Price Discovery in the E-mini Futures Markets: Is the Tail Wagging the Dog?

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Abstract

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Abstract

This paper examines the price discovery process in the S&P 500 and Nasdaq-100 index futures contracts. By utilizing transactions data with attached trader type identification codes, this paper is able to analyze price discovery contributions of trades initiated by exchange locals and off-exchange customers. The empirical results show that price discovery appears to be initiated in the electronically traded E-mini index futures contracts and is driven by trades initiated by exchange locals. Furthermore, the information share of trades initiated by locals appears to be particularly pronounced in the beginning of the trading day when a large proportion of the daily price discovery takes place. Finally, results show that E-mini locals "front-run" large trades that occur on the open outcry floor. We maintain that this trading technique at least partially explains the result of the price leadership of the E-mini contracts. Overall, the results are consistent with the notion that locals are informed traders who derive their informational advantage from the proximity to order flow.

I. Introduction

Price discovery, or transmission of information into prices, is a crucial function of financial markets. Price discovery takes place when order flow from different types of traders is aggregated in a single market, which can be a physical exchange floor or an electronic trading system. This aggregation of trading interests allows for trade prices to correctly represent supply and demand, although market frictions, noise trading, and investor psychology ensure that observed prices are imperfect proxies for the underlying asset values. As markets evolve, it is imperative that the new market structures and trading protocols continue to provide reliable price discovery.

Toward this end, there has been an ongoing transition from open outcry to electronic trading by equity and futures exchanges around the world that has accelerated dramatically in recent years.[1] Several studies have looked at relative rates of price discovery in electronic and open outcry markets. Grünbichler, Longstaff, and Schwartz (1994) report that futures prices lead spot prices more when futures are traded electronically. They interpret this finding as evidence that electronic trading accelerates price discovery. Breedon and Holland (1998) examine the German Bund futures that trade on both the LIFFE and the Deutsche Terminborse (DTB), which are floor-based and electronic markets, respectively.[2] The study shows that LIFFE and DTB make similar contribution to the price discovery of the Bund futures. Koffman and Moser (1997) also conclude that LIFFE and DTB are equally informationally efficient. In his study of price discovery on LIFFE and DTB, Martens (1998) shows that when volatility is high the contribution of open outcry market to price discovery increases. The paper concludes that open

[1] For example, the London International Financial Futures Exchange (LIFFE), MATIF, the Sydney Futures Exchange (SFE), the New Zealand Stock Exchange (NZSE), and several other major exchanges around the world switched from open outcry to automated trading systems in the last five years.
[2] LIFFE moved to electronic trading in May 1999.

outcry has an advantage over electronic trading systems in volatile periods because floor traders can observe actions of other traders and that helps them to react faster. Similarly, Tse and Zabotina (2001) argue that the open outcry market is more resilient and therefore can be expected to be more informationally efficient than the electronic market in periods of high price volatility.

Although most futures industry participants share the view that a permanent move from open outcry to electronic trading in most futures markets is all but inevitable,[3] the majority of the futures trading in the US is still done through traditional open outcry. However, faced with a threat of losing market share to new electronic trading systems and attempting to expand its retail customer base, the Chicago Mercantile Exchange (CME) pioneered the approach of "side-by-side trading." In this hybrid trading model so-called "E-mini" versions of several of the CME's high-volume futures contracts trade virtually around the clock on the electronic GLOBEX trading system. The E-mini S&P 500 futures contract was introduced in September 1997 and the E-mini Nasdaq-100 futures started trading in June 1999. E-mini futures contracts are sized at one-fifth of their floor-traded counterparts to make E-mini trading affordable to traders with small margin accounts. These contracts are the fastest-growing products in the CME's history.[4]

Hasbrouck (2002a) shows that the E-mini futures contracts dominate price discovery in the S&P 500 and Nasdaq-100 indexes. When the E-mini contracts were introduced, the full-sized contracts traded through open outcry were expected to serve as the price discovery

[3] See, for example, Slutsky (1999), who interviews a number of prominent futures players.
[4] Since 1999, the CME has introduced E-mini versions of futures contracts on the Russell 2000 Index, S&P MidCap 400 Index, Euro FX, Japanese Yen, Lean Hogs, and Feeder Cattle. In addition, electronic daytime trading of Eurodollar futures was initiated in 1999. According to CME's Chairman Scott Gordon, "The largest growing, the fastest growing segment of our business comes from individual investors that are trading our E-mini products online. It's by far and away the largest growth area." Reported in Carlson (2000).

mechanism for the new electronic markets.[5] GLOBEX monitors were installed around the trading pits, so that the exchange locals could use the price established through open outcry trading to make the market in the electronic system. However, Hasbrouck demonstrates that instead of being an informational satellite of the trading floor the electronic trading system appears to play an important role in the price discovery process. The fact that he examines a period when the floor-traded contracts had a dominant market share in terms of dollar volume makes this finding even more striking.

The primary contributions of this paper are two-fold. First, we use a detailed data set that identifies contra party trader type for each transaction in order to directly test the notion suggested by Manaster and Mann (96, 99) that exchange locals are informed traders who derive their informational advantage from the proximity to order flow. Second, we lend evidence toward explaining the result of price leadership of the E-mini futures. Previous research on price discovery has looked at price leadership among several related markets. In contrast, this study analyzes relative contributions to price discovery of trades initiated by exchange locals versus trades initiated by off-exchange traders in the S&P 500 and Nasdaq-100 E-mini index futures markets.

The empirical results indicate that the price discovery is initiated in the E-mini index futures contracts and is driven by trades initiated by locals. The contribution of locals' trades to the price discovery process exceeds the proportion of trades and volume initiated by locals. Furthermore, local-initiated trades have the largest contribution to price discovery at the beginning of the trading day when a large proportion of the daily price discovery takes place. Finally, the results strongly support the hypothesis that E-mini locals use their proximity to the

[5] See Panel Discussion on Chicago Mercantile Exchange Technology, CNNFN Transcript # 97090409FN-L03, September 4, 1997, 11:30 EST.

order flow into the pit and superior execution speed of GLOBEX to "front-run" large trades that occur on the floor. This trading technique used by E-mini locals appears to at least partially explain the result of the price leadership of the E-mini futures contracts.

The remainder of the paper is as follows. Section II below describes the mechanics of the E-mini market, reviews relevant literature, and suggests testable hypotheses for the paper. Section III describes the data used in the paper. Section IV discusses the methodology and the empirical results. Section V provides a brief summary and conclusions.

II. Background and Hypotheses

The regular and E-mini futures contracts are essentially identical instruments. Traders can liquidate E-mini positions against offsetting positions in the regular futures. The two main differences between the regular and E-mini futures are the smaller size of the E-mini contracts and the fact that, as opposed to the regular futures, the E-minis are traded electronically through GLOBEX.[6]

Important advantages of E-mini trading that could lead to significant improvements in price discovery include increased speed of execution, timely and accurate reporting of fills, improved pricing transparency, high liquidity, and trader anonymity. E-mini traders report that even when they execute trades in GLOBEX through an electronic broker, market orders take only 1-2 seconds to be filled. Traders in the electronic system receive accurate and instantaneous feedback about the status of their orders. Alternatively, speed of execution in open outcry markets is limited by the mechanics of pit trading. The process of order submission, execution,

[6] GLOBEX is an electronic limit order book market. The system prioritizes limit orders first by price and then by time. Traders can see five best bids and offers in the limit order book. Depending on the depth available at the best bid or offer (BBO), an order can receive a full or partial fill. A partially filled market order in GLOBEX becomes a limit order at that price. Coppejans and Domowitz (1999) describe operation of GLOBEX during the period when it was used as a strictly off-hours trading system.

and relaying the trade information to the customer may take several minutes, especially in periods of high activity in the pit.

Furthermore, GLOBEX trading improves pricing transparency. Even in periods of average trading activity different prices may prevail simultaneously in different areas of the futures pit. This inefficiency is likely to be exacerbated in periods of high volatility. All traders with access to GLOBEX are able to see current bid and offer quotes at all times and have their orders filled at the best available price on a first-in, first-out basis.[7]

Alternatively, E-mini trading has higher transaction costs for larger trades. Brokerage commissions are charged on a per contract basis. Therefore, even if bid-ask spreads in the E-mini market are somewhat smaller, the total transaction costs per dollar of trading volume are likely to be higher in the E-mini market. As a result, one may expect the trading in the E-mini market to be dominated by small retail traders who simply do not have sufficient capital to trade the full-size contracts, while large institutional traders may still actively trade in the lower cost regular contracts.[8]

Traders on the futures trading floor can often get an idea about the type of customer behind the order. At the same time, like most other automated trading systems, GLOBEX offers trader anonymity. Therefore, traders that possess an informational advantage may prefer the anonymous electronic system even if they have to pay higher commissions.[9]

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[7] The fact that unfilled quantities remain on the limit order book may prove to be a liability in "fast markets". Canceling and reentering orders could take some time.

[8] While our data does not identify trade contraparties as institutions or retail traders, the average trade sizes shown in Table 2 can be instructive in this regard. The average trade size during our sample period is only 2.60 contracts for the E-mini S&P 500 futures and 2.05 for the E-mini Nasdaq-100 futures. The corresponding averages for the regular futures are 4.36 and 3.37, respectively.

[9] Huang (2002) shows that electronic communication networks (ECNs), which are electronic limit order books, make a dominant contribution in price discovery of actively traded stocks. Trader anonymity on ECNs is likely to contribute to better price discovery by attracting informed traders.

With regard to price discovery, Manaster and Mann (1996, 1999) lend evidence that exchange locals have informational advantage over the off-exchange traders. Locals in futures markets play an important role of providing liquidity by acting as voluntary market makers. However, Manaster and Mann show that market making is not the main source of their trading profits. Far from being passive order fillers, locals actively take positions based on their observations of order flow from off-exchange customers. Locals have an advantage in both timing their trades and execution costs. In order to fully exploit their advantage in timing, the locals often sacrifice execution profits. Frino et al. (2000), Frino and Jarnecic (2000) and Fong (2001) report evidence supporting the notion that locals often trade aggressively to exploit their informational advantage. Alternatively, Daigler and Wiley (1999) suggest that in futures markets institutional traders with access to the trading floor are more informed than the off-exchange traders. In addition to their ability to infer information from the pit dynamics, these traders also have access to real-time information about the cash market and can therefore know the fair value of the contract at any time.

Massimb and Phelps (1994) argue that, given a choice between open outcry and electronic trading, locals are likely to prefer traditional open outcry because "compared with open outcry, an electronic matching system imposes additional costs and risks on the local." Chow, Lee, and Shyy (1996) report empirical evidence supporting this argument.

Trade data analysis from this study, as well as our conversations with traders and several CFTC staff, suggest that CME locals trade very actively in GLOBEX.[10] This evidence does not necessarily contradict the line of reasoning pursued by Massimb and Phelps (1994) given the

[10] CME's Chairman Emeritus Leo Melamed, describing the introduction of the E-mini S&P 500 futures, says: "The E-mini idea worked and that changed the whole view of our entire floor community…. All of a sudden, there were lines to sign up for computer training and to get a GLOBEX terminal. We literally had people waiting for months to get their hands on a terminal." Reported in Sales (2001).

CME operates electronic and open outcry markets side by side. The E-mini terminals on the CME floor are located in an area adjacent to the trading pits.[11] Floor traders can also use handheld electronic trading devices to execute trades in GLOBEX while stationed in the pits. This direct access to open outcry trading produces a number of powerful reasons for the locals to trade in the electronic system. First, they can use order flow information from open outcry to take positions in the electronic system. Active liquidity trading in the E-mini market makes it possible for the E-mini locals to trade aggressively against customer limit orders in GLOBEX. Second, the locals can profit by arbitraging between the pit and GLOBEX. Finally, if a local chooses to act as a market maker in GLOBEX by submitting limit orders instead of trading aggressively, her ability to observe order flow into the pit allows her to quickly adjust the quotes and be one step ahead of the off-exchange traders.

The central hypothesis of this paper is that price discovery occurs primarily in the E-mini contracts and is driven by locals who take advantage of their proximity to order flow information and superior execution speed of the electronic system. The informational advantage of locals increases in periods when trading is more active or when order flow is more informative. Therefore, during these periods, when most of the daily price discovery takes place, one would expect locals to trade more and make greater contribution to the price discovery in the E-mini futures. Large trades move prices. When the E-mini locals see large orders coming into the pit, they are able to respond quickly and trade in GLOBEX to profit from the price impact of the large trades. The above discussion leads to the following hypotheses:

[11] According to the CME's 2000 Annual Report, "Some of our members trade the E-mini products from computer workstations surrounding the trading pits while flashing orders to the pits for the larger-sized contracts."

Hypothesis 1. E-mini S&P 500 and E-mini Nasdaq-100 futures contracts make a dominant contribution to price discovery in their respective indexes, i.e. the result from our sample is consistent with Hasbrouck (2002a).

Hypothesis 2. Trades initiated by exchange locals account for most of the price discovery in the E-mini futures contracts.

Hypothesis 3. Contribution of trades initiated by E-mini locals to price discovery increases during periods characterized by the largest cumulative price change.

Hypothesis 4. E-mini locals trade ahead of large regular contract trades to profit from the price impact of the large orders.

III. Data and Descriptive Statistics

This study employs trade data for the regular and E-mini S&P 500 and Nasdaq-100 futures. These data are obtained from the Commodity Futures Trading Commission (CFTC) and contain the contract ticker symbol, trade date, trade time to the nearest second, the contract month, buy/sell code, number of contracts traded, trade price, customer type indicator (CTI), CTI of the opposite side of the trade, and session indicator (pit or GLOBEX). CTI ranges from 1 to 4 as follows:[12]

CTI1 – trade executed for a floor trader's personal account (local trade);

CTI2 – trade executed for a clearing firm's account;

CTI3 – trade executed for a personal account of another floor trader;

CTI4 – trade executed for an account of an outside customer.

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[12] Daigler and Wiley (1998) and Daigler and Wiley (1999) provide a detailed discussion of the four CTI categories.

Our sample period extends over the 86 trading days from May 7, 2001 to September 7, 2001. We choose this period for two reasons. First, prior to May 7, 2001, the maximum size of a trade in the E-mini S&P 500 futures was limited to 30 contracts. Second, we want to exclude the period of abnormal market volatility that followed the September 11, 2001 events.

Open outcry trading opens at 8:30 a.m. and closes at 3:15 p.m. (Chicago time). Our analysis is limited to these regular trading hours. For every trading day, only the contract with the largest number of trades is considered.[13] For contracts traded through open outcry the CME uses a computer algorithm that imputes execution time for every trade by using time and sales data, timestamps on order tickets and other available audit trail data.[14] In contrast, E-mini trades are recorded in the exact sequence of occurrence. We eliminate observations reported out of time sequence, as they are likely to contain errors. The basic information on the futures contracts considered in our paper is given in Table 1.

[Insert Table 1 about here]

Table 2 reports average daily volume and number of trades for different counterparty combinations in regular and E-mini futures. Consistent with Manaster and Mann (1996) and Ferguson and Mann (2001), trades of locals (CTI1) with off-exchange customers (CTI4) account for the largest proportion of trades and volume in all four considered contracts. The second most frequent combination (ranging from 25.0% to 29.9% of total number of trades and from 14.5% to 33.9% of total volume) is trades of locals with other locals. Interestingly, for regular futures the volume share of this combination is only about half of the corresponding proportion of trades.

[13] Trading activity typically shifts from the futures contract approaching expiration to the next available contract during the second week of the expiring contract's month.

[14] Trade prices in the pit are reported by hand signals to pit reporters who type them manually. Our conversations with CFTC staff suggest that the time delay between the moment when the price change actually occurred and the timestamp in the time and sales sequence, which is used to impute a time for each trade, is typically under five seconds. Hasbrouck (2002a) shows that when E-mini trade prices are delayed by five seconds the E-mini contracts are still the price leaders.

This suggests that most of the trades between locals on the floor are small. CME traders attribute high local-to-local trading activity to arbitrage between the E-mini futures and their pit-traded counterparts. Customer-to-customer trading accounts for between 5.2% and 18.4% of total number of trades and between 8.7% and 18.2% of total volume.

[Insert Table 2 about here]

Summary statistics for regular and E-mini futures are reported in Table 3. The trading of the E-mini contracts is much more frequent than that of the regular futures. For example, trading frequency of the E-mini Nasdaq-100 futures exceeds that of the regular Nasdaq-100 futures by a factor of eleven. The open interest in the E-mini futures is smaller than the daily trading volume, while for the regular futures the opposite is true. This suggests that E-mini trading has a greater proportion of day traders who do not keep overnight positions. The open interest in the E-mini futures is still substantial, however, indicating that some institutional traders use these contracts for hedging purposes.

[Insert Table 3 about here]

Table 3 also reports customer execution spreads calculated as mean customer buy price minus mean customer sell price for a 5-minute interval.[15] For both E-mini S&P 500 and E-mini Nasdaq-100 futures the execution spreads are substantially smaller than for corresponding floor-traded contracts. Strikingly, the mean execution spread is negative for the E-mini Nasdaq-100 futures. Furthermore, the execution spread in trades with locals is even smaller, suggesting that in this market locals tend to trade aggressively against customer limit orders, effectively paying off-exchange traders for provision of liquidity. The negative execution spread result is consistent with findings of Manaster and Mann (1999) and Ferguson and Mann (2001) who show that

[15] This direct measure of transaction costs is used by Locke and Venkatesh (1997) and Ferguson and Mann (2001), among others.

locals often sacrifice their advantage in execution to take positions ahead of favorable price movements. In contrast, for the E-mini S&P 500 futures the customer execution spread in trades with locals is greater than the all-trade spread. This suggests, unsurprisingly, that the timing advantage of locals is more important in the volatile Nasdaq-100 market. Table 3 also reveals that the E-minis have a large dollar market share ranging from 29.5% for E-mini S&P 500 to 58% for E-mini Nasdaq-100 futures.

IV. Methodology and Empirical Results

A. Calculation of the information shares using Hasbrouck (1995) model

In our analysis of price discovery, we use the Hasbrouck (1995) model that calculates "information shares" as relative contributions of variance of a security in the variance of innovations of the (unobservable) efficient price. According to Hasbrouck, the efficient price m_t follows a random walk:

(1) $$m_t = m_{t-1} + u_t$$

The observed prices of several cointegrated markets contain the same random walk component and components incorporating effects of various market frictions. As the initial step in calculation of the information shares, the following vector error correction model (VECM) is used:

(2) $$\Delta p_t = \gamma\alpha' p_{t-1} + \sum_{i=1}^{k} A_i \Delta p_{t-i} + \varepsilon_t$$

where p_t is an $n \times 1$ vector of cointegrated prices, A_i are $n \times n$ matrices of autoregressive coefficients, k is the number of lags, $\alpha' p_{t-1}$ is an $(n-1)\times 1$ vector of error correction terms, γ is an $n \times (n-1)$ matrix of adjustment coefficients, and ε_t is an $n \times 1$ vector of price innovations.

We use log-prices and employ ten lags in the VECM.[16] The VECM is estimated with OLS separately for each day or several intraday intervals.

The error-correction representation uses the intuition that a change in price is determined by the deviation from the long-term equilibrium relationship. We use the cointegrating vector $\alpha = [1 \quad -1]'$.[17] For example, in the case of the pricing relationship between regular and E-mini S&P 500 futures, the error correction term is $\alpha' p_{t-1} = p_{t-1}^{SP} - p_{t-1}^{ES}$. In this case the coefficients γ of the error correction term measure the price reaction to the deviation of the price difference between the two markets from zero. The greater the coefficient, the more the particular market reacts to deviations from equilibrium.

Hasbrouck shows that the following vector moving average (VMA) model can be derived from the VECM (2):

(3) $$\Delta p_t = \Psi(L)\varepsilon_t,$$

where $\Psi(L)$ is a polynomial in the lag operator.

The VMA coefficients can be used to calculate the variance of the underlying efficient price:

(4) $$\sigma_u^2 = \psi\Omega\psi',$$

where ψ is a row vector composed of VMA coefficients and $\Omega = \mathrm{var}(\varepsilon_t)$.

After transforming Ω into a lower triangular matrix F by the Cholesky factorization, $\Omega = FF'$, it is possible to calculate the information share of the market j as:

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[16] Increasing the number of lags to 20 or 30 did not significantly influence the results. Both computational considerations and the Schwartz information criterion favor the use of ten lags in the VECM.
[17] This cointegrating vector can be specified a priori, since arbitrage insures that prices of regular and E-mini futures as well as prices of trades initiated by different types of traders do not diverge without bound.

(5) $$I_j = \frac{(\psi F)_j^2}{\sigma_u^2},$$

where $(\psi F)_j$ is the jth element of the row matrix ψF.

When the price innovations are correlated across markets, it becomes impossible to attribute part of the variance of the underlying efficient price to either of the markets. The Hasbrouck's model produces estimates of the upper (lower) bound of the information share for the first (last) variable in the factorization. Hasbrouck suggests reordering variables in factorization to estimate lower and upper bounds of the information shares for each market. Baillie et al. (2002) show how to calculate information shares directly from the VECM results without obtaining the VMA representation. We use their approach in our analysis.

B. Price discovery between regular and E-mini futures

We begin by calculating information shares of the regular and E-mini futures contracts. Hasbrouck (2002a) performs price discovery calculations for each day separately and then averages the resulting information shares across days. We use a similar approach to make sure that the result of price leadership of the E-mini futures holds in our sample. In addition, we estimate information shares for nine 45-minute intraday intervals. With arbitrageurs reacting to pricing discrepancies in a matter of seconds, a 45-minute interval can reasonably be considered "long term" in these actively traded markets.

We use trade prices for both regular and E-mini futures because bid-ask quotes are reported relatively infrequently and are short lived in the open outcry market. The initial data for the price discovery calculations between regular and E-mini futures are time and sales data derived from the trade data by eliminating repeated prices. As the input data for the VECM analysis we use matched time series with one-second intervals between observations. If there is no price reported at a particular second, the previous available price is used. If there are several E-mini trades reported with the same timestamp, only the last trade price is used.[18]

The results of the calculation of information shares are shown in Table 4. The average midpoint of the upper and lower bounds of the information share for our sample period is 96.7% for E-mini S&P 500 futures and 95.6% for E-mini Nasdaq-100 futures.[19] This finding is consistent with the result from a different sample period reported by Hasbrouck (2002a). Table 4 also reports the result of calculation of the information shares of E-mini and regular futures for nine 45-minute intraday intervals. In almost all intervals the information share of the E-mini futures exceeds 90%.

[Insert Table 4 about here]

C. Price discovery between E-mini trades initiated by locals and off-exchange traders

Given the time series of prices of trades initiated by locals and off-exchange traders should be cointegrated with cointegrating vector $\begin{bmatrix}1 & -1\end{bmatrix}'$, it is appropriate to use the Hasbrouck (1995) model to calculate contributions of the two types of traders to price discovery. The model was originally intended to analyze contributions to price discovery by multiple markets trading equivalent or closely linked securities. However, while markets often appear fragmented, in many cases they are so closely informationally integrated that in essence they function as a single market. For example, Huang (2002) analyzes information shares of various Nasdaq quote participants including ECNs and Nasdaq market makers. ECNs directly compete for order flow

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[18] High frequency of the input series minimizes the correlation of VECM residuals, allowing for a more precise identification of the upper and lower bound of the information shares. Alternative matching algorithms, for example, the MINSPAN procedure suggested by Harris et al. (1995), involve data thinning. Hasbrouck (2002 a, b) argues that data thinning can lead to incorrect inferences. A thorough analysis of methodological issues involved in calculation of information shares is offered by Hasbrouck (1995, 2002 a, b).

[19] Baillie et al. (2002) provide evidence that the midpoint between the upper and lower bounds of information shares is a reasonable measure of a market's contribution to price discovery. We use this measure in the current paper.

with Nasdaq dealers and the ECN quotes are displayed in Nasdaq. Similarly, CME locals and off-exchange customers compete for execution in GLOBEX. By using trade data that include trader type identification codes, we are able to see whether information impounded into E-mini prices comes from trades initiated by exchange locals or from trades initiated by off-exchange customers.

The E-mini trade data do not contain bid and ask quotes. Thus, we use the tick rule to classify trades as initiated by locals and off-exchange customers. For example, a trade is classified as a buyer-initiated if it occurs on an up-tick. If in a buyer-initiated trade the buyer is a local (CTI1), then the trade is classified as a local-initiated buy trade. If a trade occurs on a zero-tick, i.e. if its price is equal to the price of the previous trade, the trade is excluded. Aitken and Frino (1996) and Finucane (2000) show that the tick rule performs well when zero-tick trades are removed.[20] Once the price time series of trades initiated by the two types of traders are identified, we calculate contributions to price discovery by locals and off-exchange customers throughout the day using the Hasbrouck (1995) model.[21]

Table 5 reports the average information share of trades initiated by locals for the entire day as well as in nine 45-minute intraday intervals.[22] Consistent with hypothesis 2, in all cases the average information share of locals' trades exceeds that of the off-exchange customer trades. There also appears to be a substantial intraday variation in the CTI1 information share. For both S&P 500 and Nasdaq-100 E-mini's, CTI1 information shares exceed the daily averages in the

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[20] The accuracy of the tick rule for zero-tick trades ranges from 68.5% in Aitken and Frino (1996) to 76.6% in Finucane (2000), while the accuracy for trades that occur on non-zero ticks exceeds 90%. We have replicated the price discovery results using all trades including those that occur on zero ticks. The results (not reported but available upon request) appeared stronger.
[21] Initially CTI2-initiated trades were included in the price discovery calculations but their information share was negligible. Consequently, trades initiated by CTI2 were omitted. Trades initiated by CTI3 account for less than 0.5% of the total number of E-mini trades. Therefore, CTI3 trades were also omitted.
[22] We also calculated information shares in 15-minute and 30-minute intervals. The results (not reported but available upon request) were qualitatively unchanged. The 45-minute intervals are chosen to reduce the variance of information shares.

beginning of the day while the information shares fall below the daily averages mid-day. For example, the average midpoint of the upper and lower bounds of the information share of trades initiated by locals in the E-mini S&P 500 and E-mini Nasdaq-100 futures contracts are 67.1% and 67.2%, respectively, during the first 45-minute interval and declines to 61.0% and 54.8% in the middle of the day.

[Insert Table 5 about here]

Furthermore, if locals are better informed than the off-exchange traders we would expect the information share of locals' trades to be larger than the percentage of trades initiated by locals.[23] Table 5 also reports the mean number of trades and volume initiated by locals and off-exchange customers in nine 45-minute intraday intervals. It is clear that locals trade most actively in the beginning and end of the day, exactly during the intervals when they have higher information share. However, the information share of their trades seems to be larger than the percentage of trades initiated by locals. We use a nonparametric two-sample test of medians to check if the information share of locals is equal to the percentage of trades initiated by locals. The z-statistic for all intervals is significant at the 1% level, supporting the intuition that the information share of locals' trades is larger than the percentage of trades initiated by locals. Large trades move prices more than small trades. Thus, it is possible that information share of locals is equal to the percentage of volume initiated by locals. However, this alternative is also strongly rejected by the two-sample test of medians.

To further test the relative information in trades initiated by locals, we calculate the cumulative impulse response functions to initiated trades by forecasting the VECM after a unit shock to one of the prices. Impulse responses are calculated separately for each day in the

[23] Similarly, Barclay and Warner (1993) suggest that, if informed traders concentrate their trades in medium sizes, medium size trades should account for a disproportionately large cumulative price change.

sample and then averaged across days. Figure 1 shows that a shock to the prices of trades initiated by locals has a larger long-term impact than a shock to the prices of trades initiated by the off-exchange customers. This result is also consistent with the hypothesis that trades initiated by locals are more informative.

[Insert Figure 1 about here]

It should also be noted that the trades of the off-exchange traders still make a substantial contribution to price discovery in the E-minis. This result is likely to be explained by several factors. First, some of the E-mini traders are institutions taking advantage of anonymity and fast execution of GLOBEX. Second, off-exchange E-mini traders actively use direct audio feed from the CME floor (so-called "squawk box") to support their trading. While the E-mini locals stationed around the trading pits still have access to a much richer information set, the ability of the off-exchange traders to listen to market commentary and background noise of pit trading[24] may reduce the comparative advantage of locals.

The intraday U-shape patterns in futures volume and volatility are well documented in the literature. The beginning of the day is the period when trading on the floor is most active. Therefore, one can expect the price discovery process to accelerate during periods of active trading. To test hypothesis 3, that the contribution of trades initiated by E-mini locals to price discovery increases during periods characterized by the largest cumulative price change, we examine the amount of price discovery (or the percentage of the daily cumulative price change) occurring during each of the nine 45-minute intervals using the measure called weighted price contribution (WPC), which is defined as:

[24] Coval and Shumway (2001) show that the sound level in the futures trading pits conveys important information.

(6) $$WPC_i = \sum_{t=1}^{T} \left(\frac{|\Delta P_t|}{\sum_{t=1}^{T} |\Delta P_t|} \right) \times \left(\frac{\Delta P_{i,t}}{\Delta P_t} \right),$$

where $\Delta P_{i,t}$ is the price change over interval *i* on day *t* and ΔP_t is the total price change for day *t*.[25] The first term in parentheses is the weighting factor for each day. The second term is the relative contribution of interval *i* on day *t* to the total price change on day *t*. The results from Table 5 show that the weighted price contribution appears to be highest during the first 45 minutes of trading for both E-mini contracts. This is also when the information shares of trades initiated by locals are the greatest.

Finally, the following regression model is used to test whether the intraday variation in the CTI1 information share is statistically significant:

(7) $$SHARE_t = \beta_0 + \sum_{i=1}^{6} \beta_i D_i + \varepsilon_t,$$

where *SHARE* is the midpoint between the upper and lower bound of the information share of E-mini trades initiated by locals calculated separately for each 45-minute interval of the day, D_1, D_2, and D_3 are dummy variables for the first three 45-minute intervals of the trading day, and D_4, D_5, and D_6 are dummy variables for the last three 45-minute intervals. The intercept of this regression corresponds to the average information share of locals during the interval between 10:45 a.m and 1:00 p.m. CST. The coefficients of the dummies measure the difference between the information share of locals' trades during respective intraday intervals and the information share in the middle of the day. We estimate equation (7) using the generalized method of moments (GMM) and the Newey and West (1987) heteroscedasticity and autocorrelation consistent covariance matrix.

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[25] The WPC measure is suggested by Barclay and Warner (1993); it is used by Huang (2002) and Barclay and Hendershott (2001), among others.

Results of estimation of the equation (7) reported in Table 6 show that the observed intraday variation in CTI1 information share is statistically significant. The coefficients of intraday dummies suggest that the intraday pattern of the information share of the locals' trades in the E-mini S&P 500 market is U-shaped. Information shares of trades initiated by locals in the E-mini Nasdaq-100 market are high in the beginning of the day but they do not increase again at the end of the day. This suggests that order flow in the Nasdaq-100 market is more informative and, consequently, the informational advantage of locals is greater in the beginning of the day.

[Insert Table 6 about here]

D. Returns and order flows around large regular and E-mini trades

Hypothesis 4 suggests that when E-mini locals see large orders arriving into the pit they trade ahead of those orders to profit from the resulting price impact. To test this hypothesis we examine returns of regular and E-mini futures and E-mini order flows surrounding large trades on the floor. Similar to Booth et al. (2001), a large trade in regular futures is defined as a trade whose size is equal to or exceeds 95th percentile. This corresponds to 11 contracts for the regular S&P 500 futures and 10 contracts for the regular Nasdaq-100 futures. The threshold that we choose for large trades in E-mini futures is 99th percentile because distribution of E-mini trade sizes is highly skewed towards very small trades. Based on this criterion, E-mini S&P 500 trades of 18 or more contracts and E-mini Nasdaq-100 trades of 10 or more contracts are classified as large.

Large trades often occur in groups. If we use simple averaging of returns and order flows around large trades, the clustering of large trades is likely to affect the results. To account for clustering we use an approach similar to the one suggested by Harris, Sofianos, and Shapiro

(1994). We estimate the following regression of 5-sec returns and order flows on 11 leads and 12 lags of large trades:

$$(8) \qquad VAR_t = \alpha_0 + \sum_{i=-12}^{11} \beta_i cti1_{t+i}^{buy} + \sum_{i=-12}^{11} \gamma_i cti1_{t+i}^{sell} + \sum_{i=-12}^{11} \delta_i cti4_{t+i}^{buy} + \sum_{i=-12}^{11} \omega_i cti4_{t+i}^{sell} + \varepsilon_t ,$$

where *VAR* is analysis variable (return of regular or E-mini futures in 5-sec intervals or order flows in 5-sec intervals), and $cti1^{buy}$, $cti1^{sell}$, $cti4^{buy}$, and $cti4^{sell}$ are (0, 1) indicator variables for large buy and sell trades initiated by locals and off-exchange customers, respectively.[26] Equation (8) is estimated using GMM and the Newey and West (1987) heteroscedasticity and autocorrelation consistent covariance matrix. Similar to Booth et al. (2001), we calculate returns based on trade prices[27] and use the tick rule to identify the trade initiator.

Accurate timing of large trades is important for our analysis. Many trades often occur in quick succession at the same price on the floor. The CME's Computerized Trade Reconstruction (CTR) algorithm matches trades to the last price change. Therefore, several trades are often reported for the same second, while in reality most of those trades occurred during the interval between the price change they are matched to and the next price change. When one of the trades reported for the same second is relatively large, it is likely that the large trade was the trade that triggered the price change and was therefore the first trade in the sequence. When several large

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[26] This specification does not account for the size of the large trades. Larger trades are typically associated with larger price impact. However, Hasbrouck (1991) and others show that price impact is a concave rather than linear function of trade size. Therefore, (0, 1) indicator variables are used to simplify the analysis. To make sure the results are not driven by a small number of extremely large trades, we have replicated the analysis after removing the trades in the top 1st percentile. The results (not reported but available upon request) were qualitatively unchanged.

[27] Returns calculated using transaction prices are affected by the so-called bid-ask bounce. Trade prices fluctuate between the bid and ask quotes, inducing a large negative correlation in returns that has a potential to affect inferences. To make sure the bid-ask bounce does not significantly influence the results, we repeated the analysis using returns based on so-called "pseudo-equilibrium prices" as suggested by Ederington and Lee (1995). Pseudo-equilibrium price is calculated as a moving average of the last two prices on the 5-sec grid. This technique reduces the negative correlation in returns induced by the bid-ask bounce. For example, for E-mini S&P 500 futures the first-order correlation of returns based on trade prices is –0.1471, while the corresponding correlation of returns based on pseudo-equilibrium price is only –0.0173. The results (not reported but available upon request) were qualitatively unchanged.

trades are reported for the same second, we cannot assume that they all occurred simultaneously. Furthermore, identifying the initiating party is also difficult in this case, as some of these trades occurred on a zero tick and the tick rule performs poorly with zero-tick trades. Therefore, we remove all instances when several large trades are reported for the same second.

To synchronize the returns of the regular futures with returns of their E-mini counterparts we use 5-sec intervals rather than transaction time. We use the price of the large trade as the price at time 0 to observe the full price impact of the large trades. Instances when several large trades occur during the same 5-sec interval are eliminated.

Figure 2 plots regular and E-mini S&P 500 and Nasdaq-100 returns around large trades initiated by off-exchange customers and locals, respectively. The figure shows that the E-mini price starts moving in the direction of the large trade about 15 to 20 seconds before the trade. By the time the large floor trade is executed the E-mini price almost reaches the level where the regular futures price is going to be after the trade. Consistent with hypothesis 4, this finding provides evidence of information leakage from the floor to GLOBEX.

[Insert Figure 2 about here]

One could argue that the lack of return drift in regular futures before large trades could be explained by the fact that trading on the floor is relatively infrequent compared to trading in GLOBEX. However, large trades tend to occur during periods of extremely active trading on the floor. For example, the average number of trades during the 30-second interval preceding the large trades is 28.8 for regular S&P 500 futures and 12.1 for regular Nasdaq-100 futures.

Figure 2 also reveals that the temporary price impact of the large trades initiated by locals is smaller and the permanent impact is larger than for the trades initiated by off-exchange traders. This result is consistent with the notion that locals are informed traders.

Table 7 reports a summary of lead-lag regression results for both S&P 500 and Nasdaq-100 markets. The standard errors of cumulative returns indicate that the drift in E-mini returns before large floor trades is statistically significant. The results for both markets are qualitatively similar. However, we observe substantially larger permanent price impacts in the Nasdaq-100 market. For example, the total cumulative return over the two-minute period surrounding large customer-initiated buy trades in the regular S&P 500 futures is 0.0231%, while the corresponding Nasdaq-100 futures return is 0.0556%. This finding suggests that the order flow is more informative in the Nasdaq-100 market than in the S&P 500 market. The cumulative returns from t=+5 to t=+20 reported in Table 7 confirm the intuition that the temporary price effect is smaller for large trades initiated by locals. For example, this transitory liquidity effect is 0.0314% for customer-initiated Nasdaq-100 futures sell trades, while for the sell trades initiated by locals it is only 0.0141%.

[Insert Table 7 about here]

The observed patterns in E-mini returns relative to large trades provide evidence of information leakage from the floor to the electronic market. To check if these return patterns are related to locals' trading, we examine order flows of E-mini locals and off-exchange traders around the large trades on the floor. The E-mini order flows of locals and off-exchange traders, calculated as the number of buys less the number of sells in 5-second intervals, are used as analysis variables in regressions on leads and lags of the large floor trades.[28] The results presented in Figure 3 support the hypothesis that locals take "correct" positions in GLOBEX

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[28] This measure of order flow (buys minus sells) is used to simplify the analysis. We repeated the analysis calculating order flow as buy volume minus sell volume. The results (not reported but available upon request) were qualitatively unchanged. We also repeated the analysis calculating CTI1 and CTI4 order flows as the number of buyer-initiated trades minus the number of seller-initiated trades and using the tick rule to classify trades. The results (not reported but available upon request) show that, while both locals and off-exchange traders tend to initiate trades in the "correct" direction around the large trades on the floor, the order flow of locals clearly dominates.

before the large trades on the floor. For example, locals become net buyers about 15 seconds before a large buy trade. Similarly, they become net sellers about 15 seconds before a large sell trade. The off-exchange traders, on the other hand, appear to be net sellers before large buy trades and net buyers before large sell trades. These order imbalances around large floor trades suggest that the E-mini locals are likely to both aggressively take positions on the "correct" side and withdraw liquidity from the "wrong" side of the market.

[Insert Figure 3 about here]

A summary of the order flow regression results is reported in Table 8. The results show that the timing advantage of the E-mini locals relative to the execution of large trades on the floor is on the order of 15 seconds. Hasbrouck (2002a) shows that the E-mini contracts lose their price leadership when the E-mini prices are lagged by 15 seconds. This suggests that the "front-running" trading technique used by E-mini locals is likely to at least partially explain the price discovery dominance of the E-mini contracts. Consequently, it should be noted that the order flow arriving into the trading pits still plays an important informational role, even though the information share calculations suggest that price discovery occurs predominantly in the E-mini futures. It appears to be the proximity of the E-mini locals to the trading pits coupled with the fast execution in GLOBEX that ensures that the prices of E-mini futures contracts reflect the open outcry order flow information before it is incorporated into the prices of the floor-traded contracts.

[Insert Table 8 about here]

It appears that E-mini returns and order flows around large trades on the floor are directly related to the large trades. However, it is also possible but unlikely that some unknown factor (for example, public announcements) could cause both the patterns of returns and order flows in

GLOBEX and the large trades themselves. If this is indeed the case, the faster reaction in GLOBEX that we document could be unrelated to information leakage from the pit to GLOBEX. Rather, the observed patterns could be explained by the superior execution speed of the electronic system. While this alternative is difficult to test formally, we believe that our evidence is inconsistent with this explanation for the following reasons. First, the E-mini returns and order flows of locals drop immediately after the large trades on the floor. Second, E-mini locals tend to make trades on the "correct" side of the market, while off-exchange traders appear to be caught on the "wrong" side. If the observed return patterns were related to public information announcements, one would not expect to see such an advantage of locals over off-exchange traders. Finally, large futures trades that we examine occur hundreds of times every trading day. Public information releases are unlikely to be so frequent.

It is interesting to see if there is any evidence of information leakage to the floor before large E-mini trades. To test for this information leakage we examine return patterns around large E-mini trades. Figure 4 shows no evidence of information leakage from GLOBEX to the floor. The prices of the regular futures tend to catch up with E-mini prices after execution of the large trades in GLOBEX. This suggests that the order flow information flows from the floor to GLOBEX but there is no feedback from GLOBEX to the floor. Consistent with previous results, the temporary price impacts are smaller and permanent impacts are greater for the large trades initiated by locals. A summary of returns around large E-mini trades is given in Table 9.

[Insert Figure 4 and Table 9 about here]

V. Summary and Conclusion

The CME employs a hybrid trading model in which so-called "E-mini" versions of several high-volume futures contracts trade on the electronic GLOBEX trading system. This paper examines the role of exchange locals in price discovery in the E-mini futures markets by considering the S&P 500 and Nasdaq-100 floor-traded and E-mini futures contracts.

Our empirical results suggest that price discovery in the E-mini index futures markets is driven by trades initiated by exchange locals. The contribution of locals' trades to the price discovery process exceeds the proportion of trades and volume initiated by locals. Furthermore, we show that the locals' trades make the largest contribution to price discovery in the beginning of the trading day when a large proportion of the daily price discovery takes place. Finally, the results are supportive of the hypothesis that the E-mini locals "front-run" large trades that occur on the floor. For example, the locals become net buyers in GLOBEX about 15 to 20 seconds before a large buyer-initiated trades. Similarly, they become net sellers in GLOBEX about 15 to 20 seconds before a large sell trade on the floor. These results strongly support the notion that locals are informed traders who derive their informational advantage from the proximity to order flow. These findings also lend evidence explaining the result of price leadership of the E-mini futures contracts reported by Hasbrouck (2002a).

Taken together, the findings of this paper suggest that despite the exceptional growth of the E-mini markets in the last few years, they are still in an important sense satellite markets. The institutional order flow that arrives to the CME floor continues to represents an important source of price discovery. However, because of the immediate access of locals to the order flow into the pit and superior execution speed of the electronic system the order flow information is first impounded into the E-mini prices.

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Table 1
Regular and E-mini S&P 500 and Nasdaq-100 futures contract information

	S&P 500 Futures	E-mini S&P 500 Futures	Nasdaq-100 Futures	E-mini Nasdaq-100 Futures
Opening Date	April 21, 1982	September 9, 1997	April 10, 1996	June 21, 1999
Ticker Symbol	SP	ES	ND	NQ
Contract Size	$250 x S&P 500 Index	$50 x S&P 500 Index	$100 x Nasdaq-100 Index	$20 x Nasdaq-100 Index
Minimum Price Fluctuation (tick)	0.1 index points = $25 per contract	0.25 index points = $12.5 per contract	0.5 index points = $50 per contract	0.5 index points = $10 per contract
Trading Hours	8:30 a.m. – 3.15 p.m. (floor) 3:45 p.m. – 8:15 a.m. (GLOBEX)	Virtually 24 hours per day (from 5:30 p.m. Sunday to 3:15 p.m. Friday)	8:30 a.m. – 3.15 p.m. (floor) 3:45 p.m. – 8:15 a.m. (GLOBEX)	Virtually 24 hours per day (from 5:30 p.m. Sunday to 3:15 p.m. Friday)
Contract Months	March, June, September, December	March, June, September, December	March, June, September, December	March, June, September, December

Chicago time shown.

Table 2
Mean number of trades and volume by CTI counterparty combination for regular and E-mini S&P 500 and Nasdaq-100 futures for May 7, 2001 to September 7, 2001

	Local (CTI1) with				Customer (CTI4) with				
	CTI1	CTI2	CTI3	CTI4	CTI2	CTI3	CTI4	other	total
Panel A. S&P 500 futures									
Mean Trades	4,592	461	2,085	6,606	233	387	798	204	15,365
Percent of Total	29.9%	3.0%	13.6%	43.0%	1.5%	2.5%	5.2%	1.3%	
Mean Volume	9,681	2,370	6,871	32,975	1,868	2,540	9,555	1,059	66,918
Percent of Total	14.5%	3.5%	10.3%	49.3%	2.8%	3.8%	14.3%	1.6%	
Panel B. E-mini S&P 500 futures									
Mean Trades	15,974	6,560	52	20,670	3,580	29	6,238	593	53,697
Percent of Total	29.7%	12.2%	0.1%	38.5%	6.7%	0.1%	11.6%	1.1%	
Mean Volume	47,480	19,567	107	50,338	8,507	49	12,128	1,725	139,900
Percent of Total	33.9%	14.0%	0.1%	36.0%	6.1%	0.0%	8.7%	1.2%	
Panel C. Nasdaq-100 futures									
Mean Trades	1,436	290	468	2,180	180	302	453	84	5,394
Percent of Total	26.6%	5.4%	8.7%	40.4%	3.3%	5.6%	8.4%	1.6%	
Mean Volume	2,756	1,063	1,127	8,420	902	1,083	2,512	305	18,166
Percent of Total	15.2%	5.9%	6.2%	46.3%	5.0%	6.0%	13.8%	1.7%	
Panel D. E-mini Nasdaq-100 futures									
Mean Trades	15,297	5,027	50	25,237	3,900	44	11,276	351	61,182
Percent of Total	25.0%	8.2%	0.1%	41.2%	6.4%	0.1%	18.4%	0.6%	
Mean Volume	29,034	11,861	69	51,016	9,430	66	22,812	1,079	125,367
Percent of Total	23.2%	9.5%	0.1%	40.7%	7.5%	0.1%	18.2%	0.9%	

All statistics are for regular trading hours.

Table 3
Summary statistics of regular and E-mini S&P 500 and Nasdaq-100 futures for May 7, 2001 to September 7, 2001

	S&P 500		Nasdaq-100	
	Regular	E-mini	Regular	E-mini
Mean number of trades per day	15,365	53,697	5,394	61,182
(per minute)	37.9	132.6	13.3	151.1
Mean trading volume (contracts)	66,918	139,900	18,166	125,367
Mean trade size (contracts)	4.36	2.60	3.37	2.05
Mean open interest (contracts)	495,114	109,281	52,132	104,668
Mean all-trade execution spread [a]	0.0073%	0.0035%	0.0152%	-0.0012%
Mean against-local spread [a]	0.0090%	0.0061%	0.0148%	-0.0061%
Mean $ market share	70.5%	29.5%	42.0%	58.0%

[a] Percent of contract value. Execution spread is calculated as mean customer buy price minus mean customer sell price for a 5-minute interval.
All statistics are for regular trading hours.

Table 4
Intraday variation in share of volume and information share of S&P 500 and Nasdaq-100 E-mini futures for May 7, 2001 to September 7, 2001

	Information share					
Time interval (Chicago time)	Upper bound [a]	Lower bound [a]	Midpoint [a]	Std dev of midpoint	% of trades [a]	Dollar market share [a]
Panel A. E-mini S&P500 futures						
Daily	96.9%	96.5%	96.7%	4.7%	77.8%	29.5%
8:30-9:15	93.7%	92.9%	93.3%	5.7%	76.8%	27.3%
9:15-10:00	94.8%	93.8%	94.3%	7.2%	78.3%	31.2%
10:00-10:45	93.2%	92.2%	92.7%	9.8%	78.2%	30.3%
10:45-11:30	93.0%	92.2%	92.6%	9.0%	77.4%	30.7%
11:30-12:15	90.1%	88.8%	89.4%	11.8%	76.6%	30.6%
12:15-13:00	93.3%	92.4%	92.8%	7.9%	77.5%	31.8%
13:00-13:45	95.3%	94.7%	95.0%	6.1%	80.0%	34.2%
13:45-14:30	95.5%	94.7%	95.1%	5.8%	80.1%	33.2%
14:30-15:15	95.1%	94.3%	94.7%	6.3%	75.0%	23.4%
Panel B. E-mini Nasdaq-100 futures						
Daily	95.9%	95.2%	95.6%	4.5%	91.9%	58.0%
8:30-9:15	96.1%	95.4%	95.8%	3.3%	91.4%	54.5%
9:15-10:00	95.7%	95.0%	95.4%	5.8%	91.5%	56.8%
10:00-10:45	93.3%	92.3%	92.8%	9.5%	91.3%	57.0%
10:45-11:30	92.8%	92.1%	92.5%	7.8%	91.4%	57.9%
11:30-12:15	92.1%	91.3%	91.7%	8.5%	90.9%	58.0%
12:15-13:00	94.0%	93.3%	93.7%	8.7%	91.5%	59.9%
13:00-13:45	96.4%	95.9%	96.2%	5.8%	93.0%	63.4%
13:45-14:30	96.2%	95.6%	95.9%	4.7%	93.8%	64.7%
14:30-15:15	92.9%	91.9%	92.4%	6.1%	91.8%	55.0%

[a] Mean values shown. The daily statistics are for regular trading hours. If several trades occur during one second, only the last trade is used in calculations.

Table 5
Intraday variation in information share of trades initiated by locals (CTI1) in S&P 500 and Nasdaq-100 E-mini futures for May 7, 2001 to September 7, 2001

	CTI1 information share							
Time interval (Chicago time)	Upper bound [a]	Lower bound [a]	Midpoint [a]	Std deviation of midpoint	Weighted price contribution	Trades per minute [a]	CTI1 % of trades [a]	CTI1 % of volume [a]
Panel A. E-mini S&P500 futures								
Daily	65.1%	60.8%	63.0%	7.4%	100%	132.6	43.5%**	57.7%**
8:30-9:15	70.7%	63.5%	67.1%	10.8%	22.4%	244.3	48.2%**	61.7%**
9:15-10:00	65.9%	61.4%	63.6%	11.8%	14.1%	190.5	45.0%**	59.1%**
10:00-10:45	64.3%	62.0%	63.2%	13.3%	13.1%	130.3	42.3%**	55.9%**
10:45-11:30	62.0%	60.2%	61.1%	13.3%	3.2%	87.7	40.9%**	55.1%**
11:30-12:15	62.0%	60.0%	61.0%	15.8%	8.1%	71.2	38.4%**	52.6%**
12:15-13:00	60.0%	57.6%	58.8%	13.6%	7.1%	85.0	38.3%**	52.5%**
13:00-13:45	60.4%	57.1%	58.8%	13.0%	10.7%	119.3	40.1%**	54.0%**
13:45-14:30	65.5%	62.3%	63.9%	12.1%	16.0%	137.6	43.1%**	56.9%**
14:30-15:15	66.4%	62.7%	64.5%	10.2%	5.4%	127.3	42.6%**	56.9%**
Panel B. E-mini Nasdaq-100 futures								
Daily	63.9%	53.7%	58.8%	6.1%	100%	151.1	49.0%**	52.3%**
8:30-9:15	75.2%	59.2%	67.2%	8.7%	29.9%	288.5	55.3%**	58.9%**
9:15-10:00	71.3%	60.4%	65.8%	9.9%	7.3%	205.2	52.8%**	56.8%**
10:00-10:45	60.8%	53.6%	57.2%	13.4%	8.0%	139.1	48.9%**	52.8%**
10:45-11:30	56.5%	50.9%	53.7%	13.7%	4.5%	92.8	43.8%**	47.2%**
11:30-12:15	57.3%	52.3%	54.8%	14.5%	6.9%	72.2	43.7%**	47.4%**
12:15-13:00	55.5%	49.9%	52.7%	14.3%	6.3%	93.6	43.6%**	47.3%**
13:00-13:45	56.0%	47.9%	52.0%	13.4%	12.6%	150.7	45.0%**	47.8%**
13:45-14:30	57.6%	48.5%	53.0%	13.6%	15.1%	176.2	46.9%**	49.4%*
14:30-15:15	59.5%	51.0%	55.3%	11.9%	9.3%	141.2	45.9%**	48.4%**

[a] Mean values shown. The daily statistics are for regular trading hours. Only trades that occur on non-zero ticks and initiated by locals (CTI1) and off-exchange customers (CTI4) are used in calculation of information shares and of the percentage of trades and volume. If several trades of the same type occur during one second, only the last trade is used in calculations. *, ** indicate that that the linear rank sum *z*-statistic of the two-sample test for difference between medians of information share midpoint and percentage of CTI1-initiated trades or volume is significant at the 5% and 1% levels, respectively. This nonparametric test statistic is used because the normality assumptions for the t test are not satisfied. The *z*-statistic is calculated using the NPAR1WAY procedure in SAS.

Table 6
Test of intraday variation in information share of trades initiated by locals

This table reports the results of the regression model:

$$SHARE_t = \beta_0 + \sum_{i=1}^{6} \beta_i D_i + \varepsilon_t ,$$

where *SHARE* is the midpoint between the upper and lower bound of the information share of E-mini trades initiated by locals calculated separately for nine 45-minute intervals of the trading day, D_1, D_2, and D_3 are dummy variables for the first three 45-minute intervals, and D_4, D_5, and D_6 are dummy variables for the last three 45-minute intervals.

	β_0	β_1	β_2	β_3	β_4	β_5	β_6
Panel A. E-mini S&P500 futures							
Value of Coefficient	0.6029	0.0681	0.0333	0.0285	-0.0154	0.0361	0.0424
t-statistic	63.20	4.56	2.14	1.83	-0.96	2.30	2.96
p-value	0.0001	0.0001	0.0325	0.0675	0.3387	0.0219	0.0032
Adjusted R^2 = 0.0306							
Panel B. E-mini Nasdaq-100 futures							
Value of Coefficient	0.5374	0.1349	0.1206	0.0349	-0.0178	-0.0071	0.0151
t-statistic	54.82	10.33	8.53	2.02	-1.16	-0.45	0.99
p-value	0.0001	0.0001	0.0001	0.0439	0.2450	0.6499	0.3241
Adjusted R^2 = 0.1444							

N=774

Table 7
Estimated cumulative event-time returns surrounding large trades in regular S&P 500 and Nasdaq-100 futures for May 7, 2001 to September 7, 2001, in hundredths of a percent

Panel A. Large trades in regular S&P 500 futures

Event time interval, seconds	Customer-initiated		Local-initiated	
	Up-tick trades	Down-tick trades	Up-tick trades	Down-tick trades
Regular futures returns				
–60 to +60	2.31	-2.25	2.50	-3.06
	(0.196)	(0.191)	(0.217)	(0.217)
–60 to –5	0.33	0.09	0.11	0.60
	(0.175)	(0.179)	(0.185)	(0.199)
0 to +60	1.98	2.16	2.39	-2.46
	(0.183)	(0.189)	(0.188)	(0.195)
+5 to +20	-5.28	3.19	-4.28	2.20
	(0.251)	(0.190)	(0.282)	(0.198)
E-mini futures returns				
–60 to +60	1.86	-1.98	2.57	-3.11
	(0.074)	(0.075)	(0.086)	(0.092)
–60 to –5	1.64	-1.67	2.16	-2.60
	(0.056)	(0.058)	(0.068)	(0.068)
0 to +60	0.22	-0.31	0.41	-0.51
	(0.059)	(0.058)	(0.065)	(0.070)
Number of trades	7,940	7,672	6,619	6,312
Mean size, contracts	28.1	25.5	23.1	21.9

Panel B. Large trades in regular Nasdaq-100 futures

Event time interval, seconds	Customer-initiated		Local-initiated	
	Up-tick trades	Down-tick trades	Up-tick trades	Down-tick trades
Regular futures returns				
–60 to +60	5.56	-6.11	8.64	-8.47
	(0.342)	(0.333)	(0.411)	(0.371)
–60 to –5	1.11	-1.11	2.72	-2.12
	(0.288)	(0.291)	(0.295)	(0.323)
0 to +60	4.44	-5.00	5.92	-6.36
	(0.329)	(0.299)	(0.363)	(0.327)
+5 to +20	-4.13	3.14	-2.34	1.41
	(0.357)	(0.272)	(0.339)	(0.255)
E-mini futures returns				
–60 to +60	4.93	-5.30	8.04	-8.32
	(0.213)	(0.209)	(0.260)	(0.242)
–60 to –5	4.52	-4.70	7.56	-7.50
	(0.170)	(0.177)	(0.211)	(0.187)
0 to +60	0.41	-0.60	0.48	-0.83
	(0.171)	(0.165)	(0.204)	(0.182)
Number of trades	5,493	5,400	4,228	4,428
Mean size, contracts	13.6	13.7	12.7	12.4

The estimates are obtained from regressions of returns on 11 leads and 12 lags of large trades in regular futures. Standard errors are given in parentheses. (0, 1) indicator variables are used for large buy and sell trades initiated by locals and off-exchange customers.

Table 8
Estimated E-mini cumulative order flows surrounding large trades in regular S&P 500 and Nasdaq-100 futures for May 7, 2001 to September 7, 2001

Panel A. Large trades in regular S&P 500 futures

Event time interval, seconds	Customer-initiated		Local-initiated	
	Up-tick trades	Down-tick trades	Up-tick trades	Down-tick trades
Local (CTI1) order flows				
–60 to +60	1.52	-3.59	-0.31	-0.30
	(0.447)	(0.449)	(0.500)	(0.536)
–60 to 0	2.29	-2.89	1.91	-3.43
	(0.304)	(0.315)	(0.346)	(0.359)
+5 to +60	-0.77	-0.70	-2.21	3.12
	(0.297)	(0.296)	(0.334)	(0.361)
Customer (CTI4) order flows				
–60 to +60	-0.62	1.98	-1.08	0.23
	(0.384)	(0.392)	(0.438)	(0.451)
–60 to 0	-2.11	2.32	-2.89	3.67
	(0.271)	(0.280)	(0.311)	(0.312)
+5 to +60	1.49	-0.35	1.81	-3.44
	(0.262)	(0.261)	(0.294)	(0.310)
Number of trades	7,940	7,672	6,619	6,312
Mean size, contracts	28.1	25.5	23.1	21.9

Panel B. Large trades in regular Nasdaq-100 futures

Event time interval, seconds	Customer-initiated		Local-initiated	
	Up-tick trades	Down-tick trades	Up-tick trades	Down-tick trades
Local (CTI1) order flows				
–60 to +60	4.56	-6.11	4.50	-4.22
	(0.491)	(0.499)	(0.582)	(0.565)
–60 to 0	3.74	-3.97	5.91	-5.82
	(0.355)	(0.356)	(0.419)	(0.413)
+5 to +60	0.82	-2.15	-1.41	1.60
	(0.355)	(0.353)	(0.404)	(0.401)
Customer (CTI4) order flows				
–60 to +60	-3.26	3.10	2.22	-2.71
	(0.472)	(0.471)	(0.562)	(0.544)
–60 to 0	-2.65	2.60	-2.44	2.20
	(0.336)	(0.336)	(0.391)	(0.389)
+5 to +60	-0.61	0.50	4.65	-4.91
	(0.322)	(0.320)	(0.381)	(0.374)
Number of trades	5,493	5,400	4,228	4,428
Mean size, contracts	13.6	13.7	12.7	12.4

The estimates are obtained from regressions of order flows on 11 leads and 12 lags of large trades in regular futures. The order flows are calculated as the number of buys minus the number of sells. CTI2 and CTI3 trades account for the imbalance between CTI1 and CTI4 order flows. (0, 1) indicator variables are used for large buy and sell trades initiated by locals and off-exchange customers. Standard errors are given in parentheses.

Table 9
Estimated cumulative event-time returns surrounding large trades in E-mini S&P 500 and Nasdaq-100 futures for May 7, 2001 to September 7, 2001, in hundredths of a percent

Panel A. Large trades in E-mini S&P 500 futures

Event time interval,	Customer-initiated		Local-initiated	
seconds	Up-tick trades	Down-tick trades	Up-tick trades	Down-tick trades
E-mini futures returns				
–60 to +60	0.06	-0.06	0.48	-0.81
	(0.318)	(0.383)	(0.172)	(0.147)
–60 to –5	-0.67	0.73	-0.67	0.38
	(0.254)	(0.342)	(0.122)	(0.108)
0 to +60	0.72	-0.79	1.15	-1.19
	(0.209)	(0.215)	(0.111)	(0.098)
+5 to +20	-0.73	0.68	-0.24	0.28
	(0.130)	(0.121)	(0.069)	(0.059)
Regular futures returns				
–60 to +60	0.04	0.77	0.56	-0.82
	(0.546)	(0.662)	(0.308)	(0.286)
–60 to –5	-0.06	-0.07	-0.43	-0.10
	(0.502)	(0.551)	(0.268)	(0.234)
0 to +60	0.10	0.84	0.99	-0.72
	(0.457)	(0.532)	(0.280)	(0.238)
Number of trades	1,020	1,020	3,083	3,588
Mean size, contracts	25.2	24.7	25.7	24.9

Panel B. Large trades in E-mini Nasdaq-100 futures

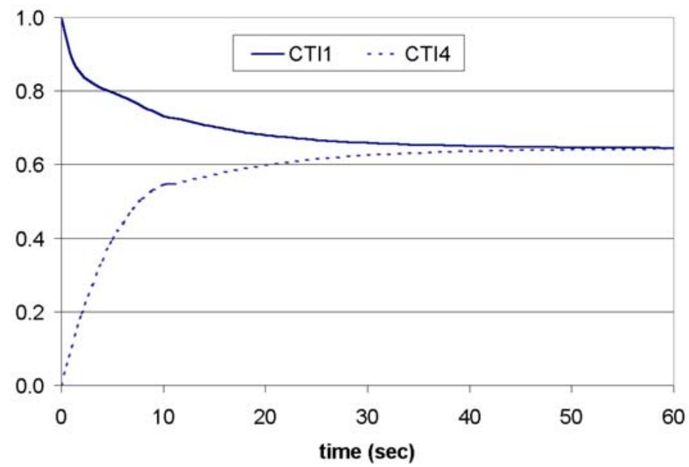
Event time interval,	Customer-initiated		Local-initiated	
seconds	Up-tick trades	Down-tick trades	Up-tick trades	Down-tick trades
E-mini futures returns				
–60 to +60	2.45	-2.42	3.24	-3.46
	(0.292)	(0.339)	(0.282)	(0.258)
–60 to –5	0.73	-0.69	0.81	-1.26
	(0.239)	(0.274)	(0.179)	(0.187)
0 to +60	1.72	-1.72	2.43	-2.19
	(0.197)	(0.239)	(0.219)	(0.188)
+5 to +20	-0.78	0.76	-0.49	0.34
	(0.119)	(0.126)	(0.109)	(0.119)
Regular futures returns				
–60 to +60	2.67	-2.44	3.32	-3.34
	(0.412)	(0.467)	(0.360)	(0.411)
–60 to –5	0.98	-0.58	0.37	-0.69
	(0.315)	(0.344)	(0.276)	(0.305)
0 to +60	1.69	-1.86	2.95	-2.65
	(0.349)	(0.356)	(0.288)	(0.348)
Number of trades	4,859	4,531	5,790	5,520
Mean size, contracts	13.8	13.8	13.7	13.9

The estimates are obtained from regressions of returns on 11 leads and 12 lags of large E-mini trades. Standard errors are given in parentheses. (0, 1) indicator variables are used for large buy and sell trades initiated by locals and off-exchange customers.

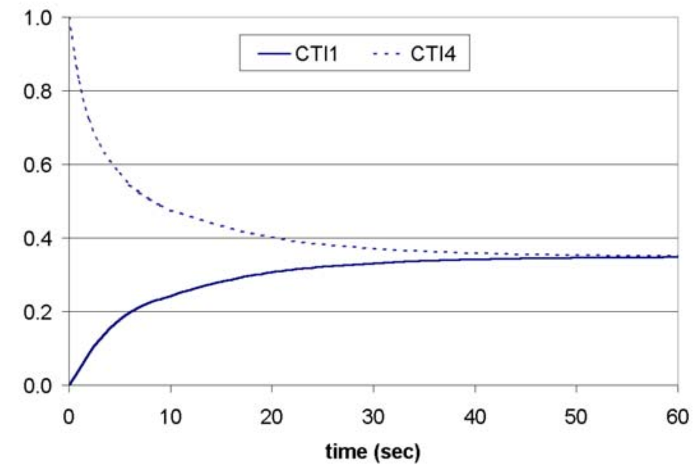
Figure 1
Cumulative impulse response functions

Panel A. E-mini S&P 500 futures

Unit shock to prices of trades initiated by exchange locals (CTI1)

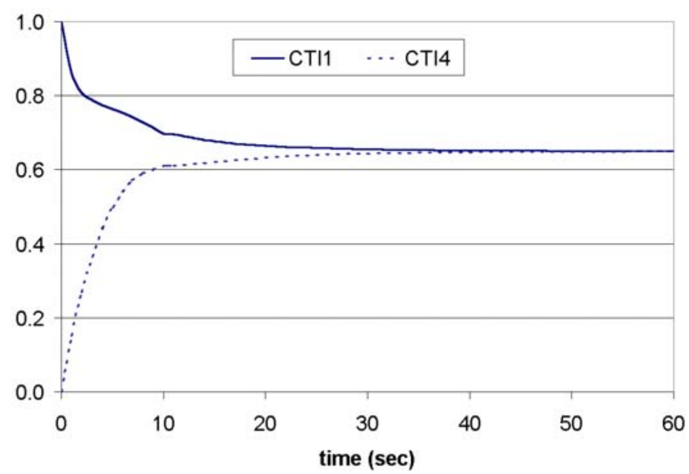


Unit shock to prices of trades initiated by off-exchange traders (CTI4)



Panel B. E-mini Nasdaq-100 futures

Unit shock to prices of trades initiated by exchange locals (CTI1)



Unit shock to prices of trades initiated by off-exchange traders (CTI4)

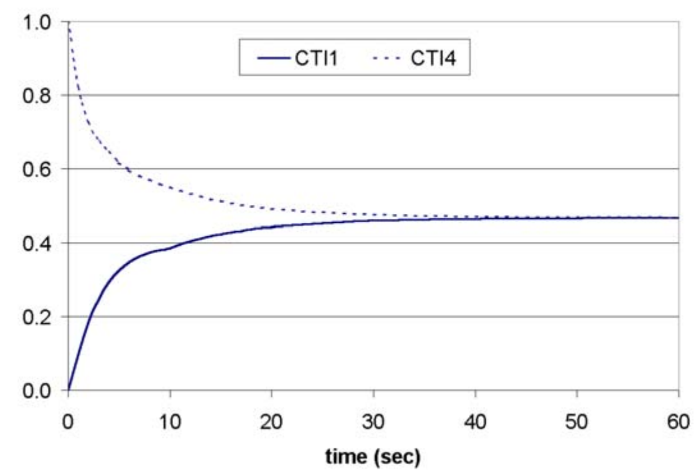
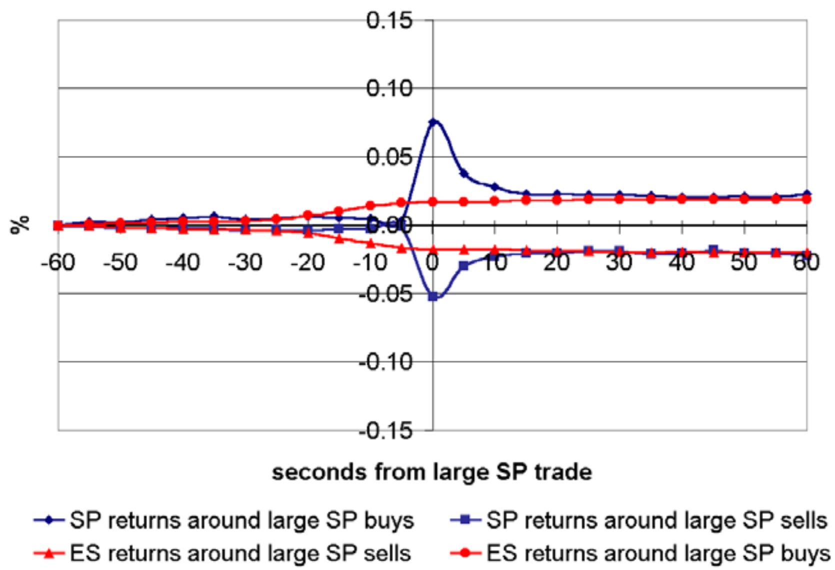


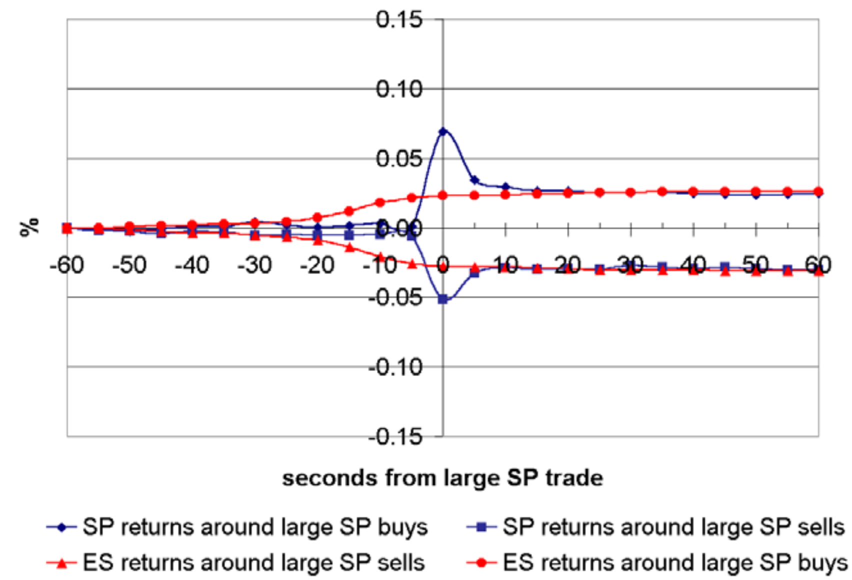
Figure 2
Cumulative average returns around large trades in regular futures

Panel A. Large trades in regular S&P 500 futures

Trades initiated by off-exchange customers (CTI4)

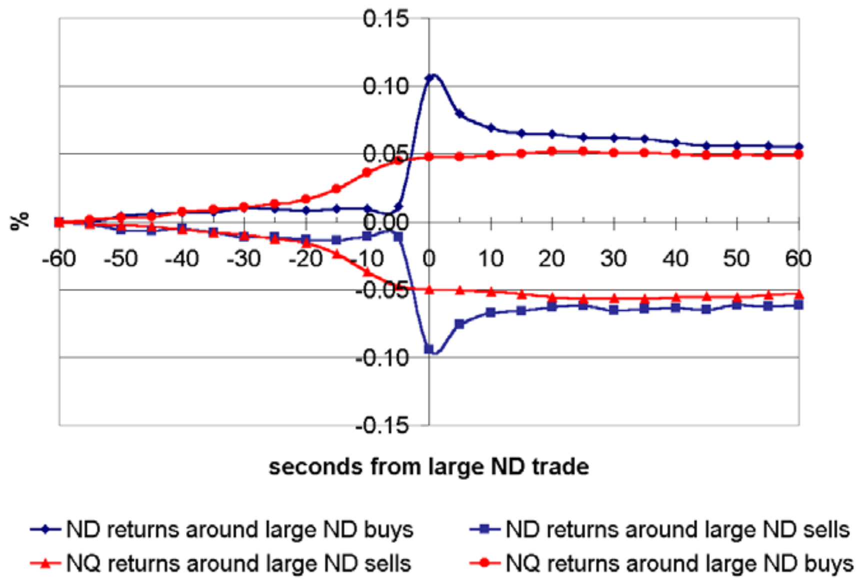


Trades initiated by exchange locals (CTI1)

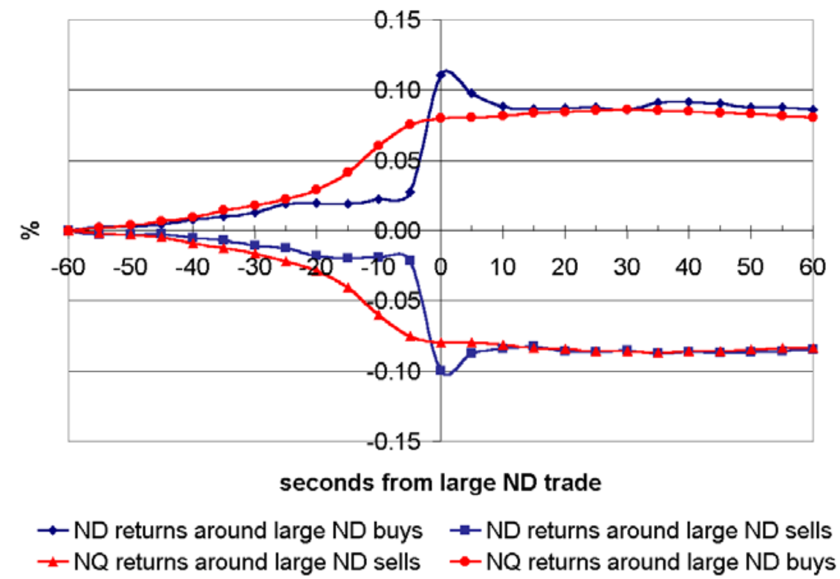


Panel B. Large trades in regular Nasdaq-100 futures

Trades initiated by off-exchange customers (CTI4)



Trades initiated by exchange locals (CTI1)

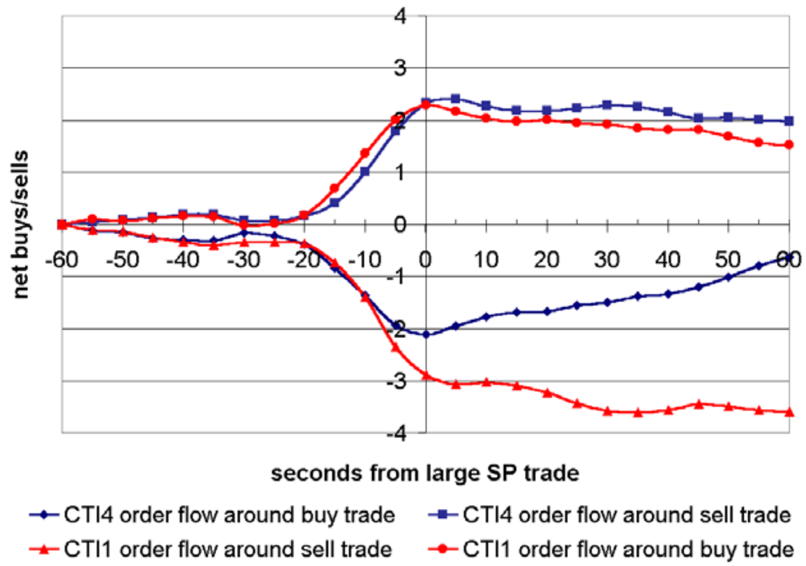


The estimates are obtained from regressions of returns on 11 leads and 12 lags of large trades in regular futures. (0, 1) indicator variables are used for large buy and sell trades initiated by locals and off-exchange customers.

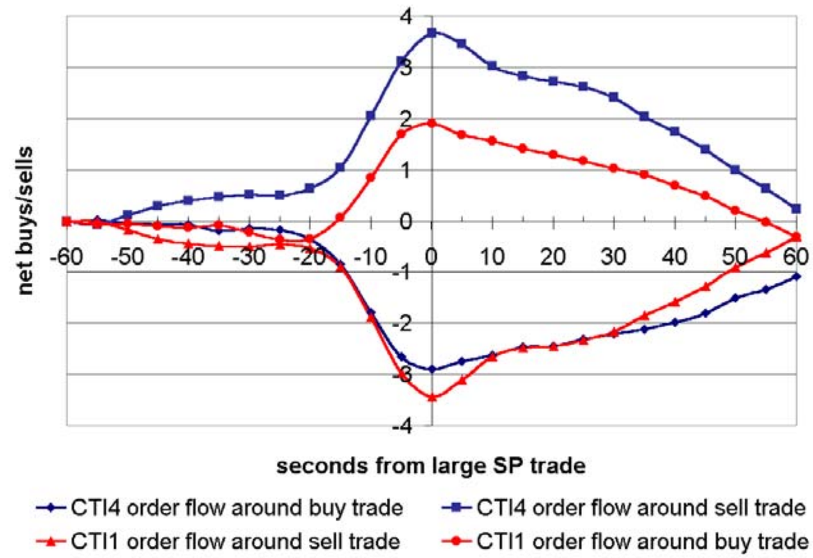
Figure 3
Cumulative order flows around large trades in regular futures

Panel A. Large trades in regular S&P 500 futures

Trades initiated by off-exchange customers (CTI4)

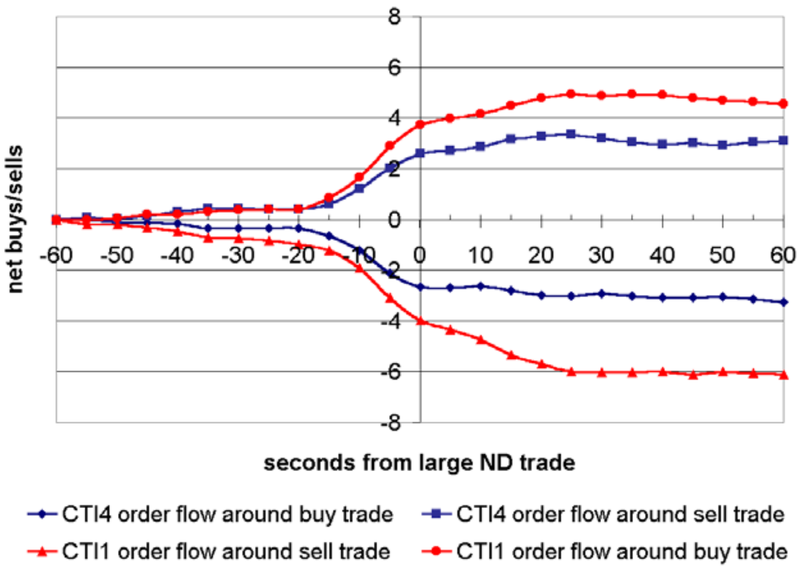


Trades initiated by exchange locals (CTI1)

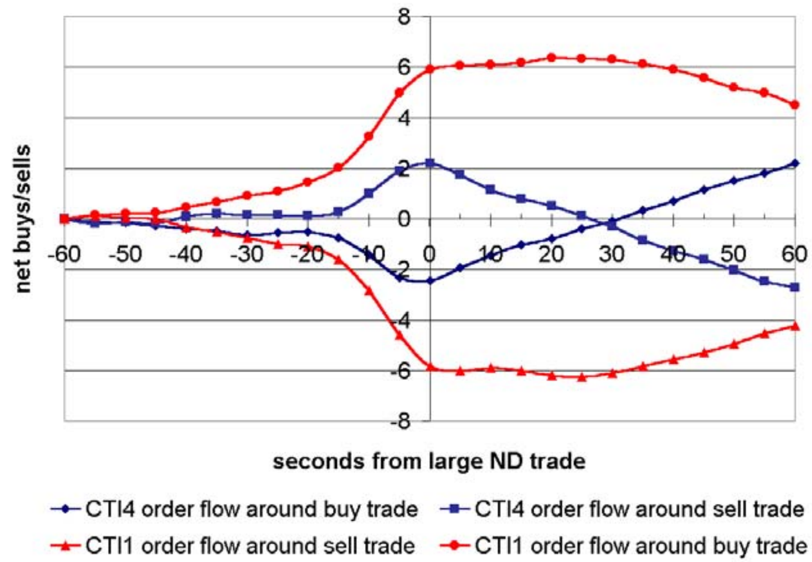


Panel B. Large trades in regular Nasdaq-100 futures

Trades initiated by off-exchange customers (CTI4)



Trades initiated by exchange locals (CTI1)

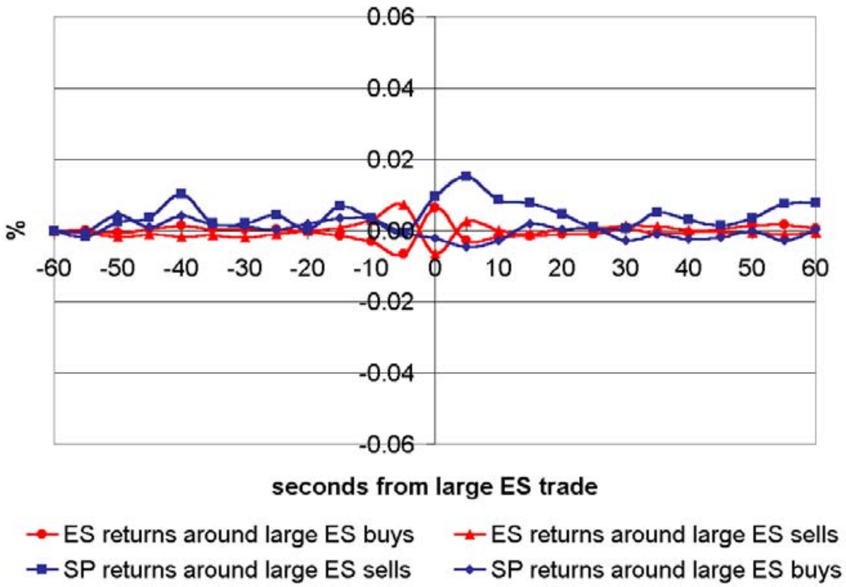


The estimates are obtained from regressions of order flows on 11 leads and 12 lags of large trades in regular futures. The order flows are calculated as the number of buys minus the number of sells. CTI2 and CTI3 trades account for the imbalance between CTI1 and CTI4 order flows. (0, 1) indicator variables are used for large buy and sell trades initiated by locals and off-exchange customers.

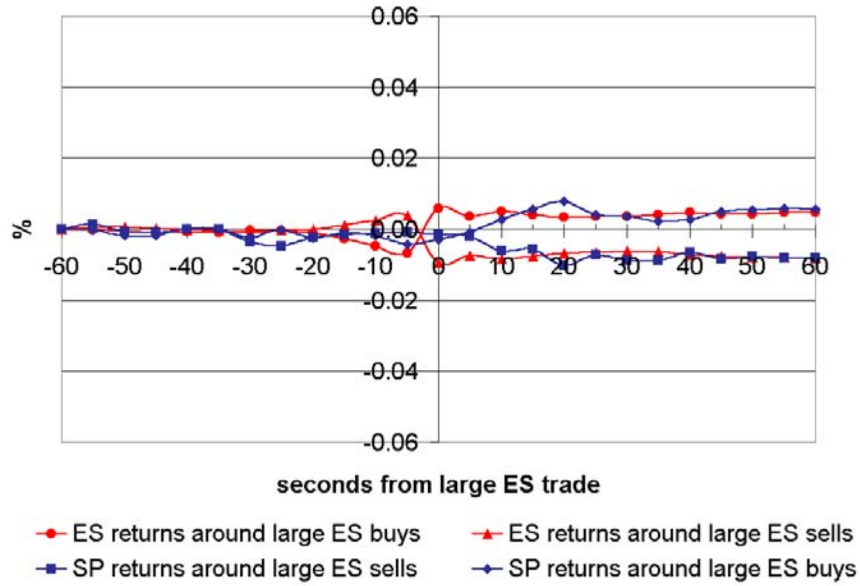
Figure 4
Cumulative average returns around large trades in E-mini futures

Panel A. Large trades in E-mini S&P 500 futures

Trades initiated by off-exchange customers (CTI4)

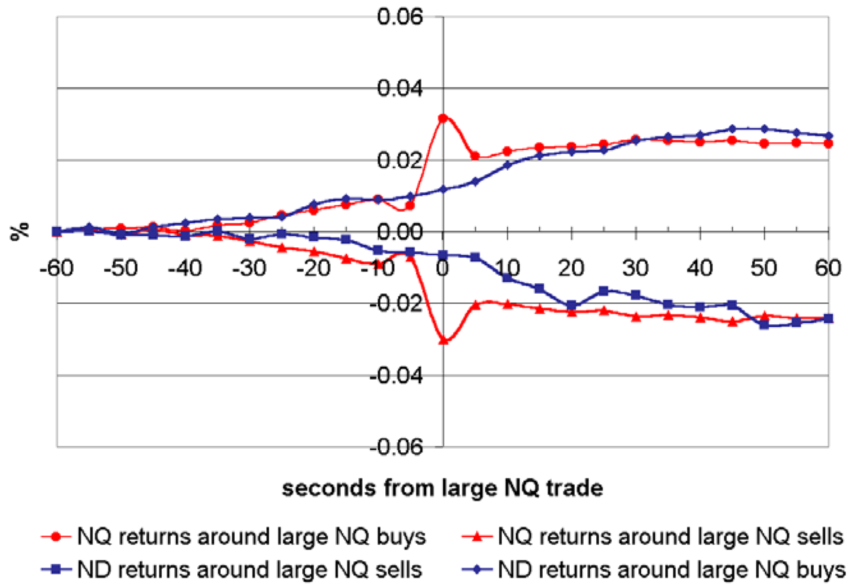


Trades initiated by exchange locals (CTI1)

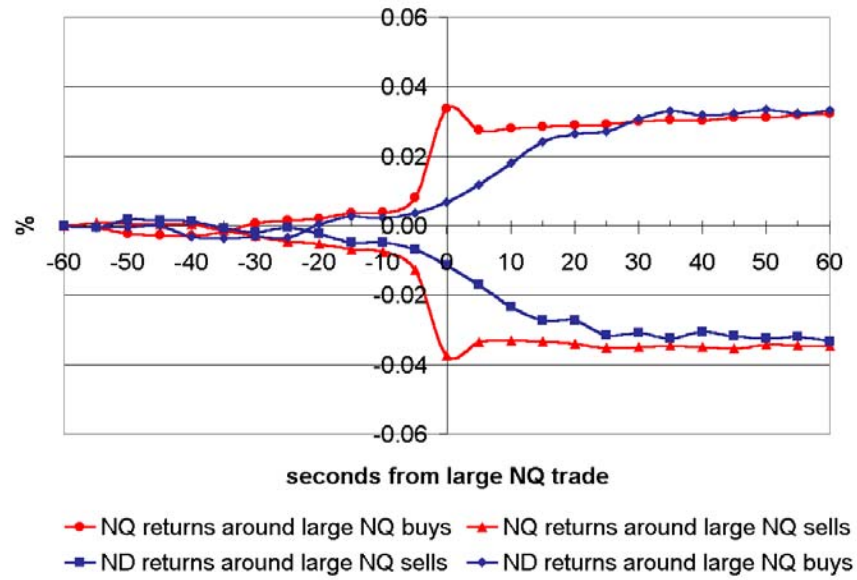


Panel B. Large trades in E-mini Nasdaq-100 futures

Trades initiated by off-exchange customers (CTI4)



Trades initiated by exchange locals (CTI1)



The estimates are obtained from regressions of returns on 11 leads and 12 lags of large trades in E-mini futures. (0, 1) indicator variables are used for large buy and sell trades initiated by locals and off-exchange customers.