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Why effective spreads on NASDAQ were higher than on the New York stock exchange in the 1990s ☆

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Abstract

Two hypotheses have been advanced to explain why spreads on NASDAQ were substantially higher than those on the NYSE in the 1990s: "collusion" and "preferencing and payment for order flow." We present data on all actively traded stocks in these markets of relative effective spreads (RES), aggregated monthly over 1987–1999 and advance a third hypothesis: NASDAQ "SOES-day-trading." We estimate NASDAQ and NYSE informed-trade losses and gains to market makers and other liquidity providers on six trade sizes, and find that losses on trades we ascribe to SOES day traders were substantially greater than those on other trades, offset somewhat by gains from small-trade-size investors. NASDAQ market makers' response to these losses and additional operations costs incurred to reduce the losses resulted in greater RES and increased trading within the best quotes, predominantly on larger trade sizes. The data are consistent with the "SOES-day-trading" hypotheses, but not with the other two. Furthermore, the mandatory SOES "experiment" provides insights into the negative effects of automated trading systems (such as ECNs, which now dominate NASDAQ) when their design does not adequately consider opportunistic traders.

JEL classification: G14; G18; L12; L22; G12; G18; D23; D82; D83
Keywords: NASDAQ; NYSE; Bid–ask spreads; Odd-eighth avoidance; Collusion; SOES bandits; Day trading; Market microstructure

1. Introduction, hypotheses, and overview

In the 1990s the NASDAQ stock market was subjected to severe adverse publicity. By the mid-1990s the greater increase in spreads on NASDAQ than on the NYSE at the beginning of the decade was noted and criticized. Christie and Huang (1993) found that quoted spreads decreased substantially on 51 stocks that moved in 1990 from NASDAQ to the NYSE or Amex, as did Barclay (1997) for 472 stocks that moved from NASDAQ between 1983 and 1992. Christie and Schultz (1994) then reported that in 1991 NASDAQ market makers, but not NYSE traders, "avoided" quoting prices in odd eighths on 70 of the 100 actively traded NASDAQ stocks they sampled. They concluded that

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even-eighths quoting is evidence of "implicit collusion" that resulted in wider spreads. Christie, Harris, and Schultz (1994) found that spreads on four of the five most heavily traded of the 70 NASDAQ stocks dropped on May 27, 1994, the day after the Christie–Schultz findings were publicized. These studies led to investigations by the Department of Justice (DOJ, 1996) and the Securities and Exchange Commission (SEC, 1996), including examination of tape-recorded conversations among traders employed by NASDAQ market makers. The recordings revealed that some traders berated and threatened traders at other firms who offered quotations that "broke the spread" and asked other traders to put in quotations that would establish a desired price. These clearly illegal (under the anti-trust statutes) acts and the evidence from the academic research and DOJ/SEC investigations were followed by a class-action lawsuit resulting in a December 1997 $925 million settlement, as well as SEC fines and changes in NASDAQ operating procedures instituted in January 1997.[1]

Christie and Schultz (1994) also spawned several conferences and academic studies. Among these, Huang and Stoll (1996) (HS),[2] Bessembinder and Kaufman (1997) (BK), and Keim and Madhavan (1997), using 1994 or earlier data, document higher NASDAQ effective spreads (the absolute difference between a transactions price and the midpoint of the prevailing best bid/offer).[3] Although these spreads were not adjusted for commissions and other trading costs, it was generally accepted that for some reason trading on NASDAQ was more costly to investors.[4] Christie and Schultz (1995, p. 199) believe that "brokerage firms making markets in NASDAQ stocks … implicitly colluded to maintain profits at supracompetitive levels." Barclay's (1997) supports this conclusion, based on his finding that spreads on NASDAQ stocks quoted on even eighths, but not those quoted on mixed eighths, dropped when they moved to the New York or American stock exchanges, thereby presumably escaping the collusion. HS, Godek (1996), Dutta and Madhaven (1997), and Kandel and Marx (1999) propose that preferencing and payment for order flow (wherein some NASDAQ market makers pay retail brokers for sending them trades and promise to match the best prices quoted) reduce NASDAQ market makers' incentives and ability to compete vigorously. BK accept both Christie–Schultz's collusion explanation and preferencing as possible reasons for higher NASDAQ spreads. However, they find no support for Christie–Harris–Schultz's (1994) drop-in-spreads conclusion when the sample is extended to 300 stocks. In addition, Grossman et al. (1997, pp. 45–50), in a more extensive study of the sample used by Christie and Schultz (1994) and of a larger sample of stocks, similarly find no support for the Christie–Harris–Schultz conclusion. Furthermore, shares of one of the four (Microsoft) experienced a two-for-one split a few days earlier and the drop in its spread is consistent with the split. Thus, the Christie–Harris–Schultz finding is based on three of the seventy Christie–Schultz even-eighths-quoted stocks. Benston (2007) replicated and extended Barclay's (1997) study and finds that the greater decline in spreads on even-eighths quoted stocks was due 21 of 362 (3.1%) thinly traded stocks with quoted spreads over 1.50 on which NASDAQ market makers faced informed-trade risk not present on NYSE/Amex. Furthermore, there is no difference in the spread decline after the Christie–Schultz results were publicized.

We suggest an alternative hypothesis that contributes to an understanding of the higher NASDAQ spreads in the 1990s — day trading primarily over its small order execution system (SOES). In June 1988 NASDAQ changed SOES from an e-mail inquiry system to an order entry system in response to the criticism the traders were unable to submit orders during the October 1987 market crash. Trades made through SOES had to be honored automatically and instantly by market makers at quoted prices for up to 1000 shares with up to five repetitions. Making SOES mandatory had a dramatic impact on NASDAQ. Day traders began using the SOES system to purchase (sell) and quickly sell (purchase) stocks with stale quotes — quotes that individual market makers failed to change coincident with market shifts when their attention was diverted to other stocks. Consequently, market makers drastically reduced the number of stocks covered by their individual dealers and implemented costly software and systems to minimize stale quotes. We hypothesize that, because market makers could not know which stocks might be "hit" by day traders and to compensate for the additional costs they incurred, as shown analytically by Glosten and Milgrom (1985) and Copeland and Galai

[1] We were not involved in the lawsuit and do not know why the parties settled. Attempts to fix prices (whether successful or not) are per se violations of law that can subject defendants to treble damages.

[2] They review earlier literature and conclude: "Despite this volume of research, the difference in execution costs between NASDAQ and the NYSE has not been clearly established [p. 317]."

[3] Kothare and Laux (1995) examined only NASDAQ quoted spreads in the month of October in 1984, 1988, and 1992. They find a substantial increase over this period, and state (p. 42): "Our main finding is that, even controlling for other factors that influence spreads, spreads are positively associated with the extent of institutional trading activity…."

[4] Chan and Lakonishok (1997) adjusted trades by 33 large investment management firms for commissions and found that the differences were related to the size of firm traded, rather than the market. However, they caution that their findings do not necessarily apply to retail trades.

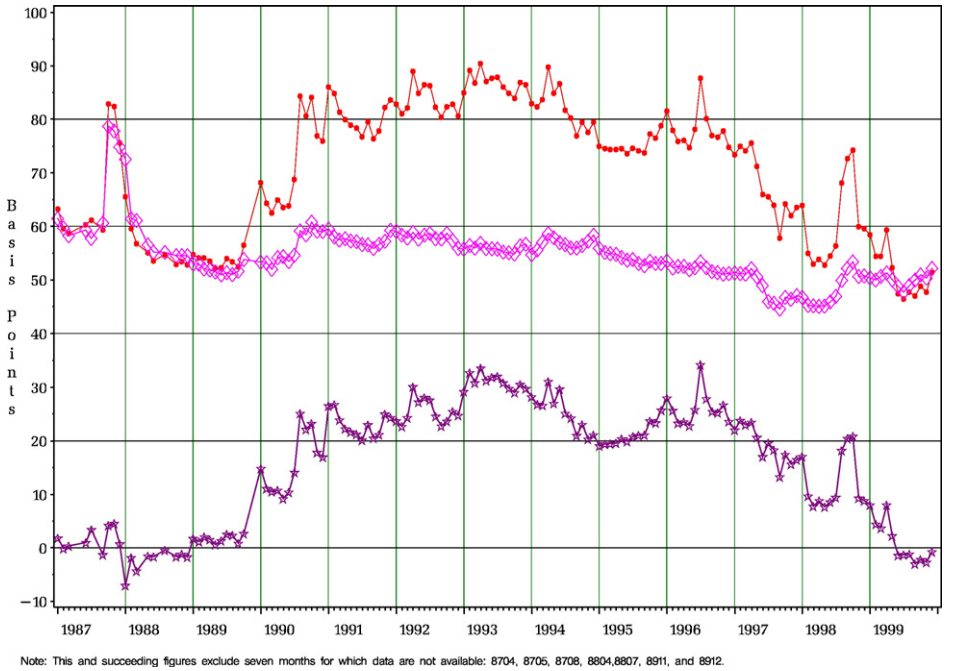

Fig. 1. NASDAQ and NYSE relative effective spreads (RES), 1987–1999 NASDAQ RES = (●), NYSE RES + 18.4 basis points = (◇), adjusted NASDAQ less NYSE RES = (☆).

(1983), they raised offer prices and lowered bids on all the stocks they followed, thereby widening quoted spreads. Whether or not as a result market makers made higher-than-competitive net profits is not our concern here; rather we offer an explanation as to why spreads on NASDAQ compared to the NYSE increased in the 1990s.

Several observers have rejected the "SOES day trade" hypothesis. Indeed, firms that promoted day trading claimed that it was beneficial, because it offered individual traders an opportunity to effect transactions efficiently, which resulted in more effective price determination (e.g., Houtkin, 1995). Kothare and Laux (1995, p. 44) dismiss day trading on SOES as an explanation for the increase in NASDAQ spreads among the three months they examined in 1984, 1988, and 1992, because "[a]t the time of this writing, SOES accounts for only 2% of total NASDAQ volume." HS [p. 348] similarly dismiss day trading as an explanation for higher NASDAQ spreads, in part because "SOES trades account for only a small fraction of NASDAQ volume." Yet by the mid-1990s the Electronic Traders Association, which represented 26 SOES dealers (not all such dealers were members) who catered to day traders, called "SOES bandits," claimed that day trades generated 20% of NASDAQ trades.[5] HS and BK additionally dismiss SOES day trading, because they find that NASDAQ market makers but not NYSE traders appear to have achieved positive realized spreads, from which they conclude that NASDAQ trades do not contain more adverse information costs than NYSE trades. In contrast to the realized spread metric employed by HS and BK, which measures costs to liquidity suppliers in an accounting sense, we calculate the opportunity gains and losses to estimate the effect of SOES day trading on spreads rather than on the dealers' accounting net profits. We also disaggregate the data by trade size to separate the effects of trades made by SOES day traders from those of other traders. Furthermore, because HS and BK studied only two years, 1991 and 1994, with relatively few observations (175 and 300 NASDAQ–NYSE pairs), their view was somewhat limited. In contrast, we present and analyze data over thirteen years, 1987–1999, years that span both NASDAQ's SOES-day-trading experience and substantial changes in NASDAQ and NYSE spreads, from which we conclude that trading by SOES bandits are an important reason for the increase in relative effective spreads on NASDAQ but not on the NYSE.

Fig. 1 shows relative effective (half) spreads (RES) on NASDAQ and NYSE trades, measured as the absolute difference between a transaction price and the midpoint of best bid and offer (BBO) in effect five seconds before the transaction divided by the transaction price. RES are computed daily from trade-weighted transactions and averaged (equally weighted) monthly from January 2, 1987 (the earliest date for which we have data) through December 31,

[5] See Byrne (1997). Gene Finn, NASD Chief Economist at the time, confirms this estimate.

1999. We calculate this metric for all actively traded stocks on NASDAQ and the NYSE, where "active" is defined as having at least five trades per trading day (9:30 AM–4:00 PM) for at least 10 days per month and a price per share of at least $10, but not more than $80.[6] We include only the days with five trades or more per day.[7] As robustness checks, we also calculated and graphed RES using observations with at least ten trades a day (based on the possibility that day traders concentrated on actively traded stocks), medians instead of means, only stocks that traded throughout the period (202 on NASDAQ and 627 on the NYSE), only stocks with trades of 1000 shares or less, 2000 shares or less, and so on by thousands through 5000 shares or less, and all shares traded. Further, we formed matched portfolios in each month with a linear programming model than minimizes the Euclidean distance measures between NYSE and NASDAQ stocks, discussed further in Section 7. In each case the resulting figures very closely mirror those shown in Fig. 1.

The use of RES rather than effective spreads accounts for changes in price levels during the thirteen years studied and which Wood and McInnish (1992) find is responsible for 80% of the variation in spreads. We examined changes in the ratio of the average price per share of NASDAQ to NYSE stocks to determine if differences in RES on these markets changed as a result of changes in the denominator rather than the numerator. The ratio is almost unchanged over the period. Other differences, though, are important. NASDAQ stocks tend to be riskier, not as liquid, and are more subject to inventory costs because they are held, bought, and sold by dealers rather than transacted through brokers. Further, during our sample period stocks traded net (principal) for institutional trades on NASDAQ, while institutional orders traded on the NYSE with commissions (agency) as an additional charge. Consequently, spreads on NASDAQ tend to be wider than those on the NYSE. To compensate (in part) for these factors, we calculate the difference between the average RES for NASDAQ minus the average RES for NYSE over the "base" period, January 1987 through May 1988 (prior to the start of mandatory SOES trading), excluding the three 1987 market-crash months, October, November, and December. We add the difference, 18.4 basis points, to the NYSE RES values to approximate comparability between the NASDAQ and NYSE metrics over our entire sample period. When the three market-crash months were included, the difference is 18.2 basis points. We recognize that over the 11.5 years to which we apply the scaling factor to equalize the two venues there were numerous changes in market mechanisms, some unique to each market center and some affecting both. Yet comparison of the two markets over an extended period is inherently interesting and the topic addressed we feel is vitally important for understanding the NASDAQ market in the 1990s. Nevertheless we must interpret our finding cautiously, considering our comparison method.

Fig. 1 reveals the shock to RES values resulting from the market crash of October 1987. Note that the NASDAQ and adjusted NYSE RES closely track one another, including the market-crash months. Focusing on the NASDAQ less adjusted NYSE metric, beginning in late 1989 we observe a surge that peaks in early 1993. The NASDAQ RES in early 1993 exceeds the market crash peak. Thereafter the difference declines steadily, with some acceleration in the decline following publication of Christie and Schultz's (1994) findings on May 26, 1994 through December 1994. Then the difference increases through 1996, and subsequently declines somewhat erratically back to zero in June 1999 as the NASDAQ and NYSE RES converge. Thus, we see that a powerful economic force increased the RES of NASDAQ relative to that of the NYSE over a ten-year period, from August 1989 through November 1999.

What economic force could have caused this large and long-lasting difference? And what caused the RES to revert to their pre-August 1989 difference? Consider, first, the collusion hypothesis.[8] If the difference between NASDAQ and NYSE RES were the result of collusion, there should be some explanation as to why it began in mid-1989 and did not end until mid-1999. There is no doubt that the Christie and Schultz (1994) and Christie, Harris, and Schultz (1994)

[6] To screen out extreme errors in the data not otherwise caught, we require an intra-day variance of the midpoints of the inside quotes (best bids and offers, or BBO) that is less than 4.0, which reduced the sample by 0.001%. In addition, extreme values of prices and quotes were filtered, removing less than 0.001% of the observations. A maximum price of $80 excludes high-tech and dot com NASDAQ stocks that were subject to extreme volatility and severely widened spreads during the bubble period of the late 1990s.

[7] The NASDAQ (NYSE) sample includes an average of 1370 (1743) stocks per month. The January 1987 NASDAQ (NYSE) sample size of 757 (1471) stocks declines through late 1988 and then increases gradually to 1718 (2000) stocks in December 1999. Through 1989, the ratio of NASDAQ to NYSE stocks ranges between .3 and .5 (14% are at .3); thereafter, the ratio ranges between .7 and 1.0 (7% are at .7). Data are missing for the NYSE and/or NASDAQ for April, May, and August 1987, April and July 1988, and November and December 1989. Data sources: 1987–1992 data were provided by ISSM; 1993–1999 data were obtained from the NYSE TAQ database.

[8] A fairly large number of papers have been written and published debating the collusion hypothesis. See, for example, papers published in volume 45 (1997) of the *Journal of Financial Economics* (which tend to support the hypothesis) and papers noted in Grossman et al. (1997), which reject it. We do not and cannot adequately review the arguments and evidence here. Rather, we only raise questions relating to the differences shown in our Fig. 1.

papers, the DOJ/SEC (1996) investigations, the class-action lawsuit, and SEC fines had a very strong impact on NASDAQ market makers. NASDAQ trading practices were scrutinized, changed, and closely monitored. It does not seem feasible that collusion could have persisted in this environment after 1994. Yet in 1995 and 1996 the gap between the NASDAQ and NYSE RES widened, even though a number of factors put downward pressure on RES. First, systems designed to eliminate stale quotes increased in effectiveness over time. Second, the Manning court rulings in 1994/95 gave public limit orders priority over dealer quotes. Third, increasingly dealers who wished to display customer limit orders would do so on Instinet (or other ECNs as they became available) where they could not be subject to SOES day trading (referred to as "being SOESed" by NASDAQ market makers).[9] Hence, executions against these ECN quotes were often inside the Level II BBO (which did not include ECN quotes), thereby depressing RES. Fourth, the "brake-light" effect, resulting from the DOJ/SEC investigations into collusion, may have depressed RES. Thus, in the face of these downward pressures and despite exposure of the alleged collusion, NASDAQ RES increased in 1995 and 1996.

In January 1997 NASDAQ implemented Order Handling Rules (OHR) that required the public display of limit orders that bettered dealer quotes (with some exceptions). Further, dealers were not permitted to post different quotes to Instinet and NASDAQ Level II. Also, brokers were able to hit multiple quotes simultaneously through SelectNet, replicating the SOES bandits use of the "monster button." In addition, the Actual Size Rule, which reduced the minimum depth that market makers had to post for quotes from 1000 to 100 shares, was implemented in three stages — 100 stocks in January and February 1997, an additional 100 stocks in October 1997, and all remaining stocks in July 1998. NASDAQ RES declined somewhat erratically throughout this period, and by mid-1999 the NASDAQ-less-adjusted-NYSE RES returned to zero. By this point in time the NASDAQ rules had been modified to the point the SOES day traders had essentially no advantages over other traders and SOES banditry gradually ceased.

If there were "even-eighths tacit collusion" among market makers, it may have resulted from a reaction to the costs imposed on them by SOES day traders, wherein market makers compensated by rounding quotations in their favor to even eighths. Or, as Finn has suggested (in conversation), market makers could have reduced the option value of stale quotes exercised against them by widening the contra side of their quotes. Since an unwritten NASDAQ rule specified that if a dealer's own quote was greater than 5/8ths they could only change their quote by 1/4ths, even-eighth quoting could be due to widened own-spreads. While it is possible that this may have widened spreads beyond the non-collusive amount resulting from SOES day trading pressure, it is unlikely that the additional amount would have been large, considering the levels of the NASDAQ/NYSE RES gap in the years before the May 26, 1994 publication of Christie and Schultz's (1994) even-eighths findings and the gap in 1996, well after publicity about those findings and the DOJ and SEC investigations of collusion, as well as the class action lawsuit. Also note that the NASDAQ market had existed for years with no evidence or charge of collusion, and that there is no evidence or charge of collusion for NYSE stocks, although for the most part broker/dealers had both NYSE and NASDAQ trading desks.

Finally, we are not aware of any paper or investigation that explains why collusion among NASDAQ market makers would have begun around mid-1989. We do not claim that there was no collusion, as the tapes of traders' conversations indicate at least an attempt by some to affect prices. Our concern is with the assertion that pervasiveness of collusion was the primary reason for the increase in NASDAQ relative to NYSE RES. It appears that some economic pressure other than collusion was responsible for the relationship shown by Fig. 1.

Although the preferencing and payment-for-order-flow hypothesis could be responsible in part for higher NASDAQ spreads, it does not appear to be responsible for the pattern shown in Fig. 1. The practice of directing institutional order flow flourished before 1987, with the relaxation in 1986 of Section 28E of the Securities Exchange Act, which governs soft-dollar arrangements. In June 1990 the SEC, in a letter ruling, decreed that directed principal trades generating soft dollars were not covered by the "safe harbor" provisions of ERISA (1984), and that pension fund managers had to prove that any directed trade obtained best execution. With respect to retail trades, before October 1991 a market maker who agreed to be preferenced for a particular stock had to accept orders from any dealer or order entry firm without pre-notification for up to 1000 shares. After that date, market makers could be preferenced only with their permission. None of these changes are noticeably related to the pattern shown in Fig. 1. From discussions with practitioners and regulators, including NASD's chief economist (Gene Finn) during this period, we are not aware of any other changes in

[9] According to Gene Finn dealers' quotes represented 95% of all ECN quotes in the 1994–1996 period, with the remainder coming from buy-side funds.

soft dollars or preferencing that could produce the results observed in Fig. 1. Further, both preferencing and payment-for-order flow affected both NASDAQ and NYSE stocks, so if these factors were influencing NASDAQ stocks we would expect to see similar influences with NYSE stocks, which is not the case.

We turn now to the SOES-day-trading explanation, which we show is consistent with the differences between NASDAQ and NYSE RES over the thirteen-year period. We describe SOES history and day trading in Section 2, which drives our division of the thirteen years studied into the seven periods specified. In Section 3 we present data on the extent of SOES day trading. Based on this analysis and following other researchers and practitioners (e.g., Battalio et al., 1997; Harris and Schultz, 1997, 1998; Houtkin, 1995), we use trades of the maximum amount eligible for SOES – 1000, 500, or 100 shares – as our initial, preliminary measure of SOES day trades. In Section 4, we calculate liquidity supplier's losses and gains to informed SOES day traders and other traders. We calculate this metric for six trade sizes, five that are eligible for trading through SOES and one that is not (which serves as a control). The metric is examined during the periods before SOES became mandatory and after it was phased out, as well as for NYSE transactions. Adjusting for trades at the maximum trade size that were not made through SOES, we find informed-trade losses ascribed to SOES day trades average at least 21 basis points on 1000-share trades, and 15 basis points on 500-share trades and 21 basis points on 100-share trades when these were the SOES maximum trade size. In contrast, we estimate that market makers obtained additional gains of 17, 7, and 10 basis points on 100-, 101–499-, and 500-share trades (when not the SOES maximum size). We believe these gains are due to market makers' actions to reduce informed trade losses to SOES day traders and related operating costs. During this time, there were very small and statistically insignificant increases in informed trade costs on NYSE stocks of 0–2 basis points.

We also find that market makers compensated for informed-trade losses to SOES day traders, as well as the costs of substantially reduced coverage by individual market makers and system enhancements to reduce stale quotes, by increasing quoted sale and decreasing quoted buy prices, thereby widening spreads. In Section 5 we present relative effective spreads (RES) for each of the six trade sizes and find that the RES increased much more for the smaller trade sizes. Thus, investors who used the smaller trade sizes, who on the whole were unable to trade within the BBO, incurred substantially greater actual transactions costs.

In Section 6 we compare changes in the percentage of volume at the maximum SOES trade size (our proxy for SOES day trades) and the percentage of stocks quoted on even eighths (the Christie–Schultz proxy for tacit collusion among NASDAQ market makers) with the difference in RES on NASDAQ and NYSE stocks over the thirteen years studied. These data are consistent with the SOES-day-trade and inconsistent with the even-eighths-tacit-collusion hypotheses. Section 7 applies robustness checks wherein prior results are verified. Section 8 states our conclusions and the implications of our study for contemporary issues.

2. Description of SOES history and day trading

In this section we provide background regarding SOES to inform the analyses that follow. In response to brokers not answering telephones during the market crash on October 19, 1987, the NASD, under pressure from the SEC, formed a blue-ribbon committee of market makers from leading broker/dealers. This committee recommended that quotes by all market makers should be executable automatically for NASDAQ Level II market orders of up to 1000 shares submitted over the already developed but voluntary SOES. The SEC approved this change on June 9, 1988. Since market makers were required to honor up to five repetitions, they were required to fill orders aggregating as much as 5000 shares at the best-posted quote. (If the market for a stock was crossed or locked – the ask less than or equal to the bid – restrictions were removed and unlimited orders could be submitted over SOES.) This requirement contrasts sharply with the 100-share minimum order size imposed on NYSE specialists. Finally, on the surface SOES may seem similar to the NYSE DOT system, but DOT machines are only issued to brokerage firms and the specialist has 15 seconds to consider market orders.

Soon after SOES was made mandatory, some dealers began picking off market makers whose quotes became momentarily stale on the NASDAQ quotation system. The NASD attempted to stop this use of the system by adopting a rule change (approved by the SEC on December 14, 1988) prohibiting members from entering orders through SOES on their own accounts or on behalf of a professional trading account, which is defined as any account in which five or more "day trades" by an individual trader or firm were executed through SOES during any trading day or where a professional pattern in SOES is exhibited. However, SOES day traders could avoid this restriction by executing one

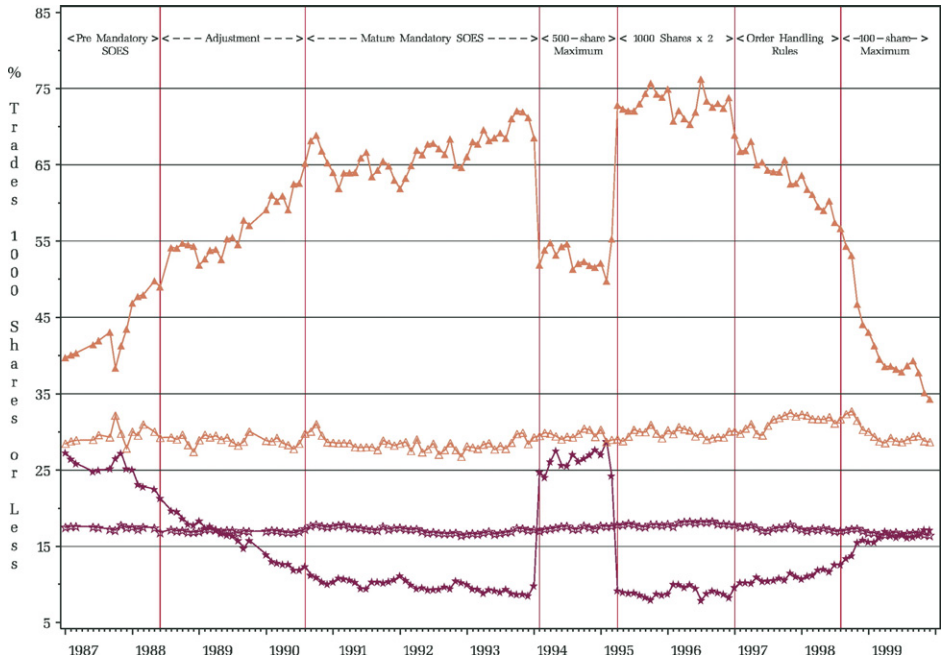

Fig. 2. 500- and 1000-share dollar volume as a percentage of total dollar volume of 1000 shares or less for NASDAQ and NYSE 500-share NASDAQ dollar volume = (★), 1000 NASDAQ = (▲), 500 NYSE = (☆), 1000 NYSE = (△).

side of a trade outside of SOES and by trading from several ostensibly separate accounts. A "professional pattern" also proved difficult to establish.[10] From conversations with NASDAQ economists, market makers, and observations of data presented later (see Fig. 2), we determined that SOES day trading did not become really active and widespread until after June 1990. We term the months 8/88 through 6/90 the "Adjustment" period.[11]

SOES day trading "took off" largely through the efforts of two NASDAQ market makers, Datek and All-Tech (especially All-Tech's CEO, Harvey Houtkin, who calls himself the "original SOES bandit" (Houtkin, 1995)). These firms recruited individual traders, now known as SOES day traders (or activists or bandits) and provided them with NASDAQ Level II terminals and software that would permit them to use the SOES system to pick off stale quotes. SOES day traders adopted a variety of strategies over time, including identifying the onset of buy/sell programs by institutional investors, stepping in front of these programs by absorbing the available liquidity, and then resupplying the liquidity at a short-term profit.[12] For example, fifteen market makers might quote the same best offer price on a stock, and a major broker (which generally deals in substantial size transactions) begins a buy program for a client with the intent of obtaining a large number of shares at or near that price. Upon observing the broker acquiring liquidity from one or two market makers, SOES day traders instantly buy the shares offered by the remaining market makers through SOES (referred to as "hitting the monster button," a procedure denied to brokers by NASD rule that required a broker to approach market makers serially). The bandits then offer the shares to the acquiring broker (who must obtain the shares to fulfill an order) at higher prices, often through SelectNet (Harris and Schultz, 1998). Thus,

[10] In 1993 the US Court of Appeals for Washington DC formally voided the rule, because it was vague and did not apply to telephone orders for quoted stocks.

[11] Data for July 1988 are not available. The analysis is not changed appreciably if the "Adjustment" period were included in the following period we delineate.

[12] See Houtkin (1995, Chapter Eight) and Harris and Schultz (1998) for descriptions of SOES trading techniques. Also see Battalio, Hatch, and Jennings (1997, Table 1) for a case study of trades in Apple Computer common stock during a ten minute period that illustrates SOES day trading. At 11:26 on June 20, 1995, between 14 and 15 market makers quoted an ask price of $46.625. Within the next minute, with the exception of one broker, the ask increased to $46.750. This broker was hit with twelve 1000-share buy orders. Before the ask quote leveled off at $46.875, four more 1000-share buy orders were placed.

the initial market maker incurred an opportunity cost, having sold the stock at too low a price. Harris and Schultz (1998, p. 45) also report that "although SOES day traders are prohibited from selling short through SOES … [they] circumvent this restriction by purchasing 1000 shares of each stock that they would like to sell short. These shares are placed in the bandit's hedge account. When the bandit believes that a stock will be moving down in the short-term, he uses SOES to sell shares from his hedge account." (Note that this process results in higher informed trading costs to market makers.) We term this period, 7/90–1/94 (after which the rules changed), "Mature Mandatory SOES." Although in the mid-1990s market makers adopted software and decreased the number of stocks their traders followed, these procedures were not sufficient to contain the increasing number of day trades who also adopted software to identify stale quotes and institutional trading programs. The procedures did, though, increase market makers' operating costs.

The NASD convinced the SEC to experiment by reducing temporarily the maximum SOES trade size from 1000 to 500 shares and from five to two the maximum number of times a market maker must honor an order before changing a quote. These rules were in effect from January 31, 1994 through March 26, 1995, when the SEC ended its prior temporary ruling. We call this the "500-share Maximum" period. After that date, the maximum trade size of 1000 shares was restored, but the number of orders that had to be filled before a quote could be changed remained at two. We call this the "1000-shares × 2" period.

In January 1997 the SEC mandated several Order Handling Rule (OHR) changes in NASDAQ operations that were applied to selected stocks in twenty-two waves, beginning on January 16 and ending on October 13, 1997.[13] Market makers were permitted to reduce their own quoted number of shares from 1000 to 100 for the 50 stocks in the January 16th wave and 50 stocks in the February 10th wave. Barclay et al. (1999) and Weston (2000) study these first two waves and find that spreads declined substantially. They say that the lower spreads were not due to a reduction in the cost of informed SOES trades. In October 1997, the rule was applied to an additional 100 stocks, and in July 1998 to all NMS stocks.[14] To examine the effects of these changes, we divide the years 1997–1999 into two periods, the "Order Handling Rules" period, 1/97–7/98, and the "100-share Maximum" period, 8/98–12/99. During and, especially, after this period, trading through ECNs increased greatly and decimalization was introduced in 2000. Hence, we do not extend our analysis beyond 1999.

To summarize, based on the development of SOES described in this section, we divide the thirteen years analyzed into seven periods: "Pre-mandatory SOES" (1/87–5/88); "Adjustment" (8/88–7/90), when SOES developed and the NASD attempted unsuccessfully to restrict its use; "Mature Mandatory SOES" (8/90–1/94); "500-share Maximum" (2/94–3/95), when the SEC allowed NASDAQ to reduce the maximum trade size from five repetitions of 1000 shares to two repetitions of 500 shares; "1000 Shares × 2" (4/95–12/96), when the maximum trade size but not the number of repetitions was restored; "Order Handling Rules" (1/97–7/98), when these were introduced; and "100-share Maximum" (8/98–12/99), when pursuant to the Actual Size Rule market makers were allowed to reduce their own quoted depth to 100 shares on their quotes. (Customer limit orders posted by dealers for their customers would reflect their actual size.) With this background we are prepared to examine the impact of SOES day trading on NASDAQ.

3. The extent of SOES day trading

As noted above, SOES was limited initially to 1000-share trades. Thus, we will confine our analysis to 1000 shares and below, using 1001–5000-share (1–5K) trades as a comparison. However, as also noted above, SOES day trading strategies morphed over time in response to regulatory pressure and evolving profitable opportunities. In particular, day traders increasingly used the NASDAQ SelectNet system and phone orders in the early 1990s, both to enter into positions and to unwind them as well in quantities that might differ from 1000 shares per trade. So the validity of using 1–5K trades as a benchmark weakens over time.

[13] SEC Release No. 34-37619A, File No. S7-30-95, Order Execution Obligations, Final Rules 17 CFR Part 240. The change also requires that better customer limit orders be reflected in the public quote (unless the customer specifically does not agree), the Excess Spread Rule (which dictates the maximum difference between bid and ask quotes) was relaxed, and market makers were permitted to quote stocks in sixteenths after June 1997. See Barclay et al. (1999) and Weston (2000) for a more detailed description and analyses.

[14] However, if customer limit orders offered more or asked less than the market maker, the sum of customer limit orders for the number of shares offered at that price are posted, pursuant to the Actual Size Rule. See Securities and Exchange Commission, Release No. 34-40139; File No. SR-NASD-97-26.

We *initially* measure SOES day trades as trades made at the maximum quantity that can be transmitted through SOES-1000 shares, except during the 500-share maximum, when the maximum was 500 shares, and the period 8/98–12/99, when market makers were permitted to quote as few as 100 shares.[15] We recognize that the maximum SOES trade size is an imperfect measure of SOES trades made by day traders. This metric both understates and overstates SOES day trading. It understates SOES day trading, because day traders can trade different quantities. They also can unwind their positions with trades of any size and not necessarily through SOES, as their goal is to end the day with no inventory. The metric overstates SOES day trading, because all 1000-share trades (and 500- and 100-share trades when these were the maximum) are not made by SOES day traders or even through SOES. This is especially true following the SEC requirement in 1991 that the NASDAQ SOES 1000-share quote minimum be extended to SelectNet and phone orders. Our base period, January 1987–May 1988, is somewhat contaminated since we are told by equity-trading professionals that day traders picked off stale quotes before SOES was made mandatory.

Fig. 2 shows the percentages of the dollar volumes of 1000- and 500-share trades to the dollar volumes on all NMS trades of SOES-eligible trades (1000 shares or less), averaged over months, January 1987 through December 1999. In this and succeeding figures, vertical lines identify the end of each of the seven periods of SOES history that we delineate. Similar data for NYSE trades offer a contrast. From the onset of our data we observe that NASDAQ 1000-share trades are 10 percentage points higher than the NYSE percentage and climbing, suggesting that day traders may have been picking off stale market-maker quotes even before SOES was made mandatory in June 1988. By the end of the "Adjustment" period, the percentage of 1000-share trades increased to 63% and the percentage of 500-share trades decreased to 12%. Over the "Mature Mandatory SOES" period, 1000-share trades averaged 67% and 500-share trades averaged 10%. During the February 1994 through March 1995 "500-share Maximum" period the dollar-volume percentages for 1000-share trades declined sharply to an average of 53%, while the percentage of 500-share trades increased to 26%, an almost exactly offsetting movement of 17 percentage points. It is important to note that the percentage of NASDAQ 1000-share trades still remained quite high relative to that of the NYSE, which likely reveals that many day traders continued to employ or even increase their use of SelectNet and phone orders to place 1000-share trades. Hence, even with the reduction of SOES pressure on market makers with the 500-share maximum, the net pressure on market makers was not substantially reduced. This important fact was apparently missed in the studies of the "500-share Maximum" period conducted by and for the SEC, which found that spreads did not decrease substantially even with the halving of mandatory SOES size. Consequently, the SEC determined that SOES day trading was not the cause of earlier-observed widened NASDAQ spreads, the "experiment" should be discontinued, and the maximum SOES trade size should be returned to 1000 shares. After the resumption to the 1000-share maximum, the percentages returned close to their previous levels. From January 1997 through December 1999, the percentage of 1000-share volume declined almost continuously to 34%, a bit below the percentage before SOES was made mandatory, thereby reflecting the impact of the rule changes and the resultant relative reduction in SOES day trading. Although the dollar amount of 1000-share trades actually increased slightly (to 112% of the December 1996 level), the dollar amounts of the smaller trade sizes increased substantially, thereby decreasing the dollar-volume percentage of 1000-share-trades.

In contrast, over the same thirteen-year period, the dollar-volume percentages of NYSE 1000- and 500-share trades to the total volume of all trades of 1000 shares or less were virtually unchanged at between 27 and 33% for 1000-share trades and 17 and 18% for 500-share trades. Considering that many traders, particularly institutional investors who trade 1000-share lots, act in both markets with a common objective, it appears that the patterns shown in Fig. 2 are endogenous to NASDAQ, rather than the result of exogenous events that affect trades in stock markets generally.

We next estimate the extent to which SOES day trading has imposed costs on market makers and other liquidity suppliers in the form of informed-trade opportunity costs. For comparison we calculate this metric for non-SOES trades and for NYSE trades. We separate the effects of SOES day trades and other trades with a simple formula (described in Section 4.4).

[15] Houtkin (1995, p. 39) states, after describing the reduction of the maximum trade size to 500 shares at the time he was writing: "1,000 shares has proven to be a more optimally sized order [than a smaller order]." Our discussions with market makers additionally support our assumption that SOES bandits trade the maximum number of shares per order. Harris and Schultz (1997) and Battalio, Hatch, and Jennings (1997) also use this metric. Harris and Schultz (1998, p. 40), who study individual SOES day trades, state: "Trades are for 1000 shares because that is the maximum size allowed in SOES."

4. Informed-trade losses due to SOES day trading

4.1. Concepts, measurement, and previous studies

As noted above, NASDAQ market makers incur an opportunity loss when they sell a stock at time t for less than they would have received had they sold it at time $t+\tau$ or when they pay more for a stock at time t than they would have paid had they bought the stock later, at time $t+\tau$. They gain from the reverse sequence — selling stock at a lower price than a later possible purchase and buying at a higher price than a later sale.[16] We term these "informed-trade" losses and gains, on the assumption that one side or the other has superior information or ability.

Harris and Schultz (1997) examine transactions from a sample of 20 NASDAQ stocks with the greatest market capitalization at year-end 1993 over the period November 1, 1993 through March 31, 1994. Defining SOES day trades as "clusters … of three or more consecutive trades [at the same quoted price] of the maximum allowable size under the prevailing SOES rules, "they find" that in the twenty minutes after 1000- [or 500-] share clustered buying [or selling] begins, the bid [or ask] price of the stock increases [or decreases] by about $.18 on average [ibid., p. 137]." No significant change was found for other trade sizes. Harris and Schultz (1997, p. 165) interpret this finding as "[indicating] that SOES trades have greater information content than other trades." They also state that their results "confirm that SOES bandits and other traders submit clusters of orders that trade ahead of short-term price changes [ibid., p. 158]." Battalio, Hatch, and Jennings (1997) report a similar trading pattern. Thus, these findings indicate that SOES day traders impose informed-trade opportunity costs on market makers.

HS (1996) study 1991 data for 175 pairs of NASDAQ and NYSE stocks with a procedure that yields opposite results. They calculate the market makers' "realized half-spread" as the increase or decrease in the price at which a stock is purchased or sold (identified as such with the Lee and Ready, 1991 algorithm, which we also use) and its price (not identified as a purchase or sale) five or thirty minutes later. They find: "For all trades at the bid, the realized half-spread averages 15.3 cents … [and] for all trades at the ask, the realized half spread averages 13.6 cents [ibid., p. 328]." These results are essentially the same for the five and thirty minute intervals and for each of the three trade sizes specified (<1000 shares, 1000<10,000 shares, and 10,000+ shares). Similar calculations reveal much smaller, insignificant amounts for a matched sample of NYSE stocks. Based on these findings, HS "reject the theory that higher execution costs on NASDAQ are the result of an inability of dealers to cope with adverse information and SOES bandits [ibid.]." BK similarly measure realized half spreads for a paired sample of 300 NASDAQ and 300 NYSE stocks in 1994. They divide this sample into small trades (less than $10,000), medium trades ($10,000 through $199,000), and large trades (over $200,000). They also report higher realized half spreads for NASDAQ than for NYSE stocks (where higher amounts indicate greater costs to investors and gains to NASDAQ market makers and NYSE specialists, floor traders, and limit orders), although their numbers are 24.9 basis points for NASDAQ and 12.5 basis points for NYSE transactions. Based on this finding, they conclude that "the wider quoted and effective spreads on NASDAQ cannot be attributed to greater adverse information costs on NASDAQ [ibid., p. 300]."[17]

The conflicting and inconsistent findings reported by Harris and Schultz (1997), HS, and BK could be due to the different samples or time periods studied or to the way they measure informed trades (which they call adverse selection).[18] Unlike the realized spread measure employed by HS and BK, we measure the opportunity gain or loss to liquidity suppliers. We ask: "if liquidity suppliers been able to wait 300 seconds before executing a buy or sell, would they have gained or lost as a result of having waited?" We measure this opportunity cost by comparing a buy/sell

[16] We did not employ the procedure used by Barclay and Hendershott (2004) (which is due to Lin et al., 1995, who cite other papers from which the method is derived), of regressing the change in quote on the effective spread to calculate a coefficient that measures the proportion of the spread due to adverse selection costs, as we believe it is not applicable to the situation we study. Day traders take advantage of stale quotes, wherein the BBO has changed but some market makers have failed to change quickly enough. Also, our method of sectioning trades into relatively small divisions allows us to control of differences in transactions costs (which Lin et al., 1995 find are a function of trade size) and inventory costs are small (given the short time spans considered herein and as found by other studies).

[17] Foucault et al. (2003) present a model of SOES bandit behavior and empirical estimates of their effect on spreads based on December 1996 data. We believe that their model is incorrectly specified, in large measure because they do not consider bandits' payoffs from picking off stale quotes and their use of the "monster button." Among other shortcomings, they do not consider the effect of ECNs in December 1996. Furthermore, they assume that the effect of SOES banditry is reflected both immediately and only on the spreads of the individual stocks they trade. As we point out, market makers could not know which stocks would be subject to SOES day trades and hence had incentives to offer quotes that reflected the cost imposed on them by that otherwise unpriced option.

[18] Neither Harris and Schultz (1997) nor BK contrast their findings with those of HS.

initiated trade with a subsequent buy/sell initiated trade 300 seconds later. In contrast, HS and BK compare each trade, identified as buy- or sell-initiated, with a subsequent trade at least 30 minutes later that can be either buy- or sell-initiated — in effect comparing the initial transaction with the subsequent spread midpoint.[19]

Realized spreads measure the cost incurred by market makers assuming that they unwind their position randomly at the bid or the ask. Our intent, though, is not to measure the change in dealer net profits from mandatory SOES. We are unable to fully measure all dealer costs since major components, such as the costs of drastically reduced coverage by individual market makers and the cost of software and systems to minimize stale quotes, are not observable. Thus, we focus directly on the information content of trades, rather than on realized spreads and dealer profits. We do not claim that NASDAQ dealers did not make potentially large profits, perhaps as a result of collusion or payment for order flow. We simply argue that SOES, both directly and indirectly, caused effective spreads to widen above and beyond the impact of other factors.

In addition, HS and BK do not distinguish among trades made by SOES bandits and those made by other traders. We separate the data into six trade sizes, which allows us to isolate and test hypotheses about the possible effect of SOES day trading.

4.2. Per trade basis point opportunity losses or gains to NASDAQ market makers (and other traders) from informed trades, not yet adjusted for other-than-SOES day trades or offset by larger effective spreads

We use the Lee and Ready (1991) algorithm to identify each transaction at time t in stock i by a market maker as a buy or sell.[20] The opportunity loss or gain on the transaction is measured by the change in the price of the next purchase if the initial transaction is a purchase or sale if the initial transaction is a sale that occurs at least five minutes later, at $t+\tau$, within the same day.[21] Consequently, we exclude trades that occur in the last five minutes of the trading day, and trades during a day that are not followed by a trade on the same side of the spread. The liquidity provider suffers an opportunity loss when, for a sale, $P_{it+\tau}-P_{it}>0$ or, for a purchase, $P_{it+\tau}-P_{it}<0$, and gains when the reverse occurs. To account for differences at a point in time and changes over time of the prices of the stocks traded, we divide the opportunity loses or gains for each transaction by P_{it}, to obtain the percentage loss or gain (in basis points).

As noted earlier, to provide adequate tests of the hypotheses, we disaggregate the NASDAQ and NYSE data into five trade sizes that can be transacted through SOES – 100, 101–499, 500, 501–999, and 1000 shares – and one trade size that cannot be transacted through SOES-1001–5000 (1–5K) shares. The informed-trade (opportunity) loss or gain is assigned to a trade size according to the number of shares of the first transaction (P_{it}). The observations are stock days. Within a day, for each trade size, we average the calculated informed-trade basis points; for trade sizes that cover a range (e.g., 101–499 shares), the dollar volumes of each transaction weight the basis points. The gains or losses are not further weighted, yielding informed-trade basis points on the average stock on the average day. If we did not do this, the very high volume stocks would dominate the findings.

Fig. 3 shows liquidity supplier's (opportunity) gains and losses per trade in basis points from informed and uninformed trades for the average stock on an average trading day in a month, January 1987 through December 1999, for each of the six trade sizes. Before June 1988, when SOES was made mandatory (excluding the 1987 "market crash" months of October, November, and December), market makers had informed-trade losses on 500- and 1000-share trades (denoted by stars and triangles), each averaging 16 basis points (17 if the market-crash months were included).

[19] We examined lengths greater than 300 seconds but found that greater lengths provided similar results while 300 seconds increased our sample size.

[20] Ellis, Michaely and O'Hara (2000) compare the accuracy of this quote procedure with a tick rule, the Lee and Ready (LR) [1991] combined tick rule for trades at the BBO midpoint and quote rule for other trades, and their alternative of using the quote rule for trades executed at the quote and the tick rule for all other trades. Using a sample where the direction of the trade is known, they find that their alternative is more accurate for transactions other than at quotes (61% vs. 55%). However, they find almost no difference in accuracy using the LR rule for trades of 5000 shares or less. (They do not present such data for their quote-tick alternative.) Hence, although their alternative might be more accurate than the quote rule we employ, we believe that there is no bias among the trade sizes we examine, which is central to our investigation. Misidentification of purchases or sales bias our measure of market makers' informed trade costs downward, as illustrated earlier, thereby understating their costs of trades by SOES bandits.

[21] To the extent that market makers do not report trades in the exact order they are effected, there can be sequencing error. However, this is mitigated by our using a five-minute delay. HS used both 5 and 30 minute delays and BK used both 30 minute and 1 day delays, with similar results. Furthermore, there is no reason to believe that this problem imparts a bias, as there was no change in practice or association with a given trade size of which we are aware over the period studied.

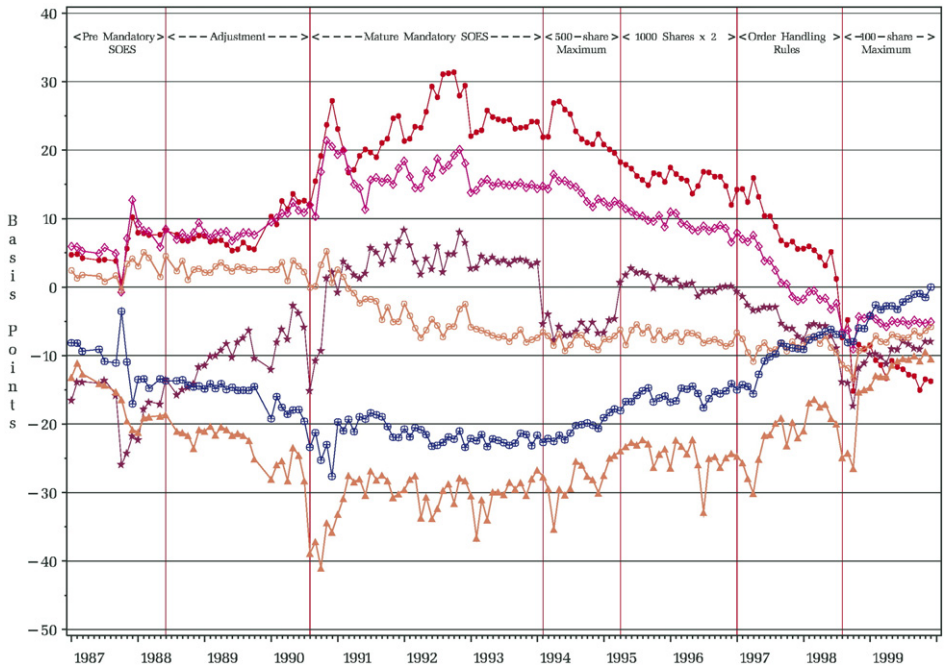

Fig. 3. Monthly average gains (losses) per trade to NASDAQ market makers from informed trades, in basis points 100 share trades = (●), 101–499 = (◇), 500 = (★), 501–999 = (○), 1000 = (▲), 1–5K = (⊕).

Apparently, informed traders used both trade sizes, as these often were the quoted amounts posted by market makers. After SOES was made mandatory, the percentage of informed-trade losses on 500-share trades declined until they became an average gain of 3 basis points in the "Mature Mandatory SOES" period, 8/90–1/94. The relative volume of 500-share trades declined similarly, as shown in Fig. 2. Informed-trade losses on 1000-share trades, which include both SOES day trades and other transactions, increased to 31 basis points, on average, in the "Mature Mandatory SOES" period.

When the maximum SOES trade size was reduced to 500 shares during the "500-share Maximum" period, market makers' informed-trade losses on 1000-share trades declined by an average of 2.5 basis points, while those on 500-share trades increased by 8.7 basis points. We interpret these continuing, though somewhat lower, average informed-trade losses on 1000-share trades when 500 shares was the SOES maximum as showing that some SOES day traders successfully shifted their trades to SelectNet and telephone orders. They took advantage of NASDAQ's requirement (beginning in 1991) that market makers must fulfill quotations for at least 1000 shares from those sources (per interview with Gene Finn, then Chief Economist for NASDAQ). Harris and Schultz (1997, p. 139) also state: "brokerage firms who specialize in trading for SOES bandits generally allow customers access to [SelectNet and Instinet] through their trading desk." Following restoration of the maximum trade size to 1000 shares, in the "1000 Shares × 2" period average informed-trade losses on 500-share trades decreased by 7 basis points to a 1 basis point gain, while average losses on 1000-share trades continued to become somewhat smaller. Over the next two periods, market makers experienced increased losses on 500-share trades and smaller losses on 1000-share trades. After July 1998, when SOES was limited to 100-share trades, informed trade losses on 1000-share trades were fairly close to the amount in the Pre-mandatory SOES period, 1/87–5/88.

In contrast, market makers experienced similar informed-trade gains from 100-share and 101–499-share trades (denoted by solid circles and diamonds) through mid-1998, when 100 shares became the SOES maximum for all stocks. (Note that, except for 500-share trades when these were the maximum, after the "Pre-mandatory SOES" period the patterns for trades of less than 1000-share trades are similar.) These gains were about 8 basis points through mid-1990, then about 14 basis points through mid-1994, after which the gains decreased. However, after market makers were allowed to reduce the number of shares quoted to 100 on some stocks after 1996 and on all stocks after July 1998 informed-trade gains on 100-share trades became losses — 14 basis points by December 1999.

Trades of 1–5K shares (denoted by crosses within circles), which cannot be made through SOES, provide a control. Market makers suffered informed-trade losses on the 1–5K-share trades averaging 11 basis points before SOES was made mandatory (excluding the market crash months), gradually increasing to about 16 basis points through March/April 1997, and then decreasing to 2 basis points by December 1999. Thus, 1000-share trades and 500-share trades during the 500-share maximum appear to have imposed substantially greater informed-trade losses (or gains) on market makers than other trade sizes. In our calculations of the amounts of these increases due to SOES day traders (presented in Section 4.4), we take into account the changes in informed-trade losses from 1–5K-share trades.

The data are summarized in Table 1, Panel A, which presents the percentage-of-share-price gains (losses) per trade in basis points for each of the six trade sizes, averaged over the seven periods that describe states of SOES history. With very few exceptions (noted in Panel D of the table), these amounts are significantly different from zero at the .01 level or lower. Over the 77 months when day trading through SOES was most prevalent (8/90–12/96), market makers had informed-trade losses on 1000-share trades averaging (over all months) 29 basis points, compared to average informed-trade losses on 1–5K-share trades of 20 basis points. Market makers had informed-trade gains averaging 21 and 14 basis points on 100- and 101–499-share trades, and almost no gains or losses on 500-share trades (excluding the period when 500 shares was the maximum SOES-eligible trade size) and losses of 5 basis points 501–999-share trades. (The averages are lower by one to two basis points if the "Adjustment" period months were included.) Also shown are the percentages of 1000-share trades to all trades of 1000 shares or less (1000 sh. % of all <=1000).

4.3. Comparison with NYSE trades

Similarly computed informed trade gains and losses for NYSE liquidity providers over the same period and for the same trade sizes as the NASDAQ trades can serve as an indicator of the extent to which the informed trade gains and losses experienced on NASDAQ are due to time-dependent factors that affect stock trading generally or the trades through SOES, which are unique to NASDAQ.[22] The data, presented in Panel C of Table 1, indicate relatively small mean informed trade losses to specialists, floor traders, and limit orders for all trade sizes and all periods, all significantly different from zero at the .01 level. (Since the pre-mandatory-SOES base period is subtracted, the *t* test provides a measure of significant difference from that period.) This finding might be due to specialists, who are required to stabilize prices by moving against the market or (more likely) to losses incurred on limit-orders, which offer other investors options similar to those offered by NASDAQ market makers to informed traders (e.g., SOES day traders). Indeed, Harris and Hasbrouck (1996, Table 7), who measure the ex-post order performance of NYSE completely filled limit orders using a procedure similar to the one we employ, find uniformly negative performance at a time (November 1990–January 1991) when the market generally was rising.[23] In our NYSE sample, the ranges of the mean number of negative basis points over the seven SOES periods for each trade size are: 100-share trades, 1–2; 101–499-share trades, 2–3; 500-share trades, 5–7, 501–999-share trades, 4–5, 1000- and 1–5K-share trades, 3–6. The changes in the means from period to period are either 0 or 1 basis point and the maximum cumulative change is 2 basis points. None of the changes is significant. Thus, the NYSE data are consistent with the hypothesis that SOES substantially affected informed trade gains and losses on NASDAQ and inconsistent with there having been a market-wide change in informed trading.

4.4. Adjustment for NASDAQ informed trades by other-than-SOES day traders

We employ two procedures for adjusting the NASDAQ data for trades by other-than-SOES day traders from which we can separate losses from SOES day traders and other traders who make 1000-, 500-, and 100-share trades, when these were the maximum SOES trade size: (1) deduction of informed-trade losses and gains in each trade size in the

[22] We understand that NYSE specialists sometimes list (report) as a single trade several individual trades that cleared at the same price. To the extent that this occurs, the NYSE trade sizes are incorrect. We understand that this practice did not change over the thirteen years studied. Indeed, as shown in Fig. 2, the proportion of NYSE 500- and 1000-share trades was almost unchanged over the period studies. Table 1 shows almost unchanged NYSE adverse selection losses by trade size over the period. Thus, either this practice does not affect the NYSE data much or, if it did, does not affect our findings.

[23] Battalio et al. (2002) also measure the performance of limit orders in October–November 1990 and find small positive returns. However, they state: "the order pairs likely to be included in our performance measure are those associated with small positive returns. Thus our economic performance measure, by examining only order pairs with exactly one order filing, is likely to differ from the negative performance of Harris and Hasbrouck (1996) and SEC (1997) that include all filled orders [ibid., note 16, p. 178]."

Table 1
Opportunity gains (losses) per trade to NASDAQ market makers from informed trades on the average stock on the average day, in basis points by size of trade averaged over pre- and post-mandatory SOES periods, January 1987–December 1999. This table shows the opportunity gains (losses) to market makers ascribed to informed trades by SOES day traders and others, grouped according to trade size. The observations include stocks for which there are at least five trades in a day and trades at least 5 min later on the same side of the BBO, aggregated daily for each stock. The observations (stock days) are averaged over months and the months are averaged over periods that describe stages of SOES history. Panels A and B show the informed-trade losses (gains) for each of the periods (and the percentages of 1000-share trades to total trades of 1000 shares or less) for the NASDAQ and NYSE samples. Panel C reduces the NASDAQ amounts to those ascribed to mandatory SOES trading by subtracting the averages of informed-trade gains (losses) in the pre-mandatory SOES period from those in the following periods and also subtracting the change from the "Pre-mandatory SOES" period in informed-trade gains (losses) on the same-trade-size NYSE stocks, except for 500-share trades and 100-share trades when these were the SOES maximum trade size, as described in note 1. The amounts estimated as due to day trades, rather than to trades of the same size when the size was the SOES maximum, are calculated with formula (1a) described in the text, using "1000 sh.% of all b = 1000" given in Panel A to estimate the percentage of 1000-share trades made by SOES day traders. The amounts for other-than day trades (IT_O) are described in note 1. Panel D indicates the statistical significance of the means presented in Panels A, B, and C

		SOES-eligible trade sizes (number of shares per trade)					1000 sh. % of all <=1000	SOES ineligible 1–5K
Periods	No. months*	100	101–499	500	501–999	1000		
A. NASDAQ								
Pre-mandatory SOES (1/87–5/88)	10**	6	6	(16)	2	(16)	41%	(11)
Adjustment (8/88–7/90)	22	8	9	(9)	3	(23)	53%	(16)
Mature Mandatory SOES (8/90–1/94)	42	23	16	3	(4)	(31)	61%	(22)
500-share Maximum (2/94–3/95)	14	23	14	(6)	(8)	(28)	52%	(21)
1000 shares × 2 (4/95–12/96)	21	16	10	1	(7)	(25)	67%	(16)
Order Handling Rules (1/97–7/98)	19	8	2	(5)	(8)	(21)	60%	(10)
100-share Maximum (8/98–12/99)	17	(11)	(5)	(10)	(8)	(14)	44%	(4)
Average 8/90–12/96 [note 2]		21	14	1	(6)	(29)	61%	(20)
B. NYSE								
Pre-mandatory SOES (1/87–5/88)	10**	0	(3)	(6)	(5)	(6)	29%	(6)
Adjustment (8/88–7/90)	22	(0)	(2)	(6)	(4)	(5)	29%	(6)
Mature Mandatory SOES (8/90–1/94)	42	(1)	(3)	(7)	(5)	(6)	28%	(7)
500-share Maximum (2/94–3/95)	14	(1)	(2)	(6)	(4)	(5)	30%	(6)
1000 shares × 2 (4/95–12/96)	21	(1)	(2)	(5)	(4)	(5)	30%	(5)
Order Handling Rules (1/97–7/98)	19	(1)	(2)	(5)	(3)	(5)	31%	(4)
100-share Maximum (8/98–12/99)	17	(2)	(2)	(6)	(3)	(5)	30%	(4)

C. NASDAQ mandatory-SOES periods less pre-mandatory period means [note 2] less similar NYSE change

	No. months*	100	101–499	500	501–999	1000 other	Day trades	1–5K
Adjustment (8/88–6/90)	22	3	2	6	(0)	(5)	(17)	(5)
Mature Mandatory SOES (8/90–1/94)	42	18	10	19	(6)	(10)	(23)	(10)
500-share Maximum (2/94–3/95)	14	18	7	0	(10)	(10)	(24)	(10)
500-share day trades							(18)	
1000 shares × 2 (4/95–12/96)	21	12	3	(3)	(11)	(5)	(15)	(5)
Order Handling Rules (1/97–7/98)	19	4	(6)	(9)	(13)	(1)	(19)	(1)
100-share Maximum (8/98–12/99)	17	0	(12)	(14)	(12)	6		6
100-share day trades							(14)	
Average 8/90–12/96 [note 2]	77	17	7	10	(8)	(9)	(21)	(9)

D. Statistical significance of means at the .01 level or lower
Panel A: significantly different from zero, all means except:
"Order Handling Rules" period: 101–499 shares (.08 level)
Significantly different from "Pre-mandatory SOES" period means, all means except:
"Adjustment" period: 501–999 shares (.09 level)
"Order Handling Rules" period-100 shares (.02 level) and 1–5K shares (.09 level)
"100-share Maximum" period: 1000 shares (.27 level)
Panel B: significantly different from zero, all means
Significantly different from "Pre-mandatory SOES" period means, all means except:
"Adjustment" period: 1000 and 1–5K shares
"Mature Mandatory SOES" period: 101–499 shares (.04 level); 500 and 501–999 shares

Table 1 (*continued*)

Periods	No. months*	SOES-eligible trade sizes (number of shares per trade) 100	101–499	500	501–999	1000	1000 sh. % of all <=1000	SOES ineligible 1–5K
D. Statistical significance of means at the .01 level or lower								
Panel B: significantly different from zero, all means								
"500-share Maximum" period: 1000 shares (.06 level); 1–5K shares								
"100-share Maximum" period: 500 shares (.03 level)								
Panel C: significantly different from zero, all means except:								
"Adjustment" period: 501–999 shares								
"Order Handling Rules" period: 1–5K shares								
"100-share Maximum" period: 1000 shares								

*data for 4/87, 5/87, 8/87, 4/88, 7/88, 11/89 and 12/89 are not available.

**excluding the 1987 market crash months of October, November, and December.

Note 1: basis points for other-than day trades (IT_O) for 1000 share trades are basis points for 1–5K trades; for 500-share and 100-share trades when these were the SOES-maximum trade size, amount in previous period plus the change in 101–499-share trades from its previous period amount adjusted for the change in those periods of NYSE amounts for 500- or 100-share trades.

Note 2: weighted by number of months; in Panel B, excludes 500- and 100-share day trades listed with 100-share trades.

period before SOES was made mandatory, adjusted for contemporaneous changes in NYSE trades, and (2) calculations based on changes in the percentages of 1000-, 500-, and 100-shares when these became and later no longer were the SOES maximum trade sizes.

As shown in Fig. 3 and Panel A of Table 1, market makers experienced informed-trade losses and gains before SOES was made mandatory in June 1988. After the SOES maximum trade size was reduced to 100 shares, largely after July 1998, the levels of informed trade losses and gains generally returned to or towards these pre-mandatory SOES levels (particularly for 1000-share trades), except for 100-share trades which then became the SOES maximum trade size. Consequently, we estimate **n**et mandatory-SOES-related **i**nformed-**t**rade costs and gains (NIT) on **N**ASDAQ (N) for each trade **s**ize (s) in a mandatory-SOES **p**eriod (p), NIT_{Nsp}, as follows. We start with the NASDAQ informed-trade basis points (IT_{Nsp}) and subtract the average basis points in the **b**ase "Pre-mandatory-SOES" period (excluding the 1987 market crash months, which only slightly affects the numbers) (IT_{Nsb}). The difference, ($IT_{Nsp} - IT_{Nsb}$), is the increase or decrease over the base. To account for changes due to other factors that occurred in the same period, we next subtract the comparable N**Y**SE change ($IT_{Ysp} - IT_{Ysb}$). Thus, $NIT_{Nsp} = IT_{Nsp} - IT_{Nsb} - (IT_{Ysp} - IT_{Ysb})$. Panel C of Table 1 presents these differences.

The net informed-trade basis points include trades by both SOES day traders and other traders of 1000 shares and, at times, 500 and 100 shares. We estimated the net informed-trade basis points on SOES day trades for each mandatory-SOES period by noting that the amounts that we calculate (NIT_{Nsp}) are weighted averages of SOES day trades (NIT_{DT}) and other informed trades (NIT_O), where P_{DT} equals the percentage of the dollar volume of day trades to the dollar volume of total trades of the same share size:

$$NIT_{Nsp} = NIT_{DT} * P_{DT} + NIT_O * (1 - P_{DT}), \text{ or} \tag{1}$$

$$NIT_{DT} = 1/P_{DT} * (NIT_{Nsp} - NIT_O) + NIT_O. \tag{1a}$$

For 1000-share trades we determined P_{DT} by deducting the percentage of 1000-share trades in the "Pre-mandatory-SOES" period from the percentage in each subsequent period (shown in the second column from the right in Panel A of Table 1 labeled "1000 sh. % of all <=1000") and dividing the difference by that percentage to obtain an estimate of the percentage increase due to SOES day trading. P_{DT}, thus calculated, is 23.6% in the "Adjustment" period, 33.3% in the "Mature Mandatory SOES" period, 21.7% in the "500-share Maximum" period, 39.0% in the "1000 Shares × 2" period, 32.1% in the "Order Handling Rules" period, and 6.5% in the "100-share Maximum" period. These percentages tend to overestimate the proportion of SOES day trading to the extent that some of the proportional increase was in other 1000-share trades. In particular, it might seem strange that when the maximum SOES trade size was reduced to 500 shares, the percentage of 1000-share trades declined by 9.1 percentage points to 52% rather than to 41%, the percentage before SOES was made mandatory. As described earlier (discussion of Fig. 3), the bandits could effect 1000-share trades through venues other than SOES (e.g., SelectNet and telephone). Note, though, that

lower P_{DT} would result in higher day-trade informed-trade losses. IT_O is assumed to be equal to the NYSE-adjusted change on 1–5K-share trades of the same stocks. (Since NIT_{Nsp} is given, lower assumed values for NIT_O would yield higher values of NIT_{DT}.) Our calculation of informed-trade losses on day trades (NIT_{DT}) is shown in Panel C of Table 1. These average informed-trade losses (which tend to be understated) range over the periods between 15 and 24 basis points and average 21 basis points over the 77 active-SOES months, 8/90–12/96 (20 basis points if the "Adjustment" period were included).

For 500-share trades, when this was the maximum SOES trade size (2/94–3/95), the dollar volume of 500-share trades to the total dollar volume of trades of 1000 shares or less increased by 10.4 percentage points (from 19.1 to 29.6% of the total), apparently due to SOES day trading. Thus, assuming that just previously there were no 500-share day trades, during the "500-share Maximum" period P_{DT} equals 54.5%. During this period, informed-trade losses on 500-share trades increased by 9 basis points, from a positive 3 to negative 6 basis points. We assumed that NIT_O is the same as the basis points in the previous period plus the NYSE-adjusted (negative) change in 101–499-share trades from its previous period basis points, from which we calculated average informed trade losses of 16 basis points. During this period we also calculate average informed-trade losses for 1000-share trades of 26 basis points, which is consistent with some day traders having shifted to SelectNet and telephone orders, as discussed earlier.

We used the same procedure to calculate informed-trade losses to SOES day traders who use 100-share trades in the "100-share Maximum" period. We calculated that P_{DT} is 116.2%. For NIT_O we use the previous period amount, 3 basis points plus the NYSE-adjusted (negative) change in 101–499-share trades, from which we calculated informed-trade losses (NIT_{DT}) of 14 basis points.

Market makers, though, obtained additional informed-trade gains from trades of 100, 101–499, and 500-shares (except when this was the maximum-SOES size). We suggest that these gains are associated with SOES day trading, because they are due to market makers' efforts to reduce informed-trade losses by updating quotes more rapidly, in part by having traders follow fewer stocks. We next measure the extent to which market makers acted to offset these increases in informed-trade and other related trading costs (e.g., labor and equipment expense), thereby increasing effective spreads.[24]

5. The effect of SOES day trades on relative effective spreads (RES)

5.1. Measurement of RES

As noted earlier, market makers might react to higher informed-trade costs imposed by SOES day traders by increasing selling prices and decreasing buying prices for stock. We analyze the extent to which this occurred with relative effective spreads (RES). The effect on RES of the number of shares traded is accounted for by grouping the data into the six trade-size groups analyzed earlier. Within each trade size group, the RES for each stock for each trading day are averages of the RES on each trade; for the trade sizes that include a range (e.g., 101–499 shares), we weight the transactions by the number of shares traded. The observations are "stock-days." The monthly data for NASDAQ stocks are presented in Fig. 4. RES on NYSE stocks are similar among the six trade sizes, with RES on 1000-share trades about 8 basis points lower through 1991, after which the difference gradually declines to about 3 basis points, as shown in Table 2, Panel B. Over the thirteen years studied the NYSE RES follow the pattern shown in Fig. 1.

5.2. Relative effective spreads (RES) by size of trade

Fig. 4 and Table 2 extend and confirm the analysis of RES shown in Fig. 1 by trade size. We estimated the effect of SOES day trading on NASDAQ RES with the same procedure used for informed trades, as described in Section 4.4. That is, we calculated the additional RES in the post-mandatory-SOES periods by subtracting from the RES in each period the RES in the pre-mandatory-SOES base period adjusted for the comparable NYSE change in

[24] We acknowledge the following limitations of the above analysis: (1) miss classification of buys and sells by the Lee–Ready algorithm and (2) the increasing posting of limit orders on Instinet (and later their competitors) by buy-side traders attracted to earning the widened spread with patient trading. Both factors will, to a degree, distort this analysis.

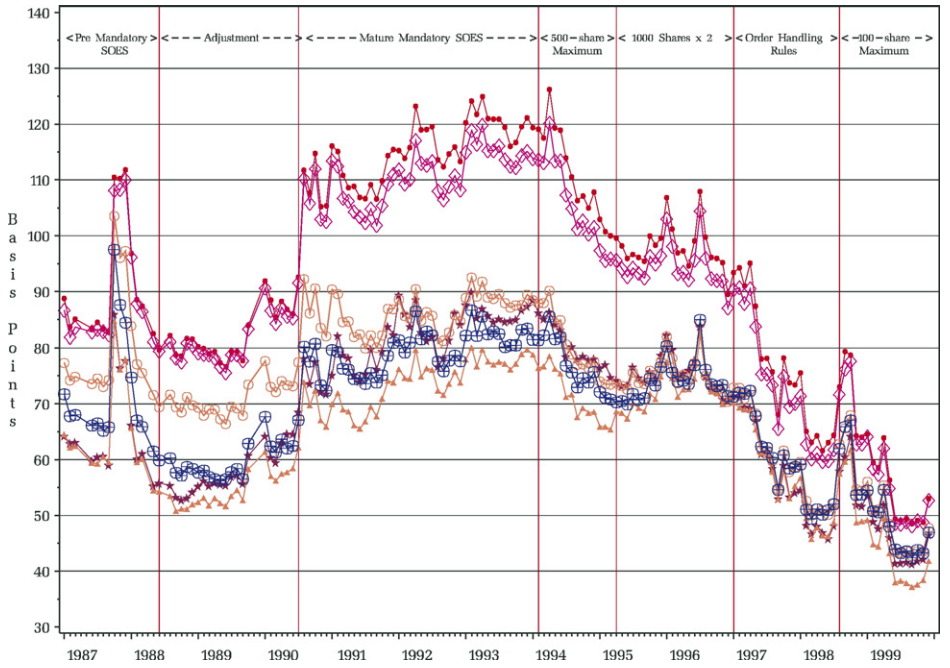

Fig. 4. Relative effective spreads (RES) by trade size 100 share trades = (●), 101–499 = (◇), 500 = (★), 501–999 = (○), 1000 = (▲), 1–5K = (⊕).

RES, and then calculated the RES due to SOES day trades with Eq. (1a), where RES is substituted for informed trades (IT).

In the "Pre-mandatory SOES" period RES are ordered by trade size with the exception of 500 and 1000-share trades, which have the lowest RES. This lends credence to the NASD's assertion that some stale quotes were being picked off before SOES became mandatory. In the "Mature Mandatory SOES" period we see the dramatic increase in 100 and 101–499 RES accompanied by substantial increases in the other trade sizes. As SOES day trading increased through mid-1990 (see Fig. 2), market makers increased their quoted offers and decreased their quoted bids, thereby increasing RES on shares traded at the quote, apparently to compensate for the informed trade losses and trading costs imposed by SOES day traders.

We ascribe the negative RES calculated for the "100-share Maximum" period primarily to the Order Handling Rules that became effective during 1997. The switch from 1/8th to 1/16th tick size in July 1997, accompanied by the elimination of the Excess Spread Rule also contributed to the decline in RES.

Note that RES on 1000-share trades did not increase as did RES on the smaller trade sizes, despite the higher informed trade and operating costs imposed on NASDAQ market makers. We believe this is due to two factors. One is that SOES day traders were able to obtain shares at quoted prices before the market makers could change the quotes, which is their essential strategy; this reduced their RES. The other factor is that they could bargain for prices within the quotes when laying off their inventory, similar to negotiations effect by other traders in large numbers of shares, as is shown next.

5.3. Trading inside the spread

In the "Pre-mandatory SOES" period the percentage of trading inside the spread on NASDAQ was under 5% with a brief exception during the crash period (see Fig. 5). Apparently traders were for the most part satisfied with trading at the spread. Then in mid-1989 the widening of spreads was accompanied by a rapid increase in trading inside the spread, ordered by trade size. We ascribe this change as due to market makers giving preferential pricing to known institutional customers that were not SOESing them.

The percentage of larger-size (1K and 1–5K) trades inside the BBO increased, as shown in Fig. 5, from about 5% in mid-1989 to 22 and 27% in early 1994. Over this period, the percentages also increased for smaller trade sizes. These increases explain the approximate stability of RES through about March 1996 for trades of 500 shares and larger, and

Table 2
Relative effective spreads (RES), transactions on NASDAQ and the NYSE by size of trade averaged over pre- and post-mandatory SOES periods, January 1987–December 1999. This table shows the RES accruing to market makers from SOES day traders and others, grouped according to trade size. For each transaction the RES are calculated as twice the absolute difference between the transaction price and the midpoint of the best bid and offer (BBO), divided by the midpoint price, in basis points, and are aggregated daily for each stock. The observations (stock days) are averaged over months, which are averaged over periods that describe stages in SOES history. Panels A and B show the RES on NASDAQ and NYSE trades. Panel C presents, for each period during which SOES was mandatory and trade size, the RES on NASDAQ stocks less the adjusted RES on NYSE stocks (RES plus the difference between the NASDAQ and NYSE RES in the "Pre-mandatory SOES" period). Panel C provides an estimate of the additional changes in RES associated with SOES, using Eq. (1a) as described in the text and in Table 1

		SOES-eligible trade sizes (number of shares per trade)					SOES ineligible
Periods	No. months	100	101–499	500	501–999	1000	1–5K
A. NASDAQ							
Pre-mandatory SOES (1/87–5/88)	10**	86	85	61	76	61	68
Adjustment (8/88–7/90)	22	82	82	58	71	55	60
Mature Mandatory SOES (8/90–1/94)	42	115	111	82	86	74	79
500-share Maximum (2/94–3/95)	14	111	106	80	80	71	77
1000 shares×2 (4/95–12/96)	21	98	95	76	75	72	74
Order Handling Rules (1/97–7/98)	19	76	73	57	60	57	60
100-share Maximum (8/98–12/99)	17	59	58	49	52	46	51
Average 7/90–12/96 [note 1]	77	110	105	80	82	73	78
B. NYSE							
Pre-mandatory SOES (1/87–5/88)	10**	39	40	41	40	31	40
Adjustment (8/88–7/90)	22	36	36	36	34	27	32
Mature Mandatory SOES (8/90–1/94)	42	37	37	37	36	30	36
500-share Maximum (2/94–3/95)	14	33	34	34	33	28	35
1000 shares×2 (4/95–12/96)	21	29	30	30	30	26	32
Order Handling Rules (1/97–7/98)	19	23	24	24	24	21	26
100-share Maximum (8/98–12/99)	17	24	25	26	26	23	30
Average 7/90–12/96 [note 1]	77	34	34	35	34	28	35

C. NASDAQ less adjusted NYSE (NASDAQ less NYSE in the "Pre-Mandatory SOES" period)

		100	101–499	500	501–999	1000 other	Day trades	1–5K
Pre-mandatory SOES: NASDAQ less NYSE	10**	47	45	20	35	29		27
Adjustment (8/88–7/90)	22	(1)	1	2	2	(1)	(7)	1
Mature Mandatory SOES (8/90–1/94)	42	31	29	24	15	15	13	16
500-share Maximum (2/94–3/95)	14	31	27	26	12	14	10	15
500-share day trades							28	
1000 shares×2 (4/95–12/96)	21	22	20	25	10	17	20	15
Order Handling Rules (1/97–7/98)	19	6	4	13	1	7	8	6
100-share Maximum (8/98–12/99)	17	(12)	(12)	3	(9)	(7)		(6)
100-share day trades							(10)	
Average 7/90–12/96 [note 1]	77	29	26	25	13	15	14	15

All means are statistically significantly different from zero at least at the .01 level, except Panel C.
Adjustment: 100, 101–499, 500 (5% level), 1000 (9% level), 1–5K.
Order Handling Rules: 101–499 (5% level), 501–999.
100-share Maximum: 500.
*Data for 4/87, 5/87, 8/87, 4/88, 7/88, 11/89 and 12/89 are not available.
**Excluding the 1987 market crash months of October, November, and December.
Note 1: weighted by number of months; in Panel B, excludes 500- and 100-share day trades listed with 100-share trades.

through March 1994 for trades under 500 shares, and the subsequent declines in RES through 1998. In the 77-month active SOES period, 7/90–12/96, NASDAQ RES averaged 77 and 110 basis points for 100- and 101–499-share trades, and between 73 and 80 basis points for the other trade sizes. In contrast, over this period, NYSE RES averaged 28 basis points for 1000-share trades and 34–35 basis points for the other trade sizes. The percentage of NASDAQ trades inside the BBO, though, continued to increase only for trades of 500 and fewer shares. By year-end 1999, NASDAQ RES were both lower and closer to each other than before SOES was made mandatory, and the percentages traded inside the

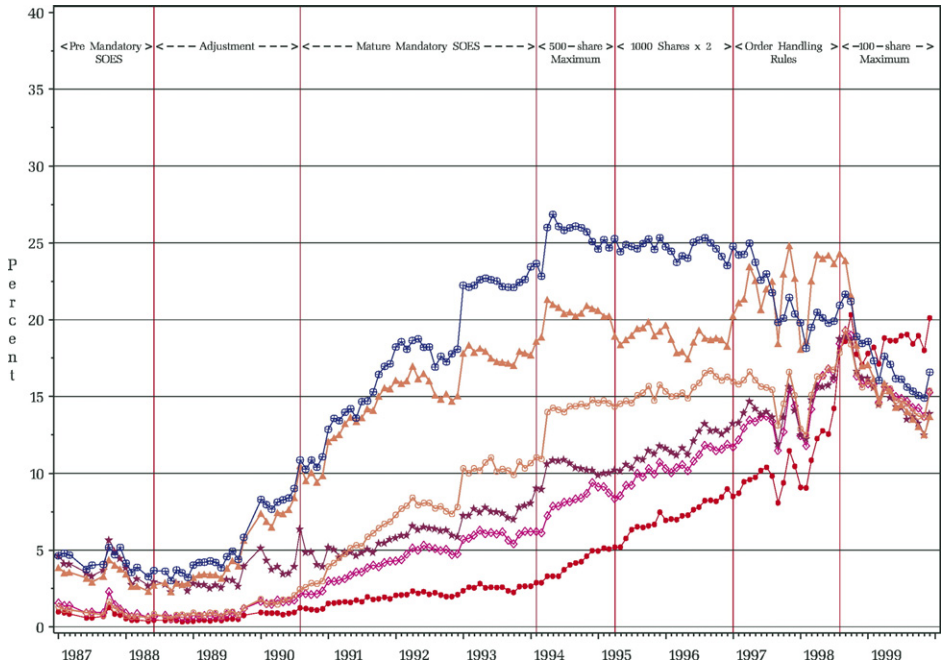

Fig. 5. Percentage of NASDAQ dollar volume traded inside the BBO by trade size 100 share trades = (●), 101–499 = (◇), 500 = (★), 501–999 = (○), 1000 = (▲), 1–5K = (⊗).

BBO were similar at about 15%. A notable exception is the increase in the percentage of 100-share trades inside the BBO after this became the maximum SOES trade size.

In June 1989 Instinet became anonymous. Then dealers who wished to display their customers' limit orders could do so without being subject to the 1/4 unwritten quote-change rule and without being SOESed. Hence, two markets developed — NASDAQ Level II and Instinet (and other ECNs as they developed). Increasingly institutional trading migrated to ECNs, as reflected in the widening gap between 100–499 share RES and the remainder. Since access to ECNs was by invitation only, retail business and SOES dealers (for the most part) were excluded from ECNs. Hence, both spreads and prices were much more favorable on Instinet. Consequently its volume soared and competition was attracted with the formation of additional ECNs. Thus all of our metrics are increasingly skewed by ECN trading, which we are unable to distinguish from NASDAQ dealer trading.

5.4. The extent to which estimated costs imposed by day traders explain the increase in NASDAQ over NYSE relative effective spreads (RES)

As shown in Fig. 3 and Table 1, we estimate that SOES day traders imposed costs on market makers. These additional costs, taken alone, only partially explain the higher RES shown in Fig. 1, since we estimate that SOES day trades comprise less than a quarter of the volume of trades of 1000 shares or less (see Table 1 Panel 3). However, the opportunity cost of "informed" day trades is only part of the cost imposed on market makers by day traders. Faced with having to offer day traders a free option to take out or sell up to 5000 shares at a quoted price before it could be changed, market makers reduced the number of companies each trader followed and invested in equipment that provide earlier warnings of interests in stocks followed. It also may be that market makers took advantage of their jointly experienced SOES day trades and increased selling prices and decreased buying prices more than necessary to offset costs imposed by day traders. Or, we may have underestimated the informed trade costs imposed by day traders.

Of course, some other factor not studied here or elsewhere may have played a role. As noted above, the possibilities suggested by other researchers are implicit collusion, preferencing, and payment for order flow. As also noted above, preferencing and payment for order flow do not fit the data pattern as there were no corresponding changes in these practices. If collusion were the prime mover, why were so many large traders permitted to trade inside the widened spreads? Consequently, we believe that the most likely cause of the dramatic increase in trading inside the spread

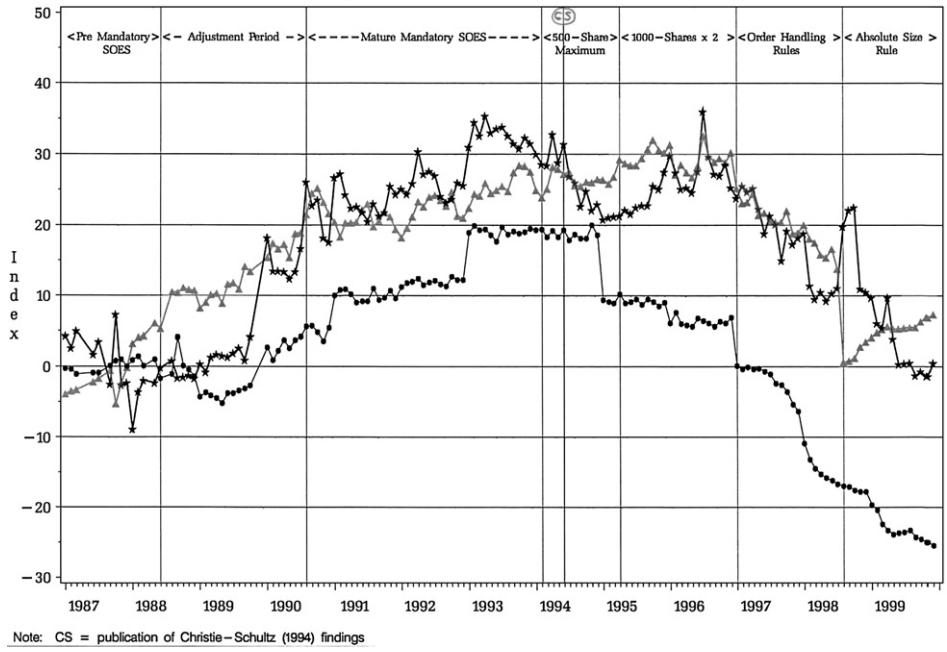

Fig. 6. Differences in relative effective spreads (RES) on NASDAQ and NYSE, percentages of volume at maximum SOES trade size to total dollar volume of 1000 shares or less, and percentage of stocks quoted on even eighths, monthly, 1987–1999 all normalized by dividing by averages over 1/87–6/88 NYSE–NASDAQ RES = (★), SOES maximum = (▲), % even eighths = (●).

coincident with mandatory SOES is pressure from SOES bandits which widened spreads, but trading inside the spread which was granted to known institutional traders.[25] The analysis of changes in the percentage of stocks quoted on even-eighths over the period studied, presented next, provides additional support for this explanation.

6. Comparison with the percentage of even-eighths

We examined the extent to which changes in SOES day trading and even-eighths quotations track changes in the difference in NASDAQ and NYSE RES over the 13 years studied in Fig. 6. For SOES day trades we used the volume of trades at the SOES maximum size to total trades of 1000 shares or less (denoted by triangles). We followed the Christie–Schultz [1994] rule for determining the percentage of even-eighths quotes. If 75% of the time-weighted BBOs in a month were both at even eighths, we classified the stock as "even-eighth."[26] Stocks quoted with an odd-sixteenth spread are less than one percent of the sample in all months prior to July 1997 and are but four percent in December 1997. However, in January 1998 this percentage is 13%, and it increases monotonically to 26% in December 1999.

To facilitate comparison, we normalized the data to equal about zero initially by dividing the monthly data by their averages over the "Pre-mandatory-SOES" period (1/87–6/88). For the even-eighths sample the average is 51.3; thus, before SOES was made mandatory, half the actively traded stocks on NASDAQ were quoted on even eighths. If "avoidance" of odd-eighths quotes by market makers were a valid measure of collusion, it would appear that there was no collusion on NASDAQ before mid-1988.

Fig. 6 shows a fairly close movement of all three series through 1994, with some important differences. The correlation coefficients of the RES Difference are 83% for the SOES Maximum Percentage and 65% for the Percentage Even Eighths. The SOES Maximum Percentage leads RES during the "Adjustment Period," while Percentage Even Eighths lags RES during this period and through most of the "Mature mandatory SOES" period. Interestingly, the percentage of even-eighths stocks increases through December 1992 and then plateaus through December 1994, before

[25] Further, as previously noted many ECN trades would occur inside the NASDAQ Level II quote.

[26] We also computed the even-eighth percentages by restricting the sample to stocks with at least 10 trades a day in ten days of a month. This restriction increases the percentage of even-eighth quoted stocks by about two percentage points.

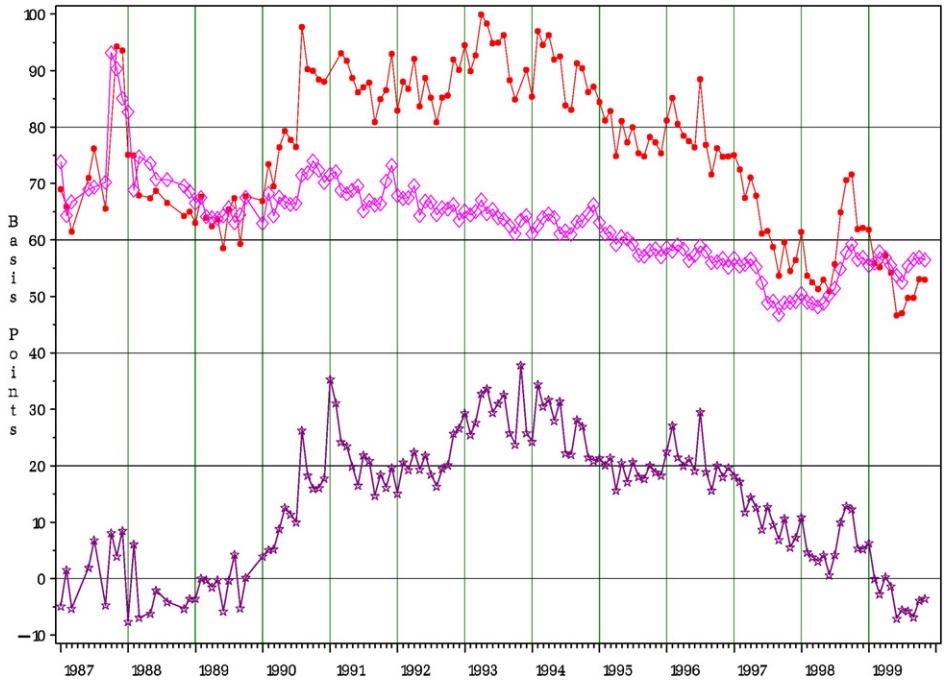

Fig. 7. NASDAQ and NYSE RES for all trades 1000 shares and less, 1987–1999, 30% NASDAQ match with NYSE NASDAQ RES = (●), NYSE RES+20.82 basis points = (◇), adjusted NASDAQ less NYSE RES = (☆).

decreasing. Thus, there is almost no change in the percentage after publication of the Christie–Schultz findings on May 26,1994.[27] Thereafter, the SOES Maximum Percentage tracks the RES very closely, with the exception of the "Actual Size Rule" period. (With these data from this period excluded, the correlation coefficient increases to 86%.) This appears to result from our having to assume that in the previous "Order Handling Rules" period the SOES maximum trade size was 1000 shares for all stocks and the quoted depth then dropped to 100 shares, even though the decline in the SOES maximum was gradual. In contrast, after 1994 the percentage of even-eighths stocks declines much more than the RES. One reason for the decline is that we included only even-eighth-quoted stocks as "evens," although with the adoption of sixteenths in 1997 one might consider a two-sixteenth-quoted stock an even.

It appears that, in response to the informed-trade costs imposed by SOES day traders, NASDAQ market makers tended to round up or down their offers and bids, apparently to even numbers. As a result, the percentage of stocks quoted on even eighths increased. As market makers gained more experience with day trades and monitored stocks more closely by following fewer issues, they were able to be selective and more precise, particularly with respect to stocks for which there was much competition. Consequently, we believe, the percentage of even-eighths-quoted stocks declined, but relative effective spreads did not decline until SOES was effectively phased out.

7. Robustness checks

In order to test the robustness of our findings we conduct several further tests. While our sample generation procedure creates the largest possible sample size of both NASDAQ and NYSE stocks, individual stocks may drop in and out of the sample set month by month. Furthermore our adjustment of the NYSE RES to match that of NASDAQ during the base period may not adequate control for difference in NYSE and NASDAQ stocks over our entire test interval. To address these concerns we consider several different sample sets of portfolios and replicate our tests.

[27] We examined the even-eighth percentage of a subsample of stocks that bridged 1994 and 1995 and found a similar sharp decrease from December 1994 to January 1995.

First, we form matched pairs of NASDAQ and NYSE stocks in each of our sample months using four Euclidean distance measures:

$$D_{i,j,k} = \frac{(Q_{i,j} - Y_{i,k})^2}{(Q_{i,j} + Y_{i,k})/2},$$

where $D_{i,j,k}$ measures the Euclidian distance between NASDAQ stock Q_j and NYSE stock Y_k for i=price, share volume traded, volatility and market cap. Then each of the four distance measures are normalized by subtracting their median value and dividing by their interquartile range (assuming that we have contaminated and non-normal distributions) within each month. These metrics are then combined into an aggregate distance measure by

$$\bar{D}_{j,k} = (2{*}D_{1,j,k} + D_{2,j,k} + D_{3,j,k} + D_{4,j,k})/4,$$

with a double weight given to the price distance, since McInish and Wood (1992) find that price is the most important spread determinant. The optimal combination of matched pairs that minimize the aggregate Euclidian distance within each sample month is found with the following linear programming model:

Minimize:

$$\sum_j \sum_k f_{j,k} \bar{D}_{j,k}, j = 1, \ldots, \text{NASDAQ stocks}, \; k = 1, \ldots, \text{NYSE stocks}$$

Subject to:

$$\sum_k f_{j,k} \leq 1 \pm \Delta, k = 1, \ldots, \text{NYSE stocks}$$

$$\sum_j f_{j,k} \leq 1 \pm \Delta, j = 1, \ldots, \text{NASDAQ stocks}$$

$$\sum_j f_{j,k} \geq .30{*}(\{\#\text{NASDAQSTOCKS}) \pm \Delta$$

where f_{jk} is the LP solution variable that will have a value of 1 if the jth NASDAQ stock is paired with the kth NYSE stock and 0 otherwise.[28] The Δ has a value of 0.1% of each of the right-hand side values, which allows the LP to attain feasibility. The first two constraints limit each NYSE and NASDAQ stock to entering at most once in the solution, while the third constraint forces 30% of the NASDAQ stocks into the solution — a level selected to generate a sufficiently large sample with the best possible matches between NASDAQ and NYSE stocks.[29] The advantage of forming matched pairs in this manner is that all possible combinations are examined simultaneously in deriving the optimal set of matched pairs.

Fig. 1 recast with these matched pairs using trades with share volumes of 1000 and less is shown in Fig. 7. As can be seen the result is quite similar to that shown in Fig. 1.

We also calculated and graphed RES using observations with at least ten trades a day (based on the possibility that day traders concentrated on actively traded stocks), medians instead of means, only stocks that traded throughout the period (202 on NADAQ and 627 on the NYSE), only trades of 1000 shares or less, 2000 shares or less, and so on by thousands through 5000 shares or less, and finally all shares traded. In each case patterns quite similar to Fig. 1 result.[30]

8. Conclusions

We find a remarkable pattern of relative effective spreads (RES) on NASDAQ compared to NYSE stocks. From January through August 1989, RES on NASDAQ (plus 18.4 basis points) and the NYSE moved in very close concert.

[28] The solution values, which are bounded between 0 and 1, will naturally gravitate to 0 or 1 since this LP is an assignment problem. The few positive solution values that are less than one are rounded to 0 or 1.

[29] As more matches are required of the LP, the quality of each successive match will deteriorate.

[30] These results will be provided upon request.

The difference then increased through the mid-1990s, and then decreased, until by year-end 1999 it returned to its pre-August 1987 level. We consider the two hypotheses that were advanced to explain this phenomenon, at least through 1994 — "collusion" among NASDAQ market makers to widen spreads and "preferencing and payment for order flow," which reduces competition, thereby widening spreads. Evidence is presented that is inconsistent with these hypotheses. We posit an alternative hypothesis that SOES day trading on NASDAQ was at least an important cause of the divergence in NASDAQ/NYSE trading costs. This hypothesis is subjected to five tests: the introduction of mandated SOES in June 1988, the change in the SOES maximum trade size from 1000 to 500 shares in January 1994 and then back again in March 1995, and the gradual and then the complete reduction of the SOES maximum trade size to 100 shares after 1996. From the changes in volume of these and other trade sizes, we compute increases in informed trade costs incurred by NASDAQ market that appear due to SOES day traders and the changes in trades within the BBO quotes and relative effective spreads that we believe resulted therefrom. These findings are contrasted with similar measurements of stocks traded on the NYSE, which did not have a mandatory SOES. The tests provide results that are consistent with the hypothesis that day trading, primarily through NASDAQ's mandatory SOES, was largely responsible for the higher NASDAQ spreads. We also find that the SOES system that was designed to benefit small traders actually hurt them, as they bore the brunt of the higher spreads.

Prior empirical studies employ from one month to one year of data. Of necessity such studies must assume an immediate correlation between SOES bandit trading and spreads, which presumes that market makers can anticipate such trading and adjust spreads accordingly. Our discussions with practitioners reveal that market makers could not anticipate such events. Furthermore, SOES banditry began slowly with the onset of mandatory SOES and continued through most of the 1990s, being mitigated with the Order Handling Rules that began with a phased introduction in June 1997, and the subsequent Absolute Size Rule. Thus, in our view only a sample window that covers the entire time period can capture the impact of SOES banditry.

Given the differences between NASDAQ and the NYSE – stock characteristics, market mechanisms, institutions trading net on NASDAQ and with commissions on the NYSE – we gross up NYSE relative effective spreads (RES) to match those of the NASDAQ sample in our base period, January 1987–May 1988. Then we maintain the same scaling factor for the remaining 9.5 years. A series of changes – some affecting just one market while others affect both – weaken this relationship over time. These include the rapid growth of ECNs on NASDAQ (which resulted from the pressure from SOES banditry), the tick size reduction to teenies in 1997, rule changes on both markets, and the impact of the DOJ NASD prosecution. Yet we take comfort from robustness checks and the convergence of NASDAQ and NYSE RES in 1999 after the introduction of NASDAQ rule changes implemented to mitigate the influences of the bandits.

The blue-ribbon committee that recommend automatic execution of trades submitted over the SOES electronic network included senior market makers who had grown up in the dealer environment and who had little comprehension of the potential impact of electronic trading on this environment. They (and the SEC) failed to recognize the impact on dealer costs of traders being able to pick off stale quotes electronically with automatic executions. This failure spawned an enormous growth in SOES day traders who ultimately executed 20% of NASDAQ trades and who greatly increased NASDAQ trading costs over a decade. Furthermore, institutional traders, as well as market makers seeking to avoid interacting with day traders, fueled the growth of ECNs − SOES day traders did not have access to ECNs. Thus, mandatory SOES executions not only affected spreads on NASDAQ in the 1990s, but continue to play out today, as ECNs have come to dominate trading in NASDAQ stocks. An important lesson from the SOES "experiment" is that traders can and will take advantage of a system that offers them the opportunity to profit from its weaknesses.

While we have focused primarily on the impact of SOES bandits on widened spreads and the resultant increased cost of trading, it is worth noting that a substantial cost was imposed on pension and mutual fund holders through front running institutional order flow. Specifically, bandits would identify the onset of institutional buy/selling, acquire existing liquidity and offer it back at worse prices, thereby increasing costs of the money funds. Hence the irony of mandatory SOES is that it not only hurt the intended beneficiaries, small investors (as shown in Fig. 3), but fund holders also paid a dear price.

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