) quotation. As a result, odd lot liquidity supplying orders are not visible to traders without access to trading venues' direct feeds.[2] Even for traders with access to data feeds that include odd lot limit orders, rules do not require market makers interacting with a liquidity demanding order to honor odd lot limit order prices resting on a competing limit order book. Furthermore, orders not executed on formal exchanges (via either lit or dark Alternative Trading Systems and reported via venues such as the FINRA's Trade Reporting Facility) typically benchmark the official NBBO to determine the price at which to fill orders. This shortcoming in the National Market System structure means that some liquidity

[2] On some exchanges, multiple odd lot orders summing to at least 100 shares are displayed. Brokers with direct feeds know of the existence of better priced odd lots and might honor them even when not required to do so.

demanding orders fill at worse prices than are actually available. In this paper, we examine the extent and magnitude of this problem for a small sample of actively traded high-priced stocks.

To address these issues, we obtain exchange feed quote, order and trade data from a quantitative trading firm with access to exchange direct data lines. This allows us to identify time periods when an odd lot limit order exists at a better price than the official NBBO. We detail how common such occurrences are and the magnitude of the price improvement that might be available if the odd lot order was protected. Using trade data, we isolate order executions occurring when the odd lot bid price is higher (offer price is lower) than the protected quote. Although not all trades are disadvantaged, we document instances where trades occur at prices worse than the best available odd lot price. We then estimate the amount of price improvement these trades would receive if market makers were required to benchmark to an NBBO that includes odd lot orders.

We begin by choosing ten high-priced stocks with greater than average daily trading volume during May 2014. Exhibit 1 lists the stocks and their mean closing prices and daily trading volumes during May 2014. To be clear, this sample is purposely not random. The high stock price increases the chances of traders using odd lot orders and the high trading volume increases the likelihood that trades occur when a better priced odd lot limit order exists.

[Insert Exhibit 1 about here.]

Our analysis employs orders and trades in the ten sample stocks from the week of April 20-24, 2015. Using exchange feed order data, we identify instances when an odd lot limit order becomes “top of book” (highest bid price or lowest ask price) at an exchange with a limit price that betters the extant official NBBO (hereafter, the protected quote). We refer to these occasions as sample events. For each sample event, we obtain the date and time (to the

microsecond - μs) that the odd lot limit order becomes the best quote, how long that particular odd lot order remains the best quote, the exchange to which the odd lot order is sent, the stock trading symbol, the order's side (buy or sell), the limit price, the order's size, the contemporary protected quote, and the actual event-time NBBO incorporating the odd lot limit order. The data also provide how each event begins and ends. An event can begin because of the arrival of a new odd lot order, because an existing odd lot order is exposed when a better priced order is cancelled or executed, or because a round lot order is partially filled or partially cancelled. An event can end because the odd lot order fills or cancels, or because the best-priced order ceases to be an odd lot when other orders join at the same price or a new round lot order arrives at a better price. Together, these data allow us to document the frequency with which protected quotes are incomplete and the magnitude of the apparent costs imposed on liquidity demanders whose orders execute at the protected quote.

For the ten sample stocks, there are 406,438 instances during the sample week in which an odd lot limit order represents a better price than the protected quote. That is an event every 2.88 stock-seconds during our sample week. The most common way odd lots become the best quote is that another order executes or cancels, leaving the odd lot as the top of book. These events represent approximately half of the sample. The second most common way is the submission of a new odd lot order, which occurs in 35.8% of the sample events. The remaining sample events occur when an order for 100 shares or more partially executes (9.3% of our sample) or partially cancels (3.3%). About 37% of the events end when the odd lot order is cancelled and another 20.6% end with the odd lot order filling. The remaining events end with the odd lot order getting joined to form a round lot or being eclipsed by a better priced order for at least 100 shares. The sample events are almost evenly split between bids and offers. The

average odd lot order in the sample events has about 33 shares and improves the protected quote by 6.2 cents. Exhibit 2 summarizes our sample events

[Insert Exhibit 2 about here.]

Across the sample events, the odd lot order is better than the protected quote for an average of 1.6367 seconds. However, this overall average is misleading because many of the sample events overlap. For example, consider two new orders for AAPL on April 24. Order 1 is an order to buy 25 shares at $125.75 arriving at 9:34:02.07717 on Nasdaq. Order 2 is an order to buy 95 shares at $125.75 getting to ARCA at 9:34:02.079498. Order 1 fills at 9:34:02.085063 and Order 2 cancels at 9:34:02.086101. Thus, even though Order 2 has a duration of 0.006603 seconds (9:34:02.086101 minus 9:34:02.079498), it is alone at the best bid only from the time Order 1 fills (9:34:02.085063) until it cancels (9:34:02.086101) – for 0.001038 seconds. When computing the amount of time in a day that an odd lot betters the protected quote, we use the 0.001038 seconds, not the 0.006603 seconds. The non-overlapping average duration of a sample event is 1.0663 seconds. The total time an odd lot limit order betters the protected quote (average duration of 1.0663 seconds times 406,438 events) represents 37% of trading time for the sample stocks during the sample week.

As one might expect, the potential for trader harm is not equal across the sample stocks. Some sample stocks (e.g., AAPL) are much more liquid and lower priced than others (e.g. PCLN). The number of instances where an odd lot potentially would produce a better NBBO range from 11,824 for ICE to 71,433 in GOOG. Although there is some variation in average event initiation time, it is generally centered on mid-day (AAPL events seem to occur earlier in the trading day and ICE events a bit later). As one might expect, AAPL events are fleeting. The longest duration events are in ICE and WYNN, both of which average over two seconds. PCLN

events produce the largest dollar advantage over the protected quote, reflecting the fact that PCLN is the highest priced sample stock with the widest bid-ask spread. Total Time an odd lot improves the protected quote is the product of the average non-overlapping duration and the number of sample events.[3] With the exception of AAPL there is an odd lot order with a better price than the protected quote a substantial portion of the trading time during the sample week. For example, the 398.8 minutes for PXD represents 20% of the 1950-minute (390 trading minutes per day*5 days) trading week, while PCN has a better priced odd lot order during roughly 84% of the trading week. Although only two percent of the average trading time in AAPL has a better priced odd lot limit order available, the very high trading volume of AAPL suggests that the failure to benchmark execution to the best available quote can still impose significant costs on liquidity demanders.

We also obtain trade data from the exchange data feeds. The detail includes trade date and time (in μs), the stock symbol, the venue on which the trade occurs, the price and size of the trade, the side of the trade (when available) and, if applicable, the trade's condition code. In cases where the trade side is unspecified, we use the Lee and Ready [1991] approach to type the trade. Exhibit 3 provides some descriptive statistics regarding the trading intensity during our sample week for the sample stocks.

[Insert Exhibit 3 about here.]

Clearly, AAPL dominates the sample in terms of trades and shares traded. On average, 32.5% of trades are odd lots, but there is significant variation across stocks. The fraction of trades that are

[3] The statistic given in the Exhibit counts instances where both the bid and ask prices of a non-protected odd lot limit order betters the protected quote as two instances and includes the duration of both sides in the total time. Noting the times that both sides of the market have a better odd lot price than the protected quote and eliminating the joint time from the total time statistic matters little. The total time calculated by eliminating the period where both bid and ask prices betters the protected quotes ranges from 95% of the total time given in the Exhibit (WYNN) to 99% (AAPL). We believe that instances where odd lot orders offer better prices on both the bid and ask side of the market simultaneously are more accurately thought of as two sample events as these cases affect both buy and sell orders.

odd lots ranges from 16% to 69% across the sample stocks and is highly correlated with average share price ($\rho = 0.72$).

We are particularly interested in trades that occur when an unprotected odd lot order exists at a price better than the protected quote. We therefore identify all trades that occur during these intervals on the same side of the market as the odd lot limit order bettering the NBBO (i.e., if the better priced odd lot order is a sell [buy] order, the liquidity demanding order must be a buy [sell]). We then categorize trade prices relative to both the protected quote price and the odd lot price. We ignore trades occurring on the same exchange where the better priced odd lot order exists as, by rule, that price cannot be ignored. This eliminates about 28% of the sample trades. Results are provided in Exhibit 4. We display five categories: worse than the protected quote, equal to the protected quote, better than the protected quote but worse that the national best quote including the odd lot order, equal to the national best price, and better than the national best price.

[Insert Exhibit 4 about here.]

The last column of Exhibit 4 provides the frequency of true price improvement relative to the national best quote that includes the odd lot limit order. Traders frequently trade at the national best quote despite the fact that the odd lot price is not protected – over half the trades match or better the odd lot's limit price. Trading through the odd lot price (trading at prices worse than the available odd lot price), however, is quite common. Except for PXD, the frequency of price disimprovement ranges from 27% to 43%. Even AAPL trades occurring when there is a better priced odd lot order trade through that price 27% of the time (19 + 701 + 6 trades of 2,668 total trades). For AMZN and NFLX, the fraction of such trades is over 40%.[4]

[4] Our data indicate when a trade price results from a liquidity demanding order finding a hidden liquidity supplying order. Such trades represent about 10% (AAPL, ICE and PXD) to 28% (GOOG and PCLN) of the trades in Exhibit 4. Without these trades,

We classify the trades at prices worse than the odd lot limit price as trade-throughs.

Exhibit 4 suggests that trade-throughs of non-protected odd lot orders are frequent, but how much do they cost liquidity demanders? In Exhibit 5, we focus on the subset of trades that occur during a sample event at a price worse than the price of the non-protected limit order (i.e., a liquidity demanding order to sell [buy] trades a price less [higher] than the odd lot limit order is willing to buy [sell]). We present the total number and dollar amount of trade-throughs, where the dollar amount is the number of shares multiplied by the difference between the trade price and the odd lot's limit price.

For our ten stocks during our sample week, we find 54,959 instances where a trade price is worse than the non-protected odd lot limit order that sets the national best quote. Comparing the number of trade-throughs to the number of trades in Exhibit 3 produces an overall trade-weighted (stock-weighted) trade-through rate associated with unprotected odd lot limit orders of 2.52% (4.06%).[5] This rate ranges from only 0.07% for AAPL to nearly 7% for PCLN. The total value of these trade-throughs for the week is $554,676. Assuming that there is nothing special about the sample week, we extrapolate this trade- through amount to $28.8 million per year for nearly 3 million trade-throughs in the ten sample stocks.

We separately analyze trade-throughs that occur on off-exchange venues. These trades are likely from market makers such as Citadel, Credit Suisse, G1 Execution Services, Knight Capital Group, and Two Sigma Securities, who act as consolidators of order flow. These consolidators typically match the protected NBBO. Exhibit 5 shows that trade-throughs occur disproportionately on the off-exchange venues; these sites represent about 24% of the trades, but

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it becomes more common for trades to occur at the protected quote and at the national best quote and less common for trades to occur at prices better than the quoted prices.

[5] Note that this trade through rate is computed from the subset of trades occurring when the NBBO is narrower than the protected quote.

nearly 48% of the trade-throughs. Extrapolating these off-exchange trade-throughs suggests an annual cost of $22.8 million for our ten stocks.

There are a few very large trades in our sample. Some of these very large trades occur at prices well outside the protected quotes. To address this issue, we sort trades by size and eliminate the largest one percent of each stock's trades. This has a disproportionate effect on our calculated price disimprovement. Using the remaining 55,400 disadvantaged trades, the dollar amount of disimprovement for our ten sample stocks is $273,913 for the week or $14.2 million per year if extrapolated. Interestingly, if measured relative to the protected quote, the pricing of these trades would suggest $102,186 in weekly price *improvement*. So, these trades allow those venues filling the orders to claim high execution quality when, if odd lots were included in the quotes, execution quality would not be as impressive.

In this paper, we analyze a small sample of high-priced stocks during a single week of trading to draw attention to a limitation in the National Market System structure that results in a hidden cost to equity traders. Specifically, we show that the exclusion of odd lot orders from the protected NBBO quote produces cases where trades fill at prices worse than available opposite-side trading interests. This problem is exacerbated by the rise in stock prices caused by the post-crisis reluctance of firms to use stock splits. Importantly, the exclusion of odd lots from the protected quote may have important effects beyond those to the limit order itself, as order consolidators/wholesalers benchmark the protected quote when making markets. If consolidators were required to benchmark to an NBBO that included odd lot orders, trades for over one-third of the consolidated volume are potentially affected.

Clearly, we must be careful extrapolating the dollar disimprovement figures in our paper to the total stock market. Firstly, the sample selection is deliberately non-random. We selected

stocks for which the use of odd lot orders is likely to be significantly more important than the typical stock. There are, however, reasons to suspect that widely traded non-sample stocks have significant trade-throughs of better priced limit orders; the average price of the stocks in the SP500 currently exceeds $88 and almost one-quarter of the index stocks have share prices above $100. Thus, many actively traded stocks are likely to have substantial use of odd lot orders. Secondly, our analysis is a static analysis that assumes that none of the market participants would change their behavior should odd lots be protected. For example, wholesalers/consolidators might not be willing to purchase and execute marketable orders in high-prices stocks if odd lots become part of the protected quotes. Alternatively, should odd lots be protected wholesalers/consolidators might choose to eliminate them before trading with customer orders.

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Exhibit 1 – Sample Stocks

Stock	Mean Daily Closing Price	Mean Daily Share Volume
PCLN	$1,180	880,818
AAPL	$603	9,769,899
GOOG	$543	1,975,325
NFLX	$362	3,577,001
BIIB	$295	1,201,516
AMZN	$303	3,753,872
WYNN	$208	2,397,580
TSLA	$200	6,443,944
PXD	$203	1,189,835
ICE	$195	973,113

Notes: To select sample stocks, we sorted by share price, required a round lot be defined as 100 shares, and imposed an arbitrary trading activity level. AAPL split its stock price between May 2014 and our sample period of April 2015.

Exhibit 2 – Sample Events by Stock

Stock	Events	Mean Begin Time	Mean Duration (seconds)	Mean Non-overlapping Duration (seconds)	Total Time Odd Lot Improves Price (minutes)	Mean Amount Odd Lot Improves Price ($)	Mean Quoted Spread ($)
AAPL	32,405	11:48	0.0757	0.0678	36.6	0.0102	0.0225
AMZN	62,379	12:29	0.7974	0.6087	632.9	0.0430	0.1915
BIIB	31,658	12:09	1.8573	1.2755	673.0	0.0761	0.3792
GOOG	71,433	12:05	1.1140	0.5725	681.6	0.0652	0.3033
ICE	11,824	12:37	3.6570	2.8609	563.8	0.0376	0.1549
NFLX	38,279	12:14	1.7367	1.2195	778.0	0.0696	0.3323
PCLN	52,957	12:09	3.5645	1.8495	1,632.5	0.1611	1.3172
PXD	15,570	12:26	1.8633	1.5367	398.8	0.0361	0.1276
TSLA	68,763	12:04	1.2366	0.8572	982.4	0.0355	0.1429
WYNN	21,170	12:00	2.9345	2.3917	843.9	0.0233	0.0978
All Stocks	406,438	12:10	1.6367	1.0663	800.1	0.0620	0.3556

Notes: A sample event is defined as a period of time where a posted odd lot limit order has a better price than the concurrent NBBO. Mean Begin Time is the simple average of the sample odd lot limit orders' arrival time. Mean Duration is the simple average of the time the sample odd lot limit order bettered the NBBO. We eliminate time in which odd lot orders with the same NBBO-bettering limit price existed simultaneously to compute the Non-Overlapping Duration. Total Time is the number of events for a given sample stocks times the average non-overlapping duration. Average spread and average dollar quote improvement are simple averages of the NBBO spread at the time of a sample event and the amount that the sample odd lot order's price betters the relevant side of the NBBO. The first entry in the final row of the table is the total number of events and the other entries are event-weighted means.

Exhibit 3 – Trading Activity by Stock

Stock	Trades	% Odd Lot Trades	Share Volume (millions)	Dollar Volume ($ millions)
AAPL	1,012,566	22.9%	187.5	$24,067.6
AMZN	284,247	35.8	32.0	13,318.5
BIIB	118,634	45.0	10.9	5,339.9
GOOG	148,739	57.9	12.5	6,843.9
ICE	41,018	48.6	3.2	724.5
NFLX	112,052	47.7	11.0	6,182.8
PCLN	38,545	69.1	2.1	2,535.6
PXD	84,912	45.6	7.1	1,242.4
TSLA	159,675	40.6	19.9	4,301.7
WYNN	166,087	16.0	6.5	840.9
All Stocks	2,166,475	21.9	292.7	65,397.8

Notes: Trades represents the total number of trades occurring in the sample stock during the sample week. The odd lot percentage is the number of trades for fewer than 100 shares divided by the total number of trades (in percent). Share (dollar) volume is the total number of shares traded (share traded times trade price) for the sample stock during the sample week. All figures in the final row are totals except the % Odd Lot Trades figure which is the trade-weighted mean.

Exhibit 4 – Trades Prices for Trades Occurring When a Better Priced Odd Lot Order Exists on the Same Side of the Market

Stock	Total Trades	Relative Trade Price				
		Worse than PQ	Equal to PQ	Worse than NB better than PQ	Equal to NB	Better than NB
AAPL	2,668	19	701	6	1,929	13
AMZN	36,672	1,613	6,635	6,662	9,409	12,353
BIIB	17,810	841	2,532	3,294	4,412	6,731
GOOG	25,573	1,067	3,484	4,817	6,798	9,407
ICE	1,147	35	257	118	399	338
NFLX	16,562	908	2,739	3,407	4,402	5,106
PCLN	6,974	512	1,000	1,172	1,533	2,757
PXD	12,134	276	827	555	5,340	5,136
TSLA	26,259	1,285	3,919	4,107	5,526	11,422
WYNN	7,419	271	1,171	729	2,955	2,293
Total	153,218	6,827	23,265	24,867	42,703	55,556

Notes: PQ represents the relevant protected quote, ignoring the odd lot order (or the official NBB or NBO). NB represents the national best quote, including the odd lot order. Total trades is the number of trades occurring during the sample time intervals when an odd lot limit order with a better price than the official NBB/O exists. These trade prices are categorized as: worse than the protected quote, equal to the protected quote, better than the protected quote but worse than the national best quote including the odd lot order, equal to the national best quote including the odd lot order, or better than the national best quote including the odd lot order.

Exhibit 5 – Trade-Throughs of Odd Lot Limit Order Price

Stock	All Venues		Off-Exchange Venues	
	Number of Trade-Throughs	Dollar Amount of Trade-Throughs	Number of Trade-Throughs	Dollar Amount of Trade-Throughs
AAPL	726	$ 2,005.94	316	$ 1,439.95
AMZN	14,910	140,644.62	6,746	110,367.59
BIIB	6,667	63,664.23	3,155	41,816.42
GOOG	9,368	196,933.19	3,974	178,841.56
ICE	410	896.49	232	670.13
NFLX	7,054	49,595.95	3,650	33,735.21
PCLN	2,684	24,803.27	1,197	13,875.50
PXD	1,658	5,266.22	680	1,886.91
TSLA	9,311	64,585.60	5,489	52,072.94
WYNN	2,171	6,280.03	893	4,251.04
Total	54,959	554,675.54	26,332	438,957.25

Notes: Number of Trade-Throughs is the total number of trades occurring at prices worse than the national best price including the odd lot order. (That is the sum of the trades in Exhibit 4's columns 3, 4, and 5.) Dollar Amount of Trade-Throughs is the sum of trade size times the amount the trade price is worse than the sample odd lot order's price, calculated across all trade-throughs. The final two columns include only off-exchange trade-throughs.