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Inferring Trade Direction from Intraday Data

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ABSTRACT

This paper evaluates alternative methods for classifying individual trades as market buy or market sell orders using intraday trade and quote data. We document two potential problems with quote-based methods of trade classification: quotes may be recorded ahead of trades that triggered them, and trades inside the spread are not readily classifiable. These problems are analyzed in the context of the interaction between exchange floor agents. We then propose and test relatively simple procedures for improving trade classifications.

THE INCREASING AVAILABILITY OF intraday trade and quote data is opening new frontiers for financial market research. The improved ability to discern whether a trade was a buy order or a sell order is of particular importance. In Hasbrouck (1988), the classification of trades as buys or sells is used to test asymmetric-information and inventory-control theories of specialist behavior. In Blume, MacKinlay, and Terker (1989), a buy-sell classification is used to measure order imbalance in tests of breakdowns in the linkage between S&P stocks and non-S&P stocks during the crash of October, 1987. In Harris (1989), an increase in the ratio of buys to sells is used to explain the anomalous behavior of closing prices. In Lee (1990), the imbalance in buy-sell orders is used to measure the market response to an information event. In Holthausen, Leftwich, and Mayers (1987), a buy-sell classification is used to examine the differential effect of buyer-initiated and seller-initiated block trades.

Most past studies have classified trades as buys or sells by comparing the trade price to the quote prices in effect at the time of the trade. In this paper, we identify two serious potential problems with this method, namely, that quotes are often recorded ahead of the trade that triggered them, and that

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trades are often (30% of the time) inside the spread. The problem of quotes recorded ahead of trades has always existed, but has increased substantially with the widespread use of "electronic books" by specialists. We show that misclassifications can be greatly reduced by comparing the trade to the quote in effect 5 seconds earlier. For trades inside of the spread, we provide evidence that the effective spread is often on one side of the quoted spread due to standing orders held by floor brokers. In these cases, we suggest that the "tick test" provides the best way to classify the trades as buys or sells. When only price data is available, we show that the "tick test" also performs remarkably well.

The paper is organized as follows: Section I reviews alternative methods for inferring trade direction when only price data is available; Section II examines the problem of quote identification; Section III deals with trades inside the spread; and Section IV concludes.

I. Comparing the Trade Price to Adjacent Trades: The "Tick Tests"

Trading in equity securities on the New York Stock Exchange (NYSE) and American Stock Exchange (AMEX) is generally a continuous two-sided auction presided over by a market maker or specialist. The specialist performs the dual role of auctioneer and dealer. As an auctioneer, he matches market orders with limit or standing orders.[1] As a dealer, he stands ready to buy or sell on his own account.[2] In this setting, trading generally takes place only when a market buy or sell order arrives.[3] The intraday trade and quote data do not identify whether a trade was triggered by a market buy or sell order, so this information must be inferred from the data. Two general approaches

[1]A market order is to be executed immediately at the best available price, whereas a limit order is an order to buy or sell at a specified price. The specialist maintains a list of limit orders at various prices on each side of the current quote. These orders are executed as prices move to the level specified in the order. When an order is large, it is sometimes more advantageous to fill it by a "standing" order. A standing order is an order to buy or sell a certain number of shares at the best available price over a certain time period. The order is given to a floor broker who is able to exercise discretion over the exact timing of the trades needed to fill the order by waiting in the "crowd" at the specialist's post and responding to incoming market orders by bettering the current quote. In terms of immediacy of execution, the market order is executed immediately, the standing order is like a limit order with priority execution, and the limit order is only exercised when price conditions dictate. See Smidt (1985) and Stoll (1985) for more detailed discussions of trading regulations and the specialist system.

[2]Specialists on both the NYSE and the AMEX are also required to provide continuous quotes. A complete quote consists of a bid and an ask price (representing the best price available to incoming market sell and buy orders, respectively) and the number of shares available at each (the "depth"). The specialist sets bid and ask prices and depths based on the limit orders (the "book") and his willingness to buy or sell on his own account.

[3]The exceptions are the opening and closing trades of each day, which may be single call auctions, and certain block trades, which are prearranged away from the exchange floor. In our analysis, opening trades not preceded by a quote are excluded. Also, it is possible for off-setting market orders to arrive simultaneously and be recorded as a single trade. However, in our experience this is an extremely rare occurrence. (Hasbrouck (1988) came to the same conclusion.)

have been used to infer the direction of a trade: 1) compare the trade price to adjacent trades (techniques commonly known as "tick tests") or 2) compare the trade price to the bid/ask prices of the prevailing quote. In this section, we discuss the first method.

The tick test is a technique which infers the direction of a trade by comparing its price to the price of the *preceding* trade(s). The test classifies each trade into four categories: an uptick, a downtick, a zero-uptick, and a zero-downtick. A trade is an uptick (downtick) if the price is higher (lower) than the price of the previous trade. When the price is the same as the previous trade (a zero tick), if the last price change was an uptick, then the trade is a zero-uptick. Similarly, if the last price change was a downtick, then the trade is a zero-downtick. A trade is classified as a buy if it occurs on an uptick or a zero-uptick; otherwise it is classified as a sell.

The tick test has been used by researchers when quote data are not available (for example, Holthausen, Leftwich, and Mayers (1987)) and by market regulators and practitioners. The Securities and Exchange Commission does not permit short selling on a down or zero-downtick. In addition, the NYSE uses the tick test to compute a monthly "stabilization ratio" for floor traders and specialists.[4] The tick test also forms the basis of certain statistics used in the investment community. For instance, *Barron's* carries two types of tick test statistics (the ratio of buys to sells for large block trades and for the last trades of each day). Each is described as an indicator of changes in the overall market direction.

In theory, all trades can be classified as either a buy or a sell order by using a tick test.[5] In practice, certain trades are not classifiable because they are either reported out of sequence or are sold with special conditions attached.[6] The primary limitation of the tick test is its relative imprecision when compared to a quote-based approach, particularly if the prevailing quote has changed or it has been a long time since the last trade.

A possible alternative to the tick test is the "reverse tick test," which classifies trades by comparing the trade price to prices of trades immediately

[4]If a floor trader or specialist sells on a uptick or buys on an downtick, this would be deemed a stabilizing trade. The "stabilization ratio" is simply the ratio of stabilizing trades to total trades. The NYSE Constitution and Rules prohibit floor traders from having a monthly "stabilization ratio" lower than 75%. A monthly "stabilization ratio" is also computed for each specialist and constitutes one statistic used to gauge his performance.

[5]By convention, the first trade of a new issue is deemed an uptick, perhaps because there is usually a ceremonial buy transaction by the president of the company.

[6]Trades are usually transacted with the understanding that settlement takes place in 5 business days. Occasionally these conditions are changed at the request of the seller or buyer. Trading premiums or discounts may be applicable in such instances, rendering the trade price unreliable relative to adjacent trades. Trades transacted under unusual settlement conditions or reported out of sequence are identified with special condition codes. Such trades have traditionally been a small proportion of the total trading volume, although the recent advent of computer generated trading strategies, such as dividend capture transactions, have increased their frequency. In this paper, these trades were excluded in computing the tick test.

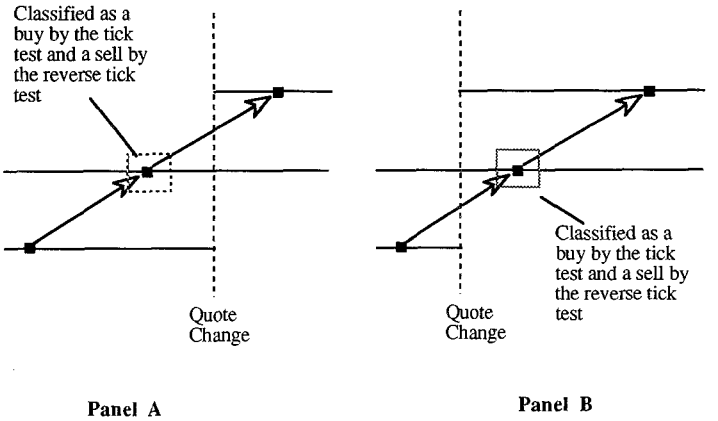

Figure 1. Classifying trades bracketed by price continuations. The tick test and the reverse tick test yield opposite results when a trade is bracketed by a price continuation, that is, when the price changes before and after a trade are in the same direction. The question of which method is likely to perform better hinges on the relationship between order imbalance and quote changes. If quotes are changed in the direction of the order imbalance, then the tick test would perform better than the reverse tick test. In Panel A, the quote change is in the direction of the preceding trade, so the middle trade is correctly classified as a buy by the tick test and incorrectly classified as a sell by the reverse tick test. In Panel B, the quote change is in the opposite direction to the preceding trade, so the middle trade is incorrectly classified as a sell by the tick test and correctly classified as a buy by the reverse tick test. The superior overall performance of the tick test suggests Panel A is the more likely scenario.

after the current trade. If the current trade is followed by a trade with a higher (lower) price, the reverse tick test classifies the current trade as a sell (buy). This method was used by Hasbrouck (1988) to classify trades at the midpoint of the bid-ask spread.

The tick test and the reverse tick test yield the same classification when the current trade is bracketed by a price reversal (i.e., when the price change before the trade is the opposite of the price change after the trade). However, the methods conflict when a trade is bracketed by a price continuation. Since the two tests differ only during periods of consecutive price movements in the same direction, their relative performance provides interesting insights into the relationship between quote changes and the direction of price movements. As shown in Panel A of Figure 1, if a quote increase follows a trade at the ask, the tick test yields the correct inference. In Panel B, a quote increase follows a trade at the bid, so the reverse tick test is correct. If quote revisions are unrelated to the direction of the prior trade, both senarios are equally likely. On the other hand, if quote revisions tend to be in the direction of the order imbalance (as in Panel A) we would expect the tick test to outperform the reverse tick test.

To evaluate the performance of the two tick tests, we selected a sample of 150 NYSE firms and examined all nonopening trades during 1988 where the

current quote had not changed in the last 5 seconds.[7,8] Table I shows that for trades at the ask, 92.1 percent are classified as buys using the tick test, whereas 90.2 percent of trades at the bid are classified as sells. Thus, there is a high degree of agreement between the tick test and quote-based classifications when the identity of the prevailing quote is unambiguous.

Table I also shows that the tick test outperforms the reverse tick test. This suggests that quote revisions tend to be in the direction of the order imbalance. Blume, MacKinlay, and Terker (1989) found a strong contemporaneous relationship between order imbalance and price changes during the 2 days October 19 and 20, 1987. Our findings show that prices tend to respond to order imbalance even in periods of normal trading.

II. Identifying the Prevailing Quote

Although some quote revisions are caused by the arrival or cancellation of limit orders, many are triggered by trades. When the specialist calls out the details of a trade and the new quotes, the quote changes are typically entered into the electronic workstation by the specialist's clerk, while the trade is typically recorded by an employee of the exchange on a mark-sense card and fed it into an optical reader. If the specialist's clerk is faster, the new quote can be entered before the trade, so using the sequence of trades and quotes

Table I

A Comparison of the Tick Test and the Reverse Tick Test When Identification of the Prevailing Quote is Unambiguous

For a sample of 150 NYSE firms during 1988, this table reports the percentage of trades classified as buys and sells by the tick test and the reverse tick test when the identity of the prevailing quote is unambiguous. A trade is classified as a buy (sell) by the tick test if the *prior* price change is positive (negative). A trade is classified as a buy by the reverse tick test if the *next* price change is negative (positive). A prevailing quote is considered unambiguously identified if the most recent quote revision occurred more than 5 seconds before the trade. This situation applied to 90.9 percent of the classified (nonopening) trades in the sample.

Classification Based on the Prevailing Quote	Tick Test Classification	Reverse Tick Test Classification
Buy—Above Ask	98.8% buy	91.3% buy
Buy—At Ask	92.1% buy	80.0% buy
Inside the Spread	52.4% sell	52.0% buy
Sell—At Bid	90.2% sell	79.4% sell
Sell—Below Bid	98.7% sell	94.5% sell

[7]Using this criterion, we examined 90.9 percent of all trades for firms in our sample. The problem of quote identification and the rationale for the 5-second delay are discussed in the next section.

[8]The intraday data for this study were obtained from the Institute for the Study of Security Markets (ISSM) based at Memphis State University.

on the tape to identify the prevailing quote can lead to an incorrect classification.[9]

We examined the frequency of quote revisions around a given trade to investigate this possibility. To avoid the confounding effects of closely-clustered trades we chose the first trade after 11 a.m. for each trading day during 1988, provided there were no other trades within a 2-minute window centered on that trade. If the first qualified trade occurred after 2:30 p.m., or if no trades qualified for a given day, that day is excluded from the sample. We examined the distribution of quote revisions in the 10 seconds before and after the qualified trades.

Panel A of Figure 2 illustrates the frequency of quote revisions around the selected trades for a sample of 150 NYSE firms. The quote revisions are clearly clustered near the trade, with a substantial portion (59.3 percent) of the quotes recorded *ahead* of the trade. The shape of the distribution suggests that these quote revisions were attributable to the trade in question. The large percentage of pretrade quotes suggests a naive approach that uses the current quote to classify a trade would lead to incorrect inferences. Panel B of Figure 2 shows the quote revisions around isolated trades for all AMEX firms during 1988. Once again a significant proportion (72.4 percent) of the total quote revisions are entered ahead of the trade.

These findings point to a data problem which will need to be addressed in future studies. The sharp drop in quotes between 5 and 6 seconds before the trade indicates that a simple procedure could mitigate this problem. If the current quote is less than 5 seconds old, it was probably caused by the trade under consideration, so the previous quote should be used for classification.[10]

When a trade causes a quote revision, the new quote tends to straddle the trade that triggered it. If new quotes are recorded ahead of the trade, then naively using the current quote should cause a larger number of trades to appear inside the spread. We test this by comparing the classification of trades using both the current quote and the most recent quote that is at least 5 seconds old. Table II shows 35.7 percent of all trades were inside the spread when using the most current quote, whereas only 30.1 percent of all trades were inside the spread when using the time-adjusted quote. We also used the tick test to check the performance of the current quote and the quote in effect 5 seconds before the trade. Table III shows that when the old and new quotes give opposite inferences about the direction of the trade, the inference based on the old quote is most likely to agree with the tick test.

[9]Electronic workstations were phased in at the NYSE and the AMEX during 1987 and 1988. At the end of 1987, 600 stocks or 36 percent of the total NYSE equity listings were on electronic workstations; by the end of 1988, 1,600 stocks or 95 percent of total listings were on electronic workstations (see NYSE Fact Book). Electronic workstations were also installed at the AMEX over this time period.

[10]The 5-second delay corresponds to the pattern detected in the test of isolated trades for NYSE and AMEX firms using 1988 data. A different delay may be appropriate for other time periods. For example, tests we conducted using AMEX and NYSE data from September and October 1987 showed that during that period, most of the pretrade quotes occurred within 2 seconds of the trade.

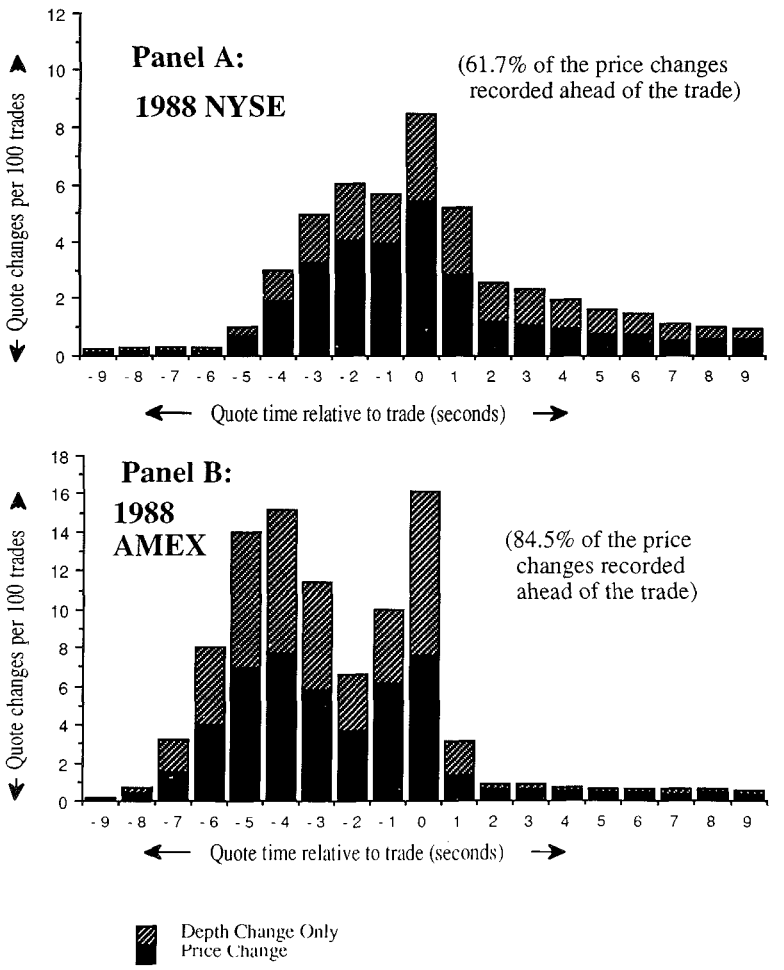

Figure 2. The frequency of quote revisions around isolated trades. The frequency of quote revisions in a 19-second window centered on isolated trades for 150 NYSE firms and all AMEX firms during 1988. An isolated trade is defined as the first trade after 11:00 a.m. but before 2:30 p.m., with no other trades within a 2-minute window centered on the trade. Both quote revisions which reflect price changes and quote revisions which affect depth changes only are shown.

III. Trades inside the Spread

Whenever the spread is more than one-eighth, trades can take place inside the spread. Although some of the apparent trading inside the spread is actually due to the timing issue identified earlier, Table II indicates that 30 percent of all trades are inside the spread even after correcting the timing problem. One way to deal with these trades is simply to ignore them (i.e., assume they have no directional inference), as was done in Blume, MacKinlay, and Terker (1989). This approach was probably reasonable in their

Table II

Comparison of Trade Prices to Prevailing Quotes

This table categorizes the 1988 trades of 150 NYSE firms by comparing the price of each trade to the bid/ask price of the prevailing quote. To qualify for consideration, a quote must be issued by the primary (NYSE) specialist and be BBO-eligible, that is, be eligible for inclusion in the National Association of Security Dealers (NASD) Best Bid and Offer calculation. The prevailing quote is defined as either the BBO-eligible quote immediately before each trade (column 1), or, the most recent quote which occurred at least five seconds before each trade (column 2). Table values in the first two columns represent the percentage of total trades in each category. Column 3 reports the percentage change in each category when moving from the first to the second column.

Category	(1) Comparison of trade price to the quote immediately preceding the trade	(2) Comparison of trade price to the most recent quote which is at least 5 seconds old	Percentage change in each category when method (2) is used for classification
Above the Ask	0.2%	0.2%	-
Equal to the Ask	30.2	33.1	+9.6%
Inside the Spread	35.7	30.1	−15.7
Equal to the Bid	32.6	35.3	+8.3
Below the Bid	0.3	0.3	-
No BBO-eligible Quote	1.0	1.0	-
Total	100	100	

study, since the order imbalance measure was a proxy for price pressure and trades inside the spread arguably do not exert significant price pressure. However, the classification of trades inside the spread can be important in other contexts, such as intraday event studies (Lee (1990)).

An alternative way to classify trades inside the spread, used by Harris (1989), is to call them buys (sells) if they are closer to the ask (bid). However, when the spread is an even number of eighths, trades at the midpoint of the spread will be unclassified. In our 1988 NYSE sample, this approach still leaves 75 percent of all trades inside the spread (22.5 percent of total trades) unclassified.

The key to classifying these midpoint trades lies in recognizing the effect of standing orders. As Hasbrouck (1988) points out, trades inside the spread can arise when a market buy and a market sell appear simultaneously (which is rare) or when the specialist or floor broker(s) with standing orders respond to a market order by bettering the current quote (which is much more often the case). In other words, standing orders create an effective spread inside the quoted spread. In Subsection A we test for the existence of an effective bid or ask price inside the quoted spread. In Subsection B a simple model is used to demonstrate the effectiveness of the tick test in classifying midpoint trades.

A. The Existence of an Effective Spread

If quotes are, on average, set symmetrically around the "true" equilibrium price and trades inside the spread are crossing market orders, then the next

Table III

Tick Test Results When Identification of the Prevailing Quote Is Ambiguous

For 150 NYSE firms during 1988, this table reports the tick test classification for all nonopening trades where the identity of the prevailing quote is ambiguous. The identity of the prevailing quote is considered ambiguous if a quote revision occurred within the 5 seconds immediately prior to the trade. This situation applied to 9.1 percent of the classified (nonopening) trades. Each trade is classified into one of nine categories on the basis of classification by either the quote in effect 5 seconds before the trade (the "prior quote") or the quote immediately before the trade (the "current quote"). The table reports the tick test classification for each of the nine categories. The relative frequency of the trades in each category, as a percentage of all trades with recent quote revisions and as a percentage of total trades by the sample firms, is also reported.

Classification Based on the Prior Quote	Classification Based on the Current Quote	Tick Test Classification	Relative Frequency of Trades in This Category	
			As a percentage of trades with recent quote revisions	As a percentage of total trades by sample firms
Buy—At Ask	Buy—At Ask	97.3% buy	4.8%	0.4%
	Inside the Spread	92.5% buy	35.2	3.2
	Sell—At Bid	83.8% buy	3.2	0.3
Inside the Spread	Buy—At Ask	61.9% buy	3.6	0.3
	Inside the Spread	51.7% buy	6.4	0.6
	Sell—At Bid	51.6% sell	3.8	0.3
Sell—At Bid	Buy—At Ask	82.8% sell	2.9	0.3
	Inside the Spread	90.2% sell	33.1	3.0
	Sell—At Bid	96.5% sell	5.2	0.5
Other			1.8	0.2
Total			100	9.1

price change will be an increase or a decrease with equal probability. On the other hand, if there is an effective spread on one side of the quoted spread, we should observe reversals on midpoint trades. In other words, given a midpoint trade on a down (up) tick the next price change would likely be an up (down) tick.

When the spread is 1/4 (69 percent of all trades inside the spread), we found that if the midpoint trade was on a downtick, the next price change was an uptick 64.2 percent of the time (Figure 3 Panel A). Alternatively, if the midpoint trade was on an uptick, the next price change was a downtick 66.6 percent of the time (Figure 3 Panel B). The frequency of price reversals indicates the presence of standing orders that cause the effective spread to be on one side of the quoted spread. It also indicates that, on average, these standing orders take more than one market order to fill, otherwise the next price change after a midpoint trade would be as likely to be positive as negative.

When the spread is 3/8 (25 percent of the trades inside the spread), for

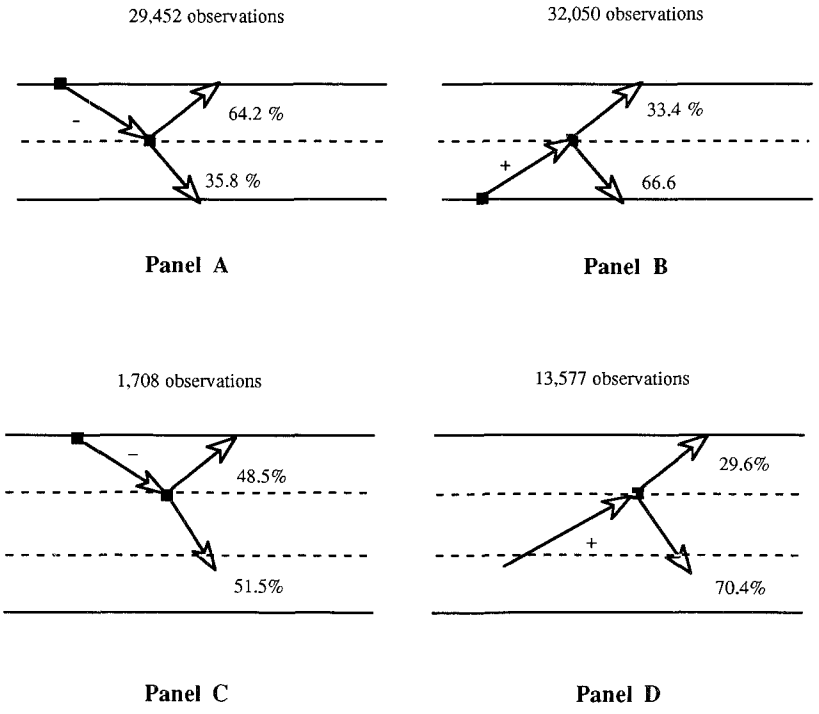

Figure 3. Frequency of price reversals for trades inside the spread. For a sample of 150 NYSE firms during 1988, these figures report the frequency of trades at the midpoint of a 1/4 spread (Panels A and B) and at the upper inside point of a 3/8 spread (Panels C and D). Panels A and C show the number of trades which occurred on a downtick and the proportion of uptick and downtick movements in the next price change. Panels B and D show the number of trades which occurred on an uptick and the proportion of uptick and downtick movements in the next price change.

trades that occur on a downtick at the higher of the two inside points, we find the next price movement is upwards 48.5 percent of the time (Figure 3 Panel C). However, for trades that occur on an uptick, a price reversal occurs 70.4 percent of the time (Figure 3 Panel D). This asymmetric response, combined with the fact that trades at the higher inside point are almost 8 times more likely to occur on an uptick than a downtick, suggests that the standing order on the higher inside point tends to be a sell order, so trades transacted at the higher inside points tend to be market buys. Tests at the lower inside point produced symmetrical results, suggesting trades at the lower inside point tend to be market sells.

B. Classifying Trades Inside the Spread

The evidence presented thus far implies trades inside the spread often arise as a result of standing orders. Moreover, the pattern of price reversals reported in Figure 3 suggests it is possible to infer the direction of these standing orders by using the tick test. Empirically, it is difficult to quantify

the expected improvement from using the tick test without knowing the actual direction of each trade inside the spread. However, the expected improvement can be evaluated analytically by means of a simple model.

Assume a 1/4 spread with quoted bid and ask prices that remain constant through time, all market orders are for one share, and market buy and sell orders are independent Poisson processes with the same arrival rate.[11] Further assume that standing buy and sell orders, which offer to trade at the middle eighth, also follow independent Poisson processes with a lower arrival rate than market orders, so there are (almost) never two active standing orders at the same time.[12]

Consider a standing order to sell (waiting for a market buy). The pattern of market orders that arrive immediately before and after the arrival of the standing order can be classified into four equally likely events (buy/buy, buy/sell, sell/buy, and sell/sell).[13] As shown in Figure 4, the tick test will correctly classify the first midpoint trade after the arrival of the standing order in 3 of these 4 cases (i.e., 75 percent of the time). The reason for this somewhat counter-intuitive result can most easily be seen by focusing on the event buy/sell. If the market order immediately before the arrival of the standing order is a buy and the next market order is a sell, the sell order will "pass through" the standing order and execute at the bid. When a market buy eventually arrives, the trade will be an uptick, so the tick test classification will be correct. In effect, the standing sell order functions like a one-sided filter on incoming trades, so that market sell orders are executed at the bid price and market buy orders are executed at the midpoint.

The extension of the model to the case where standing orders require more than one market order to be filled is straightforward. The tick test will only misclassify the second midpoint trade after the arrival of the standing order if it misclassifies the first midpoint trade *and* the second trade is in the same direction as the first trade (i.e., another buy). In our model, this means the second midpoint trade will be correctly classified 87.5 percent of the time. Similarly, the third trade will be correct 93.7 percent of the time. Accordingly, if the average standing orders are approximately 3 times as large as market orders, the tick test will correctly classify 85.4 percent of all midpoint trades.[14]

[11]This is similar to a model used by Garman (1976).

[12]This assumption simplifies the analysis by allowing us to focus on the situation when there are no confounding standing orders. In fact, with a 1/4 spread, opposite standing orders should cancel each other and standing orders in the same direction should reinforce each other, so that there is effectively just a single unidirectional standing order at the midpoint at any given time.

[13]If incoming standing orders tend to be in the same direction as incoming market orders, the sell/sell event is more likely to occur than the buy/buy event. Our assignment of equal likelihood to these four events would therefore understate the actual efficacy of the tick test. We thank the referee for pointing this out.

[14]The reverse tick test would correctly classify about 71 percent of these trades. Hasbrouck (1988) used the reverse tick test to classify roughly half of his midpoint trades. The normal tick test should give superior inference, but it is unlikely that this would significantly alter his results because his sample is very large and includes many trades that are unambiguously classified using quotes.

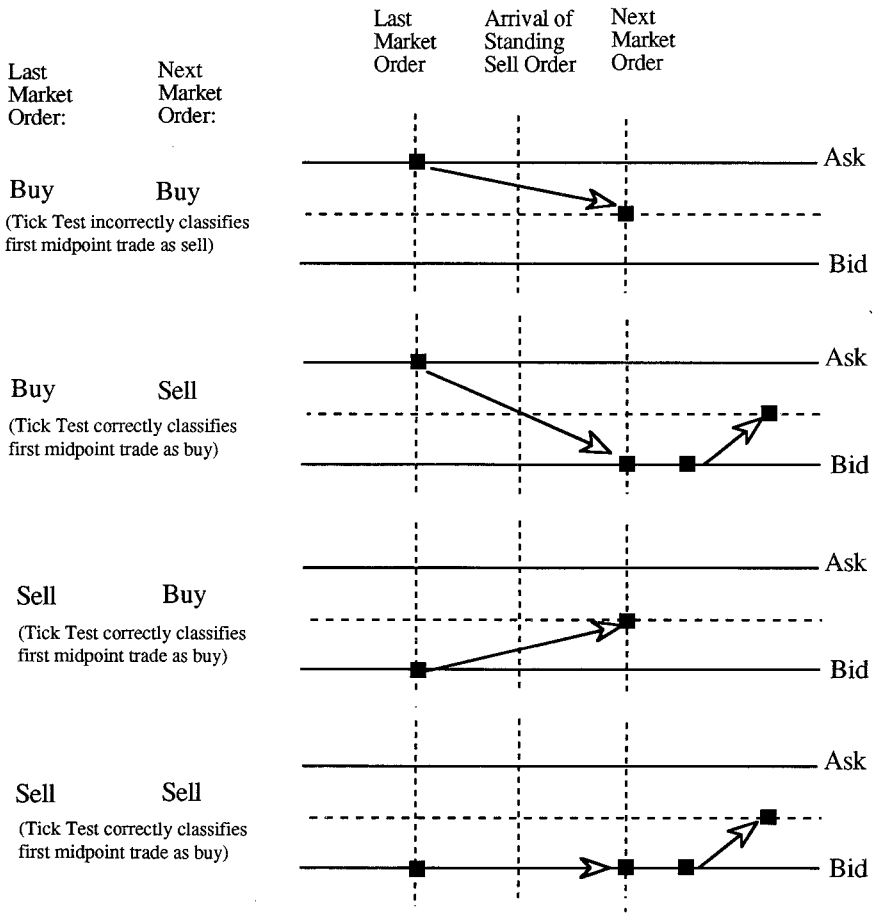

Figure 4. Classifying the first midpoint trade after the arrival of a standing sell order. Assume constant bid and ask prices and a 1/4 spread. Further assume market buy and sell orders follow independent Poisson processes with the same arrival rate. Standing buy and sell orders also follow independent Poisson processes with a lower average arrival rate than market orders. The four equally likely patterns of market orders immediately before and after the arrival of a standing order are depicted above (buy/buy, buy/sell, sell/buy, and sell/sell). In three of the four cases, the tick test classification for the first midpoint trade is correct.

The above model indicates that at 1/4 spread, the tick test will correctly classify a large proportion at the midpoint trades. What about when the spread is larger than 1/4? The pattern of price reversals when the spread is 3/8 suggests that the Harris (1989) approach of treating the higher (lower) inside point trades as sells (buys) is generally appropriate for 3/8 spreads. Although competing standing orders could potentially cause trades at the upper (lower) inside point to be sells (buys), these trades are a small part of the total picture, and our intuition is that the Harris classification will probably out-perform the tick test in this subpopulation.[15]

[15]In our sample, for approximately 1.5 percent of all trades, the tick test would disagree with the Harris algorithm.

We did not analyze the trading pattern when the spread is larger than 3/8 (6 percent of all trades inside the spread, 2 percent of total trades). However, based on the data for 1/4 and 3/8 spread, we expect that the best approach for these trades is to classify those that occur in the middle of the spread using the tick test and other trades inside the spread as buys (sells) if they are closer to the ask (bid).

Table IV

Classification of Trades Using the Proposed Algorithm

For 150 NYSE firms during 1988, this table reports the percentage of total trades classified as buys and sells using the algorithm proposed in this paper. Specifically, trades are classified by comparing the trade price to the prices of the prevailing quote, if available. Trades at the bid (ask) price are classified as sells (buys). The prevailing quote is the current quote, or the quote in effect 5 seconds ago if the current quote is less than 5 seconds old. To qualify for consideration, a quote must be issued by the primary (NYSE) specialist and be BBO-eligible, that is, be eligible for inclusion in the National Association of Security Dealers (NASD) Best Bid and Offer calculation. When a BBO-eligible quote is unavailable or when a trade is at the midpoint of a spread, the "tick test" is used, so that the trade is classified as a buy (sell) if the price change immediately before the trade is positive (negative). Trades inside the spread but not at the middle of the spread are classified by their proximity to the bid or ask price—trades closer to the bid (ask) are classified as sells (buys). All trades except opening trades are included in the analysis.

Category	Based on Current Quote (more than 5 seconds old)	Based on Prior Quote (current quote less than 5 seconds old)	Total
Buys			
Above the Ask	0.2%	0.0%	0.2%
Equal to the Ask	29.1	3.9	33.0
Inside Spread—Closer to the Ask	4.2	0.2	4.4
Middle of the Spread—Tick Test	11.5	0.5	12.0
Total Buys	45.0	4.6	49.6
Sells			
Below the Bid	0.3	0.0	0.3
Equal to the Bid	31.5	3.8	5.3
Inside Spread—Closer to the Bid	3.8	0.2	4.0
Middle of the Spread—Tick Test	10.3	0.5	10.8
Total Sells	45.9	4.5	50.4
All Trades			
Outside the Spread	0.5	0.0	0.5
Equal to Ask or Bid	60.6	7.7	68.3
Inside Spread—Closer to the Ask or Bid	7.0	0.4	7.4
Middle of the Spread—Tick Test	22.8	1.0	23.8
Total All Trades	90.9	9.1	100

IV. Summary

In this paper, we show that the price-based trade classification method commonly known as the "tick test" provides remarkably accurate directional inferences. We also identify two potential problems with classifying trades as buys or sells using quoted spreads. In a sample of trades on the NYSE during 1988, more than half of the quote changes resulting from trades are recorded ahead of the trade. In addition, 35 percent of all trade prices fall inside the most recent spread. We show that the problem of quote identification can be mitigated by using a time-delayed quote which, in the case of 1988 data, is the quote in effect 5 seconds before the trade time stamp. In addition to greatly increasing the reliability of inferences, this adjustment reduces the percentage of quotes inside the spread to 30 percent.

We present evidence that trading inside the spread is due largely to "standing orders" that cause the effective spread to be narrower than the quoted spread. As a result, in a given time span it is not generally true that trades between the spread are equally likely to be buys and sells. In the context of a simple model, we demonstrate that the tick test will correctly classify at least 85 percent of all trades at the midpoint of a spread. For trades closer to the bid or ask we show that the tick test continues to perform well, although a simple assignment of trades as buys (sells), if they are closer to the bid (ask), will also perform well.

Table IV reports the results of applying our algorithm to the 1988 trades of 150 NYSE firms. These results show that the two problems identified above do affect a significant proportion of total trades. However, as we indicated earlier, the sensitivity of research results to these problems will be application specific. Although we briefly discuss situations where these problems are most likely to affect results, the primary purpose of this paper is not to evaluate the likely bias in particular applications. Rather, it is our hope and intent that careful consideration of the issues and evidence presented here will lead to improved directional inferences in all future applications.

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