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When a halt is not a halt: An analysis of off-NYSE trading during NYSE market closures

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ABSTRACT

Though trading halts are a common feature in securities markets, the issues associated with the coordination of these halts across markets are not well understood. In fact, regulations often allow traders to circumvent trading halts through the use of alternative venues. Using a sample of order imbalance delayed openings on the NYSE, we examine the costs and benefits of continued trading on alternative venues when the main market calls a halt. We find that trades routed to off-NYSE venues during NYSE halts are associated with significant price discovery and lead to an improved post-halt trading environment. In addition, limit orders routed through ECNs reflect price-relevant information even prior to the halt, with limit book imbalances decreasing and depth filling in during the halt around the eventual reopening NYSE price. However, these informational benefits come at a substantial cost, as both execution costs and volatility are extremely high on off-NYSE venues during NYSE halts.

1. Introduction

Recent market developments, including the implementation of Regulation NMS in 2005, have significantly increased the level of fragmentation in U.S. equity markets. For example, the NYSE's share of consolidated volume in NYSE-listed securities decreased from 87% in 1980 to 72% in 2006 and to less than 50% by 2008. This fragmentation leads to serious questions regarding the ability to

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coordinate price discovery across venues, especially during extreme liquidity shocks or significant information events. These concerns were highlighted during the May 6, 2010 "flash crash", when the Dow Jones industrial average fell over 700 points (6.8%) in less than 20 min, only to rebound by over 500 points in the next few minutes. Although the root causes of the "flash crash" have not been fully determined, it appears clear that fragmentation and disparate trading procedures across venues may have exacerbated the problems.[1] This event has led market regulators to push for the implementation of individual security trading halts that would extend across markets.[2]

While many trading venues have developed procedures for halting or slowing trading in individual securities during extreme events, questions of whether and how to coordinate these procedures across venues remain. For example, both the NYSE and Nasdaq utilize some form of trading halt mechanism. In some cases, however, the lack of coordination in these mechanisms provides traders the ability to route trades to alternative venues such as ECNs even when the primary market is halted. Despite this ability to circumvent trading halts, very little is known about the effects of these halt period trades. We attempt to shed light on these issues by analyzing the costs and benefits of continued trading on alternative venues when the main market calls a trading halt. Specifically, we examine the extent to which off-NYSE trading venues are utilized during non-regulatory delayed openings on the NYSE, the informativeness of these off-NYSE trades, and the impact of off-NYSE trades on the post-halt trading environment. We then analyze liquidity and overall market quality on off-NYSE venues during NYSE halts and assess the costs associated with trading in these markets when the primary market is halted.

Notably, whether an NYSE halt results in a cessation of trading on other venues depends on the type of halt that is called. During our sample period, the NYSE utilized two primary types of individual security trading halts.[3] Regulatory (or news) halts are called in anticipation of or in response to news announcements that are expected to have a significant impact on prices. During regulatory halts, the suspension of trading is generally coordinated across venues following the CTA/CQS plans. Non-regulatory (or order imbalance) halts are called in response to large imbalances in supply and demand. During non-regulatory halts, other venues can continue to trade at their own discretion. NYSE halts can be further categorized by whether they occur prior to the opening trade (delayed openings) or after the opening trade (intraday halts). To analyze the role that off-NYSE venues play during halts, we focus on a sample of 2461 non-regulatory delayed openings. These halts make up 85.7% of the total halts and 99.5% of the non-regulatory halts during our sample period.[4]

According to the NYSE, trading halts are designed to "give all market participants a chance to receive and react to pertinent market information that might impact the valuation of a company's shares" and to "dampen price volatility" (NYSE, 1999). The first motivation is essentially an investor protection concern and is supported by Corwin and Lipson (2000) who find that traders do in fact use NYSE halts as an opportunity to cancel and reposition their orders. The second motivation is consistent

[1] Full details on the SEC's investigation of the flash crash are available at: http://www.sec.gov/news/studies/2010/marketevents-report.pdf.

[2] On May 18, 2010, the NYSE and Nasdaq, along with other national securities exchanges, filed new rules with the Securities and Exchange Commission implementing "trading pauses" for individual securities included in the S&P 500 index (see, for example, SEC file number SR-NYSE-2010-39). The proposed rules would provide for a 10-min pause in trading across all venues when a security's price moves 10% or more from a sale price in the preceding five minutes. These markets are currently considering an extension of these mechanisms to securities outside the S&P 500. While these coordinated "trading pauses" are not considered directly in this paper, they highlight the relevance of the issues studied here for market participants and regulators.

[3] While the market structure of the NYSE has changed dramatically under the new hybrid market, the mechanisms associated with trading halts remain largely unchanged (see NYSE Rule 123D). During December of 2008, for example, the NYSE's TAQ data identifies 31 news halts and 98 order imbalance halts involving NYSE-listed securities. Following the implementation of Regulation NMS, the NYSE also implemented Liquidity Replenishment Points (LRPs), as set forth in NYSE Rule 1000. LRPs are stock-specific triggers which, when reached, result in a switch from automatic to manual trading in NYSE stocks. As with non-regulatory halts, trading on other venues is not halted when an LRP is triggered on the NYSE.

[4] Throughout the paper, we refer to non-regulatory delayed openings as "trading halts". This terminology reflects that these events result in a temporary stop to the normal opening mechanism and subsequent continuous trading process that would otherwise occur. This terminology is also consistent with NYSE rules, as these halts are generally handled using the same approval, indicator quote, and reopening mechanisms as intraday halts. While we expect our results to hold for non-regulatory intraday halts, the small sample size for this halt category precludes a direct test of this hypothesis.

with models by Greenwald and Stein (1988, 1991) showing that trading halts can facilitate price discovery and encourage traders to participate in a market when information asymmetry leads to significant transaction price risk. However, trading halts also impose a substantial cost on market participants. At a minimum, trading halts disrupt both liquidity and informationally-motivated trades. This, in turn, could actually reduce the informativeness of prices. For example, models by Brown and Jennings (1989) and Grundy and McNichols (1989) suggest that trading is necessary in order for disperse information to be incorporated into prices. Consistent with these models, Lee et al. (1994) find that volume and volatility are unusually high for several hours following trading halts.

An important aspect of trading halts that has received little attention is whether halts should be coordinated across venues or whether there are potential benefits to continued trading on other venues during halts. While the continuation of trading on other venues may provide benefits in terms of liquidity provision or information production, these benefits may come at the cost of the uninformed traders whom trading halts are designed to protect. To address these issues, we focus on three primary research questions. First, we examine the extent to which traders utilize off-NYSE venues during non-regulatory halts on the NYSE and assess the factors associated with increased off-NYSE trading. Using a sample of order imbalance delayed openings between 2002 and 2005, we find evidence of substantial halt-period off-NYSE trading. However, the use of off-NYSE venues varies widely across halts, with 44% of the sample halts exhibiting no off-NYSE trading and nearly 5% of halts experiencing at least four trades per minute. We find that off-NYSE trading is more likely during halts involving large stocks and stocks with high levels of off-NYSE trading during normal periods. Off-NYSE trading also increases with the magnitude of the absolute halt return and the opposite-side depth available at the start of the halt. These findings suggest that at least some off-NYSE trading may be information-motivated, but the use of off-NYSE venues is limited by the amount of available liquidity. We also document that off-NYSE trading during halts has increased over time, reflecting the general increase in the importance of ECNs and other off-NYSE venues in the trading of NYSE-listed securities.

Second, we test whether off-NYSE trades during NYSE halts are informative. We find that off-NYSE trades are associated with significant, though incomplete, price discovery. The first off-NYSE trade captures roughly 60–70% of the total halt return and price discovery improves with additional off-NYSE trades. Overall, our results suggest that off-NYSE trades contain significant information even beyond that contained in NYSE indicator quotes and the specialist fully incorporates this information into the reopening trade price. Given that off-NYSE trades are informative, we examine whether these trades lead to an improved post-halt trading environment. Consistent with prior research, we find that trading activity and volatility are abnormally high following NYSE trading halts (see Lee et al. (1994)). However, after controlling for endogeneity, we find that off-NYSE trading is negatively related to abnormal volatility and bid-ask spreads in the post-halt period. These findings are consistent with the hypothesis that off-NYSE trades are informative and lead to reduced price uncertainty in the post-halt period.

Finally, we examine the costs associated with off-NYSE trading during NYSE halts. Despite the apparent benefits in terms of information production, off-NYSE trading during NYSE halts comes at a significant cost. Our evidence suggests that effective spreads on off-NYSE venues are as much as 10 times higher during the halt than during comparable periods on non-halt days and volatility is three to five times higher. Further, the effective spread reflects primarily the price impact from informed trades rather than compensation to liquidity providers. These results are consistent with informed traders who use off-NYSE venues to trade against uninformed liquidity traders. Thus, any potential information gains from allowing off-NYSE trading during NYSE halts must be weighed against the investor protection concerns that have been one of the primary motivations for halts in US markets.

To provide more detail regarding the information content of order flow on off-NYSE venues during NYSE halts, we analyze the characteristics of orders and trades on one of the most important off-NYSE venues during this period, the INET ECN.[5] We find that the halt period is characterized by larger than

[5] Before merging operations with Nasdaq in 2006, INET was the largest venue for automated trading of Nasdaq-listed stocks, handling over 25% of Nasdaq volume, and the single largest electronic pool of liquidity for NYSE-listed stocks, capturing about 4% of NYSE volume.

normal order size, increased execution rates, and lower cancelation rates. This apparent shift in either trader composition or trading strategies is consistent with informed trading on the INET ECN during NYSE halts. Informed trading is also reflected in the INET limit order book during the halt, where we find that depth fills in around the NYSE reopening price.

It is important to note that we cannot directly address the question of whether trading halts are beneficial, because we do not know what would have happened in the absence of a halt. However, our results provide important new insights regarding the coordination of trading halts across markets and the costs and benefits of continued trading on alternative venues during halts. Specifically, we find that off-NYSE trades during halts provide significant information benefits to the market, but these benefits come at a substantial cost in terms of market quality. These findings should be beneficial to both market participants and regulators as they consider and potentially implement additional trading halt mechanisms. While our analysis focuses on non-regulatory delayed openings on the NYSE, our findings may extend to other types of halts and to other markets, especially as the globalization of trading reduces the ability to coordinate halts across regulatory jurisdictions.[6]

The remainder of the paper is organized as follows. In Section 2, we provide some background on trading halts and the use of alternative trading venues. Section 3 describes the trading halt sample and Section 4 presents our analysis of the determinants of off-NYSE trading. In Section 5, we present evidence related to the informativeness of off-NYSE trading during NYSE trading halts and examine the effects of off-NYSE trading on the post-halt environment. In Section 6, we analyze the costs of trading on off-NYSE venues during NYSE halts. Section 7 provides a description of halt-period order characteristics on the INET ECN and Section 8 concludes.

2. Background

2.1. Trading halts

Trading halts and their effects on trading have been studied extensively in the literature. Several early studies provide evidence of price discovery during NYSE halts. Schwartz (1982) and King et al. (1991) examine specialists' indicator quotes during halts and find that these quotes gradually converge toward the reopening price. Fabozzi and Ma (1988) examine Nasdaq trading during NYSE halts and find that 71% of halts experience at least some Nasdaq trading. In addition, they find that the price of the first Nasdaq trade fully incorporates halt-related information and is indistinguishable from both the last trade price during the halt and the first trade price following the halt. Unlike these studies, we examine a time period after the development of ECNs and the associated drop in NYSE market share. Like Fabozzi and Ma, we find that the first off-NYSE trade during an NYSE halt results in significant price discovery. However, in contrast to their results, we find that this price discovery is incomplete, with both the magnitude and efficiency of price discovery improving with subsequent off-NYSE trades. We also find that off-NYSE trades provide significant information beyond that contained in NYSE indicator quotes and show that the cross-sectional variation in off-NYSE trading is at least partially attributable to the availability of liquidity.

Prior studies of trading halts also find evidence of unusually high volume and volatility after halts. For NYSE halts, Lee et al. (1994) document increases in volume and volatility that continue for several hours after the resumption of trading. They find that these post-halt effects are positively related to media coverage and that off-NYSE trades are associated with higher post-halt volume and either unchanged or marginally lower post-halt volatility. Corwin and Lipson (2000) show that the post-halt period is also characterized by increases in submissions and cancelations of limit orders, and a significant reduction in limit order book depth. However, they find little evidence that increases in post-halt volatility are related to the reduction in limit book depth after halts. Christie et al. (2002) find that volume and volatility also increase following Nasdaq halts and the magnitude of post-halt effects is significantly affected by the mechanism used to reopen trading. We contribute to these studies by testing

[6] See the Report on Trading Halts and Market Closures (International Organization of Securities Commissions, 2002) for a discussion of these issues.

whether increased off-NYSE trading leads to reductions in abnormal post-halt effects. After controlling for the endogeneity of off-NYSE trading, we find a significant negative relation between halt-period off-NYSE trading and abnormal measures of post-halt volatility and bid-ask spreads. Thus, off-NYSE trading appears to be associated with an improved post-halt trading environment and reduced uncertainty.

2.2. Off-NYSE trading venues and multi-market trading

While our study provides the first detailed analysis of price discovery on off-NYSE venues during trading halts, several prior studies examine the role of alternative trading venues more generally.[7] For NYSE-listed stocks, Easley et al. (1996) find that the probability of informed trade is higher on the NYSE than on Cincinnati and Bessembinder and Kaufman (1997) find that off-NYSE trades contain significantly less information than NYSE trades.[8] Similarly, Hasbrouck (1995) examines trading in the 30 Dow stocks and finds that the NYSE accounts for an average of 92.7% of price discovery. Together, this research suggests that for NYSE-listed stocks, trades routed to the NYSE are more informative than trades routed to other trading venues. We contribute to this research by examining the informativeness of off-NYSE trades during a period when ECNs and other off-NYSE venues captured a larger fraction of trading in NYSE-listed securities. In addition, while prior studies focus on concurrent trading across venues during normal conditions, we examine the information content of trades routed to off-NYSE venues during large information events and periods when NYSE trading is halted.

Previous research also examines the growing importance of ECNs in the trading of Nasdaq stocks. Huang (2002) examines ECN and market maker quotes in Nasdaq stocks and finds that ECNs are more likely to be at the inside, tend to post more informative quotes, and update quotes more quickly than market makers. Similarly, Tuttle (2004) finds that trades on the Island ECN are more informative than market maker trades. Barclay and Hendershott (2003) find evidence of significant, though noisy, price discovery during after-hours trading of Nasdaq stocks and Barclay and Hendershott (2008) find that pre-open ECN trading improves the efficiency of opening prices on Nasdaq. In contrast to the evidence for NYSE-listed stocks, these findings suggest that ECN trades and quotes tend to be more informative than those of Nasdaq market makers. Our results during NYSE halts are consistent with the findings for Nasdaq stocks and suggest that off-NYSE trades, including ECN trades, are associated with significant price discovery and may lead to more efficient post-halt prices on the primary market.

3. Data and sample characteristics

Because off-NYSE trading is not permitted during regulatory halts on the NYSE, we focus our attention on order imbalance halts. We begin by collecting the full sample of 3270 order imbalance (mode = 7) trading halts on the NYSE from 2002 through 2005, a period when ECNs and other off-NYSE venues captured a nontrivial and increasing market share in NYSE-listed securities. Following prior studies, we apply several additional restrictions to ensure that we identify economically meaningful trading halts and to eliminate potential confounding effects.[9] The resulting sample includes 2473 order imbalance trading halts. Only 12 of these order imbalance halts are called after the start of trading. To

[7] Our analysis of order imbalance delayed openings is also related to prior studies of price discovery at the open. For example, Biais et al. (1999) study the pre-open period on the Paris Bourse, Cao et al. (2000) study the pre-open on Nasdaq, Madhavan and Panchapagesan (2000) study the opening mechanism on the NYSE, and Ellul et al. (2005) study alternative opening mechanisms on the London Stock Exchange. Unlike these studies, we examine trading on alternative venues during a delay in trading on the primary market.

[8] These studies are consistent with cream skimming by off-NYSE venues. However, Battalio (1997) finds that effective spreads do not increase after Madoff, a major third-market broker-dealer, enters the market. Battlaio's results suggest that cream skimming is economically insignificant.

[9] We exclude 84 cases where multiple halts are called for the same security on the same day or back-to-back days. We also exclude three halts that have no indicator quotes, three halts that are not resolved by the end of the same trading day, 450 halts with a duration of less than ten minutes, 68 halts with a reopening quote midpoint of less than $5, 38 halts involving the less active of dual-class shares, four halts involving IPOs, and two halts called in close proximity to 1-for-10 reverse splits. Finally, we exclude 145 halts involving securities classified as other than common stock or ADRs (CRSP share codes other than 10, 11, 12, 30, and 31).

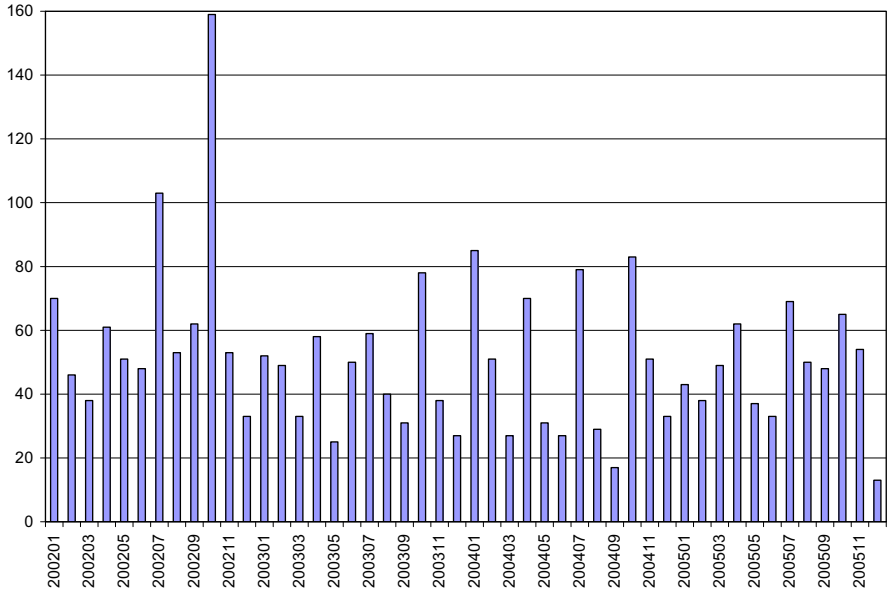

Fig. 1. Number of Order Imbalance Delayed Openings by Month. The figure plots the monthly number of order imbalance delayed openings involving NYSE common stocks and ADRs from January 2002 through December 2005.

avoid complications arising from differences between intraday halts and delayed openings, we focus throughout the paper on the subset of order imbalance delayed openings.

The final sample includes 2461 halts involving 1055 stocks. Of the sample securities, 470 had only one halt during the sample period, while eight securities were halted at least 10 times. Fig. 1 shows the frequency of sample trading halts by month. Clearly, the frequency of halts varies substantially across months. The number of halts ranges from 13 in December 2005 to 159 in October 2002.

For each halt in the sample, we collect intraday trade and quote data from TAQ for the 31-day period starting 15 days prior to the halt. This allows us to analyze trade and quote behavior before, during, and after the halt, as well as on non-halt trading days. We also use the ITCH database to collect order flow and trade data from the INET ECN, including all submissions, executions, and cancelations for the 31-day period starting 15 days prior to the halt.[10] Finally, we collect descriptive information for each sample firm from CRSP and CDA Spectrum.

Table 1 provides summary statistics for the sample halts. Because our sample includes only delayed openings, the pre-halt price is defined at the close of the previous trading day and the beginning time of the halt is set to 9:30 a.m. We define the end of the halt based on the earlier of the reopening trade or the first good quote following the halt, where good quotes have normal modes and positive prices and depths.[11] In general, the halt characteristics are consistent with prior studies of order imbalance halts. The mean halt duration is 20.6 min, the average absolute return from the pre-halt quote midpoint

[10] ITCH is the vendor-level data feed of the INET ECN (previously Island). ITCH disseminates information about all orders and executions on INET in real time and is made up of a series of sequenced messages that describe orders added to, removed from, and executed on INET. For a more complete description of the INET data, see Hasbrouck and Saar (2009).

[11] Throughout our tests, both the pre-halt quotes and post-halt quotes must have normal condition codes, positive prices, and positive depth. In 95.4% of the sample halts, the reopening trade is posted prior to or at the same time as the reopening quotes. For the remaining cases, we set the reopening time to the quote time and define the reopening trade as the first trade that either has a condition code of 'O' or occurs within 30 s of the reopening quotes. All but one of the sample halts have a reopening trade based on this definition. Beginning in 1997, NYSE specialists started indicating the end of the trading halt by posting a quote with a mode of 29 prior to posting the reopening quotes and reopening trade. Off-NYSE trading typically resumes once the mode 29 quote is posted. As a result, we define off-NYSE trades during halts as any trades that occur after the start of the halt and before the mode 29 quote. We do not include off-NYSE trades during the pre-opening period.

Table 1
Summary statistics. The table reports summary statistics for the sample of NYSE order imbalance delayed openings from January 2002 through December 2005. We exclude multiple halts for the same firm on the same or back-to-back days, halts with no indicator quotes prior to the reopen, halts that are not resolved on the same trading day, halts lasting less than 10 min, halts with a reopening midpoint less than $5 or greater than $1000, and halts in the less-active of dual-class shares. The final sample includes 2461 order imbalance delayed openings. The table provides results for the full sample, for halts categorized by whether or not off-NYSE trading occurred during the halt, and halts categorized by whether they resulted in positive or negative quote midpoint returns. *p*-values are from a test of whether means are equal across subsamples.

	Full sample	Off-NYSE trading category			Halt return direction		
		Off-NYSE trading	No off-NYSE trading	*p*-value	Positive return	Negative return	*p*-value
N	2461	1377	1084	–	1064	1397	–
Halt length (min.)	20.56	20.26	20.93	0.028	18.86	21.85	0.000
Midpoint return (%)	−2.24	−2.36	−2.09	0.570	8.61	−10.51	0.000
Absolute midpoint return (%)	9.69	9.49	9.94	0.127	8.61	10.51	0.000
# Indicator quotes	1.51	1.58	1.42	0.000	1.42	1.58	0.000
Reopening spread (cents)	13.11	12.27	14.18	0.113	16.35	10.64	0.000
Reopening spread (%)	0.49	0.47	0.51	0.428	0.55	0.44	0.067
Reopening volume (000)	229.45	305.95	132.27	0.000	181.13	266.26	0.000
% with off-NYSE trading	55.95	100.00	0.00	0.000	54.23	57.27	0.132
Off-NYSE volume (000)	13.30	23.76	0.00	0.000	10.58	15.36	0.142
Off-NYSE trades	16.34	29.21	0.00	0.000	15.80	16.75	0.765
Off-NYSE trades per minute	0.83	1.49	0.00	0.000	0.87	0.80	0.634
Off-NYSE trade size	1366.95	1366.95	–	–	763.48	1802.21	0.052
Off-NYSE/reopening vol (%)	8.47	15.13	0.00	0.000	5.49	10.74	0.185

to the reopening quote midpoint is 9.7%, and the number of indicator quotes during a halt averages 1.51. The reopening trade tends to be very large, averaging 229 thousand shares. Off-NYSE trading occurs in 56.0% of the sample halts. The average number of off-NYSE trades is 16.3, with an average trade size of 1367 shares, and off-NYSE trading is equivalent to 8.5% of the NYSE's reopening trade size.

Comparing halts with and without off-NYSE trading, we see that halts with off-NYSE trading are marginally shorter in duration. While absolute halt returns are similar across these subsamples, the number of indicator quotes is significantly higher during halts with off-NYSE trading. The most striking difference across these categories is in the reopening trade. This trade averages 306 thousand shares for halts with off-NYSE trading and 132 thousand shares for halts without off-NYSE trading. Thus, off-NYSE trading appears to reflect a more general increase in the level of trading interest. Among halts with at least one off-NYSE trade, the average number of off-NYSE trades is 29.1 or 1.5 per minute.

The trading strategies employed during halts may differ by return direction. In addition, the ability to trade during negative return halts may be limited by short sale constraints. We therefore provide separate summary statistics for subsamples categorized by the return direction during the halt. The results show that negative return halts have a longer duration and result in a larger absolute return and reopening volume. Negative return halts also appear to have smaller reopening spreads. Despite these differences, however, neither the proportion of halts with off-NYSE trading nor the number of off-NYSE trades differ significantly by return direction. Throughout most of the paper, we provide results for the combined sample of positive and negative return halts, noting differences between these categories where necessary.

4. Predicting off-NYSE trading

As noted above, the use of off-NYSE venues varies significantly across halts. In this section we analyze the factors that drive off-NYSE trading during NYSE halts. We are not aware of any regulatory

restrictions that would limit the ability of traders to utilize off-NYSE venues during non-regulatory halts. The occurrence of off-NYSE trades therefore requires a two-sided decision involving the trading venue and the trader (or broker). Each venue must first decide whether to continue trading the stock based on an assessment of their ability to properly price the security and offer best execution. However, discussions with market participants suggest that it was unlikely during our sample period that any ECN or exchange would have stopped trading an NYSE-listed security due to a non-regulatory halt on the NYSE. It appears then that the occurrence of off-NYSE trades results primarily from the decision of individual traders or their brokers, who decide to route trades to alternative venues during the NYSE halt. This decision involves a tradeoff between the liquidity or informational motives of the trader and the potential costs associated with trading on a venue that may have low liquidity and high levels of uncertainty.

While we cannot directly analyze the motivations of individual traders, we hypothesize that off-NYSE trading will be highest when the constraints imposed by the halt are most binding and when the costs of trading are lowest. In particular, we expect off-NYSE trading to be positively related to the demand for liquidity and the level of halt-related information, and negatively related to the expected trading costs on off-NYSE venues. We therefore model off-NYSE trading as a function of both stock and halt characteristics. We estimate two alternative models of off-NYSE trading. First, we use OLS regressions to analyze the number of off-NYSE trades. Second, we use logistic regressions to analyze the likelihood of off-NYSE trading. In both models, we include dummy variables for 2003, 2004, and 2005, in order to capture any time series variation in the level of off-NYSE trading during halts.

The stock characteristics included in the regressions are the natural log of market capitalization, the natural log of price, turnover, volatility, and institutional holdings. These variables proxy for differences in the demand for liquidity across stocks and may also reflect differences in the information environment. Market capitalization and price are defined as averages over the calendar year prior to the halt. Turnover is defined as the average daily volume over the year prior to the halt divided by shares outstanding on the halt date. Volatility is defined as the standard deviation of daily quote midpoint returns over the year prior to the halt. All variables calculated over the year prior to the halt exclude the 15 days immediately preceding the halt. Institutional holdings is defined as the proportion of shares held by institutions as of the most recent 13F filing prior to the trading halt. To control for possible difference across industries, we include dummy variables for each of the 17 industry classifications described in Fama and French (1997). Finally, to control for differences across stocks in the normal level of off-NYSE trading, we include the total number of off-NYSE trades during the 15 days prior to the halt.

To proxy for differences in halt-related information we include two alternative sets of variables. First, we include several halt characteristics including halt duration, the number of indicator quotes during the halt, the absolute return during the halt, and a dummy variable for negative return halts. While these variables are clearly associated with halt-related information, they reflect information that may not be available to investors either prior to or during the halt and may themselves be endogenous. We therefore include an alternative set of proxies for halt-related information and available liquidity based on the condition of the INET limit order book at the start of the halt.[12] This information was available to investors throughout our sample period and also serves as a proxy for NYSE order flow at the time of the halt. We focus on two primary INET variables. The first is the absolute value of the depth imbalance in the INET limit order book based on orders placed within $5 of the pre-halt NYSE quote midpoint. To make this variable comparable across stocks, we standardize by shares outstanding. The second variable is the total depth available within $5 of the pre-halt quote midpoint on the opposite side of the depth imbalance.[13] For example, if there is a buy imbalance, the opposite-side depth is defined based on limit sell orders. To capture differences driven by trade direction, such as effects related to short sale constraints, we also include a dummy variable to identify negative (sell) imbalances and an interaction between this dummy variable and the two previous variables. Finally, to examine whether off-NYSE

[12] Details regarding the construction of the INET limit order book are provided in Section 7.
[13] The conclusions are similar if we use total depth rather than opposite-side depth.

trading is affected by the type of news, we include a dummy variable to identify halts associated with earnings announcements.

The results are provided in Table 2. The first two columns describe OLS and logistic regressions including halt characteristics. The last two columns describe regressions including INET limit book variables. The results for stock characteristics show that off-NYSE trading is more likely during halts involving large stocks and stocks that exhibit high levels of off-NYSE trading during normal periods. After controlling for firm size, institutional holdings are positively related to the likelihood of off-NYSE trading, but are not significantly related to number of off-NYSE trades. Off-NYSE trading is also higher for low-priced stocks. The restriction that off-NYSE trading is equal across industries is rejected at the 5% level in one of the four specifications, but cannot be rejected in the remaining specifications. Thus, there is little evidence of strong industry effects in halt-period off-NYSE trading. The coefficients on the year dummy variables point to a significant increase over time in the amount of off-NYSE trading during halts and the restriction that off-NYSE trading is equal across years is easily rejected. This trend

Table 2
Regressions predicting off-NYSE trading during NYSE Halts. The table reports coefficients from regressions of off-NYSE trading during NYSE halts as a function of halt and firm characteristics. The sample includes 2461 order imbalance delayed openings on the NYSE from 2002 to 2005. In the OLS regressions, the dependent variable is the number of off-NYSE trades during the halt. In the logistic regressions, the dependent variable is equal to one for halts with off-NYSE trading and zero otherwise. The explanatory variables are defined as follows: We define three variables based on the state of the INET limit order book at the start of the halt (9:30). *AbsImbal* is the absolute value of the depth imbalance on INET, *NegImbalD* is a dummy variable to identify negative (sell) imbalances, and *OppDepth* is the total depth on the side opposite the imbalance. *AbsHaltRet* is the absolute value of the return during the halt and *NegHaltRetD* is an indicator for negative return halts. *Halt Duration* is the number of minutes from the beginning of the halt to the reopening trade. *Indicator Quotes* is the number of NYSE indicator quotes posted during the halt. *MktCap* is the natural logarithm of the market capitalization over the year prior to the halt. *Price* is the natural logarithm of the average stock price over the year prior to the halt. *Turnover* is the average daily share volume over the year prior to the halt divided by shares outstanding as of the halt date. *Volatility* is defined as the standard deviation of daily quote-midpoint returns over the year prior to the halt. *InstHoldings* is the percentage institutional holdings on the halt date. *EarningsD* is an indicator of whether the halt is related to an earnings announcement. *OffTrdsBef* is the number of off-NYSE trades up to 15 days before the halt. *2003D*, *2004D*, *2005D* are dummy variables identifying halts during 2003, 2004, and 2005, respectively.

	Regression using halt characteristics		Regressions using inet characteristics at 9:30	
	OLS	Logistic	OLS	Logistic
Intercept	−160.700***	−10.030***	−89.426***	−8.714***
AbsHaltRet	120.600***	1.731*	–	–
NegHaltRetD	0.328	0.253	–	–
AbsHaltRet∗NegHaltRetD	−42.340	−0.801	–	–
Halt Duration	0.016***	0.000	–	–
Indicator Quotes	15.600***	0.354***	–	–
OppDepth			53.202**	5.568***
AbsImbal			32.619***	0.071
NegImbalD	–	–	6.777**	0.439***
OppDepth∗NegImbalD	–	–	−50.083	−4.035*
AbsImbal∗NegImbalD	–	–	−27.084***	0.489
MktCap	7.370***	0.591***	5.749***	0.552***
Price	−1.199***	−0.440***	−2.390	−0.400***
Turnover	−0.573	0.382**	−9.532**	0.114
Volatility	143.000	5.414	280.338*	8.574*
Holdings	−0.009	0.005**	0.014	0.005**
EarningsD	−7.003**	−0.268***	−5.494	−0.235**
OffTrdsBef	0.036***	0.003***	0.035***	0.002***
2003D	18.600***	1.601***	15.699***	1.550***
2004D	21.610***	1.422***	16.025***	1.235***
2005D	26.890***	2.098***	21.491***	1.914***
p-value for year differences	0.000	0.000	0.000	0.000
p-value for industry differences	0.499	0.027	0.821	0.123
R-square	0.144	0.452	0.107	0.432

* Significance at the 10% levels.
** Significance at the 5% levels.
*** Significance at the 1% levels.

is consistent with the increasing importance of ECNs during the sample period. In addition, all four specifications suggest that off-NYSE trading is less likely for halts associated with earnings announcements than for other halts.

The coefficients on halt characteristics in the first two columns show that both the likelihood and amount of halt-period off-NYSE trading are positively related to the absolute halt return and the number of indicator quotes. These results are consistent with the hypothesis that off-NYSE trading is more likely when the informational motives for trade are high. The amount of off-NYSE trading is also positively related to halt duration. Again, however, the specification based on halt characteristics includes some variables that are not known at the time of the halt. Turning to the results based on the state of the INET limit order book, we see that the likelihood of off-NYSE trading is significantly higher for halts with high levels of posted liquidity, as defined by opposite-side depth. In addition, the number of off-NYSE trades is significantly related to the magnitude of the limit book imbalance. These results suggest that off-NYSE trading is related to both available liquidity (or expected execution costs) and to the level of information asymmetry. The interaction terms involving the negative imbalance dummy suggest that the effects of imbalance and opposite-side depth are weaker for halts with negative (sell) imbalances. This is consistent with restrictions related to short sale constraints, but could also reflect other differences between buy and sell orders.

The results in Table 2 suggest that off-NYSE trading during NYSE halts is driven by both stock characteristics and halt-related information. In addition, the results reflect the increasing ability of off-NYSE venues to capture market share in NYSE-listed securities over time and suggest that off-NYSE trading is affected by the availability of liquidity on off-NYSE venues. Overall, we find that while traders may use off-NYSE venues as a source of liquidity during halts, informational motives appear to be an important factor. We investigate these issues in more detail below.

5. The informativeness of off-NYSE trades

In this section, we provide direct tests of the informativeness of off-NYSE trades during NYSE halts. First, we use average price contributions and absolute pricing errors to analyze the magnitude and efficiency of price discovery from individual off-NYSE trades. Second, we use two-stage return regressions to test the incremental information in off-NYSE trades beyond that provided by indicator quotes. Finally, we examine whether increased off-NYSE trading leads to an improved post-halt trading environment.

5.1. Off-NYSE trades and price discovery

To analyze price discovery during halts, we must first make an assumption about the total impact of halt-related information. We define the pre-halt price as the midpoint of the last good pre-halt NYSE quotes. This provides an estimate of the price prior to the incorporation of halt-related information. Following Corwin and Lipson (2000), we define the post-halt price as the midpoint of the NYSE quotes outstanding one hour after the reopen of trading. This provides an estimate of the true price after the incorporation of halt-related information and allows for the possibility that halt-related information is not fully incorporated in the reopening price. Based on these prices, we define the total return as the return from the pre-halt midpoint to the midpoint of the quotes one hour after the reopen.[14]

For each off-NYSE trade during the halt, we define the price contribution as the return from the pre-halt midpoint to the off-NYSE trade price divided by the total return. Similarly, for each NYSE indicator quote during the halt, we define the price contribution as the return from the pre-halt midpoint to the indicator quote midpoint divided by the total return. We then calculate the weighted-average price contribution across all halts, where each halt is weighted according to the absolute return from the pre-halt midpoint to the midpoint one hour after the halt. This weighting reduces the effects of outliers caused by very small halt-period returns. This measure is similar in

[14] Conclusions based on the closing quote midpoint are similar.

spirit to the weighted-average price contributions in Barclay and Warner (1993) and Barclay and Hendershott (2003). However, because we have only one event for each security, we do not average across days. We define the absolute pricing error for each off-NYSE trade (indicator quote) as the absolute value of the percentage difference between the trade price (indicator quote midpoint) and the quote midpoint one hour after the reopen.

Panel A of Table 3 provides results for the first through tenth off-NYSE trades and the last off-NYSE trade. For comparison, results are also provided for the pre-halt quote midpoint and the reopening trade price. On average, the first off-NYSE trade occurs 6.0 min after the start of the halt and the last off-NYSE trade occurs 14.8 min after the start of the halt. The weighted price contribution is 62.4% as of the first off-NYSE trade and increases gradually to 84.2% by the tenth off-NYSE trade. Notably, there appears to be little incremental change in the weighted price contribution after the seventh or eighth trade. In comparison, the weighted price contribution for the reopening trade equals 99.1% for halts with off-NYSE trading and 97.3% for halts with no off-NYSE trading. Thus, while off-NYSE trades are associated with significant price discovery, prices do not fully adjust until the reopening trade.

The absolute pricing error based on the pre-halt midpoint averages 10.35%, with a standard deviation of 10.99%. Pricing errors improve substantially with the first off-NYSE trade and continue to improve with subsequent trades. The absolute pricing error at the first off-NYSE trade has a mean of 5.20% and a standard deviation of 7.57%. By the last trade, the mean and standard deviation of absolute pricing errors drop to an average of 3.99% and 3.20%, respectively. In comparison, the absolute pricing error associated with the reopening trade has a mean and standard deviation of 2.50% and 3.02% for halts with off-NYSE trading, and 3.11% and 3.62% for halts with no off-NYSE trading. Again, these results suggest that prices do not fully adjust until the reopening trade.[15]

To allow more precise inferences about the incremental price discovery from sequential off-NYSE trades, we repeat the analyses using only the subsample of 567 halts with at least 10 off-NYSE trades. In general, the results are similar to those reported in Table 3 and are not tabulated. However, to illustrate the results we plot in Fig. 2 the mean pricing errors across the first 10 off-NYSE trades. As the figure shows, the mean absolute pricing error drops substantially with the first off-NYSE trade. Pricing errors continue to drop with subsequent trades, with the most noticeable drops for the first through fourth trades, the last trade, and the reopening trade.

For comparison, we repeated this analysis based on NYSE indicator quotes. On average, the weighted price contribution associated with NYSE indicator quotes is substantially higher than that associated with off-NYSE trade prices. As noted by Corwin and Lipson (2000), this may reflect the specialist's ability to incorporate information from multiple sources, including off-NYSE trades, the NYSE limit order book, and NYSE floor traders. In the next section, we test directly whether off-NYSE trade prices provide incremental information beyond that contained in NYSE indicator quotes. We also repeated the analysis using off-NYSE quotes. The results suggest that off-NYSE trades are significantly more informative than off-NYSE quotes.

5.2. Price efficiency regressions

In this section, we analyze both the efficiency and evolution of price discovery using the two-stage regression methodology of Madhavan and Panchapagesan (2000) and Corwin and Lipson (2000). The first stage of the regression is similar to the "unbiasedness" regressions of Biais et al. (1999) and Barclay and Hendershott (2003). In this stage, the total return from the pre-halt midpoint to the midpoint one hour after the halt is regressed on the return from the pre-halt midpoint to some reference price during the halt. This regression takes the following general form:

$$\text{Stage 1}: Ln(P_{i,post}/P_{i,pre}) = \alpha + \beta \cdot Ln(P_{i,1}/P_{i,pre}) + e_i, \quad (1)$$

[15] Although not shown, subsample results suggest that the price discovery associated with off-NYSE trades is less complete for negative return halts. For example, the weighted price contribution at the first off-NYSE trade is 57.4% for negative return halts, compared to 74.8% for positive return halts. However, negative return halts are also associated with larger absolute price changes. This difference in halt returns makes it difficult to interpret differences across the two subsamples.

Table 3
Price Contribution and Pricing Errors during NYSE Halts. The table provides summary statistics for measures of price contribution and pricing error at various reference points during the halt. The sample includes 2461 order imbalance delayed openings. For each halt, the price contribution associated with a specific reference price is defined as the return from the pre-halt midpoint to the reference price divided by the return from the pre-halt midpoint to the midpoint 60 min after the reopen of trading. The table then reports the weighted-average price contribution across halts, where each halt is weighted according to the absolute value of the return from the pre-halt midpoint to the midpoint 60 min after the halt. Absolute pricing error is defined as the percentage difference between the reference price and the midpoint 60 min after the reopen of trading. The pre-halt midpoint is defined based on the last good quotes prior to the halt. In Panel A, reference prices are defined as off-NYSE trade prices and prices are included for the first 10 and the last off-NYSE trades during the halt. In Panel B, reference prices are defined as the midpoint of NYSE indicator quotes and are included for the first, second, third, and last indicator quotes during the halt. The table also provides information on the timing of off-NYSE trades and indicator quotes relative to both the beginning of the halt and the end of the halt (defined as the mode = 29 quote time).

Reference price	*N*	Minutes after start of halt	Minutes before end of halt	Wtd. price contribution (%)	Mean abs. pricing error (%)	Std. dev. of abs. pricing error (%)
Panel A – Off NYSE Trades						
Pre-halt Midpoint	1377	0.00	20.26	–	10.35	10.99
1st Trade	1377	6.03	13.98	62.44	5.20	7.57
2nd Trade	1140	7.12	12.78	70.60	4.68	7.60
3rd Trade	979	7.69	12.25	73.89	4.44	7.17
4th Trade	865	8.08	11.85	77.43	3.99	5.86
5th Trade	795	8.40	11.51	79.02	3.89	5.68
6th Trade	726	8.69	11.35	80.20	3.80	5.78
7th Trade	679	8.94	11.27	81.85	3.80	6.84
8th Trade	638	9.13	11.01	83.61	3.61	5.74
9th Trade	602	9.32	10.79	84.05	3.60	6.21
10th Trade	567	9.37	10.78	84.24	3.61	5.79
Last Trade	1377	14.82	5.20	77.24	3.99	5.20
Reopen Trade (off-NYSE trading)	1377	–	–	99.05	2.50	3.02
Reopen Trade (no off-NYSE trading)	1084	–	–	97.29	3.11	3.62
Panel B – NYSE Indicator Quotes						
Pre-halt Midpoint	2461	0.00	20.56	–	10.69	11.36
1st Indicator Quote	2461	6.01	14.29	92.65	4.13	6.08
2nd Indicator Quote	931	12.71	10.12	99.54	4.41	7.43
3rd Indicator Quote	235	17.97	9.49	94.55	4.96	9.95
Last Indicator Qt	2461	9.66	10.64	99.24	3.25	3.86

where $P_{i,pre}$ is the midpoint of the pre-halt quotes, $P_{i,post}$ is the midpoint of the quotes one hour after the reopen, and $P_{i,1}$ is a reference price during the halt. The reference price could be an off-NYSE trade price during the halt, the midpoint of an NYSE indicator quote, or the reopening trade price. If the reference price is a perfect predictor of the future price, the intercept from this regression will be zero, the slope will be one, and the *R*-square will be one. If, on the other hand, the reference price provides no information about the future price, the slope and *R*-square will equal zero, and the intercept will equal the mean return from the pre-halt midpoint to the midpoint one hour after the halt.

The slope coefficient in the first-stage regression can be interpreted in two ways. First, it can be interpreted as an estimate of the bias in the reference price. A slope coefficient greater than (less than) one suggests that the reference price tends to undershoot (overshoot) the future price. In other words, a coefficient greater than one suggests that returns exhibit continuations from before to after the reference price and a coefficient less than one suggests that returns exhibit reversals. Barclay and Hendershott (2003) provide an alternative interpretation of the slope coefficient. They note that if the reference price is measured with error, the slope coefficient will be reduced. Thus, for coefficients less than one, the magnitude of the coefficient provides an estimate of the signal-to-noise ratio for the reference price.

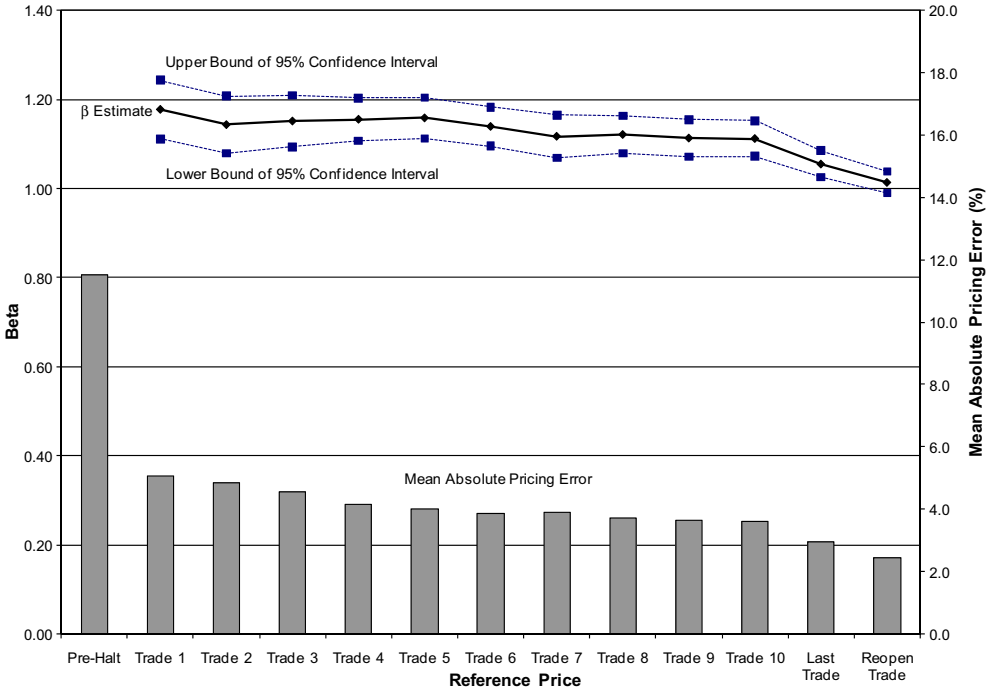

Fig. 2. Absolute Pricing Errors and Price Efficiency Coefficients for off-NYSE Trades. The figure shows the slope estimates and 95% confidence intervals from price efficiency regressions for the subsample of delayed openings with at least 10 off-NYSE trades during the halt. The dependent variable is the return from the pre-halt midpoint to the midpoint 60 min after the halt. The explanatory variable is the return from the pre-halt midpoint to some reference price during the halt. Reference prices include the first 10 off-NYSE trade prices, the last off-NYSE trade price, and the reopening trade price. For comparison, the figure also shows the mean absolute pricing error from the reference price to the midpoint 60 min after the halt.

In the second stage, we regress the residual from the first-stage on the return from the pre-halt midpoint to an alternative reference price. This second-stage regression allows us to test whether the second reference price provides incremental explanatory power beyond that provided by the first reference price. Specifically, we test whether each subsequent off-NYSE trade price provides incremental explanatory power over the prior trade price, whether the reopening price following NYSE trading halts provides incremental explanatory power beyond that in off-NYSE trade prices, and whether off-NYSE trade prices have incremental explanatory power beyond that in prior indicator quotes. The second-stage regression takes the following general form:

$$\text{Stage 2}: e_i = \gamma + \delta \cdot Ln(P_{i,2}/P_{i,pre}) + u_i, \tag{2}$$

where e_i is the residual from the first-stage regression and $P_{i,2}$ is the alternative reference price.

As an initial test, we estimate Eq. (1) for the first through tenth off-NYSE trade prices and the reopening trade price, using the subset of halts with at least 10 off-NYSE trades. The results are illustrated in Fig. 2, which plots slope estimates and 95% confidence intervals. Beginning with the first off-NYSE trade, the slope coefficient is significantly greater than one. With subsequent off-NYSE trades, the slope coefficient gets closer to one and the confidence interval narrows. However, the coefficient remains significantly greater than one even at the last off-NYSE trade. These results are consistent with off-NYSE trade prices that only partially adjust to halt-period information. As noted earlier, the reopening trade appears to incorporate additional information, resulting in a slope coefficient that is not significantly different from one.

The results in Table 3 and Fig. 2 suggest that both off-NYSE trade prices and NYSE indicator quotes reflect price-relevant information during NYSE trading halts. However, it is difficult to tell from these

tests whether off-NYSE trades provide price discovery or simply reflect price discovery already contained in previous NYSE indicator quotes. To address this, Table 4 provides price efficiency regressions that directly test the informativeness of off-NYSE trade prices relative to NYSE indicator quotes. The regressions follow the two-stage procedure outlined above.

We begin by testing whether NYSE indicator quotes provide incremental information beyond that in off-NYSE trade prices. We examine both the *first* indicator quote in those cases where the quote is preceded by an off-NYSE trade and the *last* indicator quote in those cases where the quote is preceded by an off-NYSE trade. In both cases, the regressions show that the indicator quote provides significant incremental explanatory power beyond that in the off-NYSE trade price. The associated *R*-squares from the second-stage regressions are 0.132 and 0.135, respectively. For completeness, we also show the incremental explanatory power of the reopening trade price. Regardless of whether or not the

Table 4
The Relative Informativeness of off-NYSE Trades and NYSE Indicator Quotes during NYSE Halts. The table lists coefficient estimates from two-stage regressions of price informativeness. The sample includes 2461 order imbalance delayed openings on the NYSE from 2002 to 2005. In the first-stage regression, the total return is regressed on the return from the pre-halt midpoint to given reference price. The total return is defined as the return from the pre-halt quote midpoint to the quote midpoint one hour after the reopen. In the second-stage regression, the residual from the first stage is regressed on the return from the pre-halt midpoint to next reference price. References prices during the halt include both off-NYSE trade prices and midpoints from NYSE indicator quotes. The regressions take the following form:

$$\text{Stage 1}: Ln(P_{i,post}/P_{i,pre}) = \alpha + \beta \cdot Ln(P_{i,1}/P_{i,pre}) + e_i$$

$$\text{Stage 2}: e_i = \gamma + \delta \cdot Ln(P_{i,2}/P_{i,pre}) + u_i$$

If the reference price used in the first-stage regression is a perfect predictor of the future stock price, the intercept will equal zero, the slope will equal one, and the *R*-square will equal one. If the second-stage reference price provides additional information beyond that contained in the first-stage reference price, the beta and *R*-square in the second-stage regression will be greater than zero. In the first-stage regression, the significance test for β_1 is from a test of the restriction that the coefficient equals one. All other significance tests are from a test of the restriction that the coefficient equals zero.

Sample	First-stage regression					Second-stage regression			
	Reference price	*N*	α	β	R^2	Reference price	γ	δ	R^2
1st Ind Qt – prior trd	Prior Trade	635	−2.332***	1.155***	0.654	Indicator Qt	0.807***	0.242***	0.132
1st Ind Qt – prior trd	Indicator Qt	635	−1.041***	1.018	0.808	Reopening Trd	0.517**	0.125***	0.073
1st Ind Qt – no prior trd	Indicator Qt	1826	−0.915***	1.018	0.752	Reopening Trd	0.439***	0.167***	0.104
Last Ind Qt – prior trd	Prior Trade	882	−2.013***	1.077***	0.729	Indicator Qt	0.820***	0.200***	0.135
Last Ind Qt – prior trd	Indicator Qt	882	−0.528***	0.976*	0.879	Reopening Trd	0.133	0.031**	0.007
Last Ind Qt – no prior trd	Indicator Qt	1579	−0.374***	0.967***	0.856	Reopening Trd	0.091	0.039***	0.010
1st Trd – prior Ind Qt	Prior Ind Qt	742	−0.711***	0.893***	0.744	Off-NYSE Trd	0.053	0.065***	0.010
1st Trd – prior Ind Qt	Off-NYSE Trd	742	−1.400***	1.070***	0.687	Reopening Trd	0.559**	0.247***	0.195
1st Trd – no prior Ind Qt	Off-NYSE Trd	635	−2.397***	1.201***	0.613	Reopening Trd	1.413***	0.341***	0.270
Last Trd – prior Ind Qt	Prior Ind Qt	1258	−0.556***	0.958***	0.868	Off-NYSE Trd	0.065	0.037***	0.008
Last Trd – prior Ind Qt	Off-NYSE Trd	1258	−1.120***	1.045***	0.828	Reopening Trd	0.305**	0.104***	0.060
Last Trd – no prior Ind Qt	Off-NYSE Trd	119	−5.202***	1.206	0.337	Reopening Trd	3.432***	0.645***	0.579

* Significance at the 10% levels.
** Significance at the 5% levels.
*** Significance at the 1% levels.

indicator quotes are preceded by an off-NYSE trade, the results suggest that the reopening trade provides significant incremental information beyond that contained in the NYSE indicator quote. However, the incremental information provided by the reopening trade is substantially reduced when moving from the first to the last NYSE indicator quote.

As expected, the first two tests suggest that NYSE indicator quotes are informative with respect to the post-halt price. Next, we test whether off-NYSE trades provide incremental information beyond that in NYSE indicator quotes. We examine both the *first* off-NYSE trade during a halt in those cases where the trade is preceded by an NYSE indicator quote and the *last* off-NYSE trade during a halt in those cases where the trade is preceded by an indicator quote. For both the first and last off-NYSE trade, the results show that off-NYSE trade prices provide significant incremental explanatory power beyond that in the NYSE indicator quote. However, while the pricing coefficients are statistically significant, the associated *R*-squares from the second-stage regressions are relatively small at 0.010 and 0.008, respectively. Further, the reopening trade price provides significant incremental explanatory power beyond that in off-NYSE trade prices.

Overall, the results in this section provide evidence that off-NYSE trades during NYSE halts provide significant price discovery that is incremental to that contained in NYSE indicator quotes. For halts with multiple off-NYSE trades, both the magnitude and efficiency of price discovery improve across subsequent trades. Consistent with the results in Corwin and Lipson (2000) and Madhavan and Panchapagesan (2000), we find that the NYSE specialist appears to fully incorporate the information from these trades into the reopening price, but also appears to incorporate valuable information from other sources, such as the limit order book and the trading floor.

5.3. The effects of off-NYSE trading on post-halt abnormal activity

The results above suggest that off-NYSE trades during NYSE halts contain significant price-relevant information. In this section, we analyze whether increased off-NYSE trading also leads to an improved post-halt trading environment, as might be suggested by the "learning through trading" models of Grundy and McNichols (1989) and Brown and Jennings (1989). Specifically, we test whether post-halt increases in volume and volatility are reduced by halt period off-NYSE trading.

To define abnormal post-halt effects, we follow the methodology of Lee et al. (1994) and Corwin and Lipson (2000). In particular, we compare the value of each variable during a specific period on the halt day to the value of that variable during the same time period on non-halt trading days. For each variable, the abnormal statistic for stock i and time period t is defined as follows:

$$\text{Abnormal Statistic} = 100 * \left[\frac{\text{Halt Period Value}_{i,t} - \text{Nonhalt Day Mean}_{i,t}}{\text{Nonhalt Day Mean}_{i,t}}\right], \tag{3}$$

where non-halt days are defined as the 15 days prior to and 15 days after the halt day, excluding days where another trading halt occurs.

We calculate abnormal statistics for the 30-min period starting from the reopening trade based on five trade and quote variables. Following Lee et al. (1994), we measure volatility using the absolute return and the number of quote revisions. However, we note that quote revisions may also reflect increased order submissions and trade activity. We measure trading activity using both volume and number of trades. Finally, we measure execution costs using the trade-weighted percentage quoted spread. This measure may also proxy for the level of uncertainty in stock prices.

Mean abnormal statistics are provided in the first row of Table 5. The results are consistent with prior studies and point to unusually high levels of trading, volatility, and bid-ask spreads following NYSE trading halts. For the average halt, absolute returns are 290% higher, quote revisions are 75% higher, and quoted spreads are 76% higher during the 30 min after the halt than during the same period on non-halt days. Trade volume and trade frequency are 738% and 230% higher, respectively, during the first post-halt period than during comparable periods on non-halt days.

To test the relation between off-NYSE trading and post-halt abnormal effects, we estimate cross-sectional OLS regressions where the dependent variables are abnormal post-halt statistics. The explanatory variables include halt characteristics that may affect post-halt activity, as well as stock

Table 5

Regressions of Post-Halt Abnormal Activity on off-NYSE Trade Frequency. The table reports results from cross-sectional regressions of abnormal post-halt statistics in the first half hour after the halt is lifted on stock and halt characteristics and off-NYSE trading (halt and post-halt measures). Abnormal statistics are defined as the halt-period value minus the mean value for the same time period on non-halt days, stated as a percentage of the non-halt day mean. Non-halt days are the 15 days prior to and 15 days after the halt. Off-NYSE trades are measured both during the halt and for the 30-min period after the reopening trade. Explanatory variables are defined as follows: *AbsHaltReturn* is the absolute return from the pre-halt quote midpoint to the reopening trade price. *Halt Duration* is the length of the halt in minutes. *IndQuotes* is the number of specialist's indicator quotes during the halts. *MktCap* is the natural logarithm of the market capitalization over the year prior to the halt; *Price* is the natural logarithm of the average stock price over the year prior to the halt; *Turnover* is the average daily share volume over the year prior to the halt divided by shares outstanding as of the halt date; *Volatility* is defined as the standard deviation of daily quote-midpoint returns over the year prior to the halt; *2003D*, *2004D* and *2005D* are dummy variables for the three years respectively. We report results based on both ordinary least squares results (OLS) and two-stage lease squares (2SLS). The first-stage regression is an OLS regression predicting off-NYSE trades as a function of halt and firm characteristics, institutional holdings, industry dummy variables, and year dummy variables as in Table 3. The sample includes 2461 order imbalance delayed openings on the NYSE from 2002 to 2005.

	Absolute return (%)		# of Quote revisions		Share volume (000)		# of trades		Quoted spread (%)	
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
Mean abnormal measure:	289.81***	289.81***	75.38***	75.38***	738.07***	738.07***	230.17***	230.17***	76.13***	76.13***
Regression coefficients:										
Intercept	908.36***	727.87***	610.39***	658.03***	3447.18***	2957.64***	2036.69***	2222.57***	−26.22	−92.19***
Off-NYSE $\text{Trades}_{\text{Halt}}$	−0.49***	−1.24***	0.03	0.37***	−0.37	−2.43*	0.02	1.52***	−0.07***	−0.51***
Off-NYSE $\text{Trades}_{\text{Post}}$	0.10***	0.08***	−0.02***	−0.03***	0.12***	0.14***	0.02	−0.01	0.03***	0.04***
AbsHaltReturn (%)	12.20***	12.45***	2.25***	2.29***	61.44***	62.93***	5.23***	5.47***	2.29***	2.27***
Halt duration	0.18***	0.17***	0.02***	0.02***	0.24***	0.25***	0.12***	0.13***	0.02***	0.01***
Indicator quotes	6.10	−1.11	−1.18	−0.48	129.45***	160.97***	−22.25**	−20.94*	7.42***	6.12***
MktCap	−61.50***	−47.48***	−36.62***	−40.10***	−244.08***	−216.39***	−135.85***	−149.16***	0.89	5.76***
Price	5.52	0.01***	−5.89*	−4.44	121.65***	112.09***	35.66**	41.31***	4.05	2.04
Turnover	−38.27**	−37.17**	−15.16***	−15.12***	−151.79***	−145.95***	−73.26***	−72.72***	−5.37**	−5.34*
Volatility (%)	−40.54***	−35.16***	−8.28***	−9.94***	−154.76***	−144.53***	−24.17***	−30.92***	−4.09***	−1.86
2003D	−26.90	−8.97	−6.86	−12.51**	114.49**	158.55***	−25.01	48.08**	−1.17	6.40
2004D	34.40	53.88	2.88	−3.37	111.02**	160.75***	−36.61*	−62.26***	−7.88*	0.48
2005D	27.22	53.81	31.65***	22.27***	37.61	107.39	17.25	−56.55**	−17.42***	−5.01
Adjusted R^2	0.161	0.159	0.373	0.372	0.349	0.354	0.220	0.231	0.174	0.179
N	2461	2461	2461	2461	2461	2461	2461	2461	2461	2461

* Significance at the 10% levels.
** Significance at the 5% levels.
*** Significance at the 1% levels.

characteristics. The stock characteristics are the natural log of market capitalization, the natural log of price, turnover, and volatility. Halt characteristics include the absolute return during the halt, the duration of the halt, and the number of indicator quotes during the halt. These variables are defined as in Section 4.

The main variable of interest is the number of off-NYSE trades during the halt. If off-NYSE trading results in an improved post-halt trading environment, we expect the number of off-NYSE trades to be negatively related to post-halt abnormal measures.[16] It is possible that abnormal post-halt effects are related to both halt-period and post-halt off-NYSE trading. In addition, off-NYSE trading during the halt is highly correlated with off-NYSE trading following the halt. To capture the relation between halt-period off-NYSE trading and post-halt abnormal effects, we therefore control for post-halt off-NYSE trading.

Our previous results show that off-NYSE trading is significantly related to halt-related information and to stock characteristics. To control for the endogeneity of off-NYSE trading, we also provide results based on two-stage least squares (2SLS). In the first stage, we estimate predicted halt-period off-NYSE trading using the OLS prediction regression described in Section 4. In the second stage, we regress post-halt abnormal activity on the predicted value of off-NYSE trading, controlling for stock and halt characteristics. Notably, the first-stage model includes all explanatory variables from the second-stage regression, as well as industry dummy variables, an earnings announcement dummy variable, and institutional holdings. We test the overidentifying restrictions using Basmann's (1960) test. The results suggest that the instruments are valid and the model is correctly specified.[17]

Results for both the OLS and 2SLS models are provided in Table 5. All measures of abnormal post-halt activity are significantly positively related to the absolute halt return and halt duration. Thus, longer halts and halts with larger price effects are associated with larger post-halt abnormal effects. In addition, market capitalization, turnover, and volatility are all negatively related to abnormal post-halt absolute return, quote revisions, and trade frequency. Finally, post-halt off-NYSE trades are positively related to absolute returns, trade volume, and quoted spreads, and negatively related to quote revisions.

In the 2SLS model, halt-period off-NYSE trades are positively associated with post-halt quote revisions and trade frequency. These results may suggest that halt-period off-NYSE trading reflects a general increase in trading interest that continues into the post-halt period.[18] However, these results are not evident in the OLS regressions for these variables or in either of the trading volume regressions. In both the OLS and 2SLS regressions, the results suggest that halt-period off-NYSE trading is significantly negatively related to both abnormal absolute return and abnormal quoted spreads. These results are consistent with the hypothesis that off-NYSE trading provides price-relevant information and leads to reduced uncertainty in post-halt prices.

6. The costs of off-NYSE trading

The results in Section 5 suggest that off-NYSE trades are informative and are associated with reduced post-halt uncertainty. Despite these apparent benefits, however, off-NYSE trading occurs in only 56% of sample halts and the amount of off-NYSE trading varies significantly across halts. These findings suggest that, for many halts, the costs of off-NYSE trading outweigh the benefits. In this section, we attempt to quantify the costs associated with off-NYSE trading and to examine the relation between these costs and the occurrence of off-NYSE trades.

To begin, we calculate three measures of market quality on off-NYSE venues during NYSE halts: *Absolute Return*, *High-Low Range*, and *Effective Spread*. First, we calculate the *Absolute Return* between

[16] Results in this section are similar if we use off-NYSE trading volume rather than number of trades. The conclusions are also unchanged if we define variables based on the full post-halt period through the close of trading.

[17] The results in Table 5 are based on predictive regressions that include halt characteristics not known at the time of the halt. As a robustness check, we repeated the two-stage analysis using the alternative prediction regression specification from Table 2 based on pre-halt INET limit order book characteristics. The conclusions are unchanged.

[18] The effects of halt-period off-NYSE trades are generally insignificant if we exclude post-halt off-NYSE trades. However, as we want to capture the relation between halt-period off-NYSE trading and post-halt abnormal effects over and above the effect of post-halt off-NYSE trading, we believe it is necessary to include both off-NYSE trade variables in any model specification.

each pair of sequential off-NYSE trade prices and take an average across all pairs of sequential off-NYSE trades. This measure captures variation in off-NYSE trade prices, which has been a major criticism of off-NYSE trading during NYSE halts. This measure is also closely related to the transaction price risk modeled in Greenwald and Stein (1988, 1991) and shown to be an important motivation for trading halts. As an additional measure of transaction price variation, we calculate the *High-Low Range* based on all off-NYSE trade prices during the halt, defined as a percentage of the high-low midpoint. As shown in Corwin and Schultz (2011), the high-low range reflects both the underlying volatility of the stock and the bid-ask spread. *Absolute Return* and *High-Low Range* are defined only for those halts with at least two off-NYSE trades.

To provide a more direct measure of transaction costs, we estimate the effective spread on off-NYSE trades during NYSE halts. Unlike the two measures defined above, the effective spread requires us to compare transaction prices to posted quotes. We define the percentage *Effective Spread* for each off-NYSE trade as $2D_t((P_t - M_t)/M_t)$, where P_t is the transaction price associated with trade t, M_t is the midpoint of the NYSE indicator quotes outstanding at the time of trade t, and D_t equals 1 for a buy and -1 for a sell. Trades above (below) the quote midpoint are defined as buyer- (seller-) initiated and trades executed at the midpoint are unsigned.[19] We aggregate for each period by taking a trade-weighted average across all trades during the period.

To put the market quality estimates in perspective, we provide comparison results based on trades during the same time period as the halt on non-halt days, where non-halt days include the 15 days prior to and 15 days after the halt.[20] We note, however, that the market quality measures may not be directly comparable between halt periods and periods of normal trading. In particular, because halt-period effective spreads are defined based on NYSE indicator quotes, results based on this measure should be interpreted with caution. Nonetheless, we believe an analysis of these measures provides a useful overview of the potential costs associated with trading on off-NYSE venues during NYSE halts. We address the robustness of the effective spread results to alternative pre-trade benchmarks below.

Table 6 provides summary statistics for the three market quality measures defined during the halt period and the non-halt comparison period. To assess differences between halts with active vs. inactive off-NYSE trading, we provide results based on the full sample of halts with at least one off-NYSE trade, and the subsamples of halts with fewer than 10 and 10 or more off-NYSE trades, respectively. For each comparison period result, the table indicates whether the mean (median) differs significantly between the halt and non-halt periods. The last column of the table provides a p-value from the test of whether the mean (median) differs significantly between the active and inactive halt subsamples.

The mean absolute return during halts with at least two off-NYSE trades is 0.68%. This is more than 10 times higher than the comparison period mean of 0.06%, with the difference being highly statistically significant. The subsample results suggest that absolute returns are approximately twice as large for halts with fewer than 10 off-NYSE trades (0.94%) than for halts with 10 or more off-NYSE trades (0.41%). However, this difference should be interpreted with caution, as the mean absolute return tends to decrease with the number of trades. Conclusions based on medians are similar.

The high-low range averages 3.8% for halts with at least two off-NYSE trades and, unlike the absolute return, is significantly higher for halts with at least 10 off-NYSE trades (5.34%) than for halts with fewer than 10 off-NYSE trades (2.27%). In all three cases, the halt period high-low range is significantly higher than the comparison period high-low range. For example, the mean high-low range for the full sample is more than three times the mean during non-halt periods. Conclusions based on medians are similar except in the case of inactive halts, where the median high-low range does not differ significantly between the halt and non-halt periods. Together with the results for absolute return, these results suggest that trades during NYSE halts are subject to significantly higher price volatility than trades during comparable non-halt periods.

[19] For trades that occur prior to the first NYSE indicator quote, M_t is defined as the midpoint from the previous day's closing quotes. As discussed below, the conclusions regarding effective spreads are similar if we define the benchmark quote midpoint using the reopening quotes on the NYSE or the best bid and ask quotes at the time of the trade across all off-NYSE venues.

[20] For the non-halt comparison periods, effective spreads are calculated relative to the NYSE quote midpoint at the time of the trade and trades are signed based on the Lee and Ready (1991) algorithm with no lag between trades and quotes. The post-trade price for realized spread calculations is the NYSE quote midpoint 20 min after the trade.

Table 6
Market quality during halt and non-halt periods. The table provides mean and median (in parentheses) values of several measures of market quality during NYSE halts and during the halt period on non-halt days. The non-halt days include the 15 days prior to and 15 days after the halt. Results are provided for the sample of 1377 order imbalance delayed openings with at least one halt-period off-NYSE trade, and for the subsamples of halts with at least 10 off-NYSE trades ($N = 567$) and one to nine off-NYSE trades ($N = 810$). *Absolute Return* is defined as the absolute value of the trade-to-trade return, averaged across all trades during the period. *High-Low Range* is defined as the difference between the high trade price and low trade price during the period, divided by the high-low midpoint. For the post-halt period and the non-halt day, the *High-Low Range* is standardized by the square root of the ratio of comparison period length to halt period length. For each trade, the *Effective Spread* is defined as $2D_t((P_t - M_t)/M_t)$, where P_t is the transaction price associated with trade t, M_t is the midpoint of the NYSE quotes (or indicator quotes) at the time of trade t, and D_t equals 1 for a buy and -1 for a sell. For halt-period trades that occur prior to the first NYSE indicator quote, M_t is defined as the midpoint from the previous day's closing quotes. Trades above (below) the quote midpoint are defined as buyer- (seller-) initiated and trades at the midpoint are left unsigned. We define the *Realized Spread* as $2D_t((P_t - P_{reopen})/M_t)$, where P_{reopen} is the reopening midpoint following the halt. We define *Price Impact* as the difference between the effective and realized spread, or $2D_t((P_{reopen} - M_t)/M_t)$. The *Effective Spread*, *Realized Spread*, and *Price Impact* for each period are then defined as trade weighted averages of the relevant measures across all trades during the period. The table also provides the mean (median) ratio of price impact to effective spread, where outliers have been eliminated in the calculation of the mean above (below) the 95th (5th) percentile.

	All halts with off-NYSE Trades		Less than 10 off-NYSE trades		At least 10 off-NYSE trades		p-Value for differencebetween active and inactive halts
	Halt period	Non-halt periods	Halt period	Non-halt periods	Halt period	Non-halt periods	
Absolute return (%)	0.68	0.06***	0.94	0.07***	0.41	0.06***	0.000 (0.000)
	(0.32)	(0.05***)	(0.39)	(0.06***)	(0.28)	(0.05***)	
High–low range (%)	3.79	1.17***	2.26	1.12***	5.34	1.23***	0.000 (0.000)
	(2.57)	(1.04***)	(1.17)	(1.01)	(3.84)	(1.07***)	
Effective spreads (%)	7.62	0.22***	7.84	0.24***	7.31	0.19***	0.188 (0.988)
	(5.40)	(0.16***)	(5.36)	(0.18***)	(5.52)	(0.13***)	
Realized spread (%)	2.28	0.09***	3.74	0.10***	0.19	0.09***	0.000 (0.000)
	(0.82)	(0.08***)	(1.85)	(0.09***)	(0.30)	(0.07***)	
Price impact (%)	5.34	0.12***	4.10	0.14***	7.11	0.10***	0.000 (0.000)
	(3.88)	(0.08***)	(3.01)	(0.10***)	(4.87)	(0.06***)	
Ratio of price impact to effective spread (%)	72.28	50.24***	62.07	53.18***	84.90	46.06***	0.000 (0.000)
	(81.81)	(54.37***)	(63.88)	(59.77***)	(94.40)	(48.89***)	

The last column provides a p-value from the test of whether mean (median) halt-period values are equal across the high and low off-NYSE trade subsamples.
* The halt period mean is significantly different from the comparison period mean at the 10% levels.
** The halt period mean is significantly different from the comparison period mean at the 5% levels.
*** The halt period mean is significantly different from the comparison period mean at the 1% levels.

The mean effective spread for halts with at least one off-NYSE trade is 7.62%. This is significantly higher than the mean of 0.22% during comparable non-halt periods. These results are consistent with the volatility measures described above and suggest that trading costs on off-NYSE venues are extremely high during NYSE halts. In particular, the mean (median) effective spread is more than 30 (six) times higher during NYSE halts than during comparable non-halt periods. Effective spreads also appear to be marginally higher for halts with fewer than 10 off-NYSE trades (7.84%) than for halts with 10 or more off-NYSE trades (7.31%). However, this difference is not statistically significant.

The large effective spreads associated with halt-period off-NYSE trades could reflect either profits to liquidity providers or information effects. To separate these effects, we decompose effective spreads into realized spreads and price impact. If effective spreads reflect primarily realized spreads, it would suggest that liquidity providers on off-NYSE venues are making large profits from uninformed trades during NYSE halts. On the other hand, if effective spreads reflect primarily price impact, it would suggest that halt-period off-NYSE trades are associated with informed trading. For each halt-period trade, we define the realized spread as $2D_t((P_t - P_{post})/M_t)$, where P_t, M_t, and D_t are defined as above, and P_{post} is the reopening midpoint following the halt. We define price impact as the difference between the effective and realized spread, or $2D_t((P_{post} - M_t)/M_t)$. We then aggregate by taking a trade-weighted average of realized spreads and price impact across all halt-period trades.

The spread decomposition results are shown in the last three rows of Table 6. On average, price impact accounts for 72.3% of the effective spread during NYSE halts, while realized spread accounts for the remaining 27.7%.[21] This suggests that the large effective spreads during NYSE halts reflect primarily profits to informed traders rather than compensation to liquidity providers. Both components of the effective spread are significantly higher during halts than during comparison non-halt periods. However, the fraction of the effective spread associated with price impact is significantly higher during halts than during normal periods. The composition of effective spread also differs significantly based on the trading activity during the halt. For halts with at least 10 off-NYSE trades, the ratio of price impact to effective spread has a mean of 84.9% and a median of 94.4%. In contrast, the mean and median ratios for halts with fewer than 10 off-NYSE trades are only 62.1% and 63.9%, respectively. These results are consistent with informed traders who trade more frequently when their informational advantage is highest.

As noted above, there is some concern that the lack of a reliable pre-trade benchmark may lead to biases in our estimates of halt-period effective spreads. Consider the case, for example, where the trade price drifts toward the new value during the halt but indicator quotes are updated with a lag. In such a case, trades will tend to be misclassified as buys during positive return halts and as sells during negative return halts, with the effective spread reflecting the price drift. Trade misclassification can also arise if the indicator quotes are widened asymmetrically, with the ask increased significantly during positive return halts and the bid decreased significantly during negative return halts. In this case, a comparison to the indicator quote midpoint could result in too many trades classified as sells during positive return halts and as buys during negative return halts.

To address these concerns, we estimate three robustness tests.[22] First, we estimate effective spreads using two alternative benchmark quotes: the midpoint from the best quotes across all off-NYSE venues at the time of the trade and the post-halt reopening quote midpoint on the NYSE. The halt-period effective spread has a mean (median) of 14.63% (3.95%) based on the off-NYSE quote benchmark and 7.49% (4.08%) based on the reopening quote benchmark. This compares to a mean (median) of 7.62% (5.40%) based on NYSE indicator quotes, as reported in Table 6, and suggests that the large effective spreads we document during NYSE halts are not driven solely by the choice of pre-trade benchmark.

To address concerns regarding the signing of trades, we estimate the proportion of halt-period trades signed as buyer- and seller-initiated based on NYSE indicator quotes and the two alternative benchmarks. When trades are signed based on NYSE indicator quotes, the fraction of buys (sells) is 55.47% (39.69%) during negative return halts and 42.31% (53.46%) during positive return halts. The proportions are generally similar when based on the alternative quote benchmarks. For example, based on the off-NYSE quote benchmark, the fraction of buys (sells) is 54.93% (44.28%) during negative return halts and 51.22% (47.75%) during positive return halts. Thus, while the reliability of the pre-trade benchmark is certainly a concern, the conclusions appear robust to alternative methods for signing trades.

As a final robustness test, we estimate trade-weighted quoted spreads based on both NYSE indicator quotes and off-NYSE quotes. While these measures are at best noisy proxies for transaction costs, they have the advantage that they do not rely on the signing of trades. For both NYSE indicator quotes and off-NYSE quotes, we find that quoted spreads are very similar in magnitude to our effective spread estimates. For the full sample, the mean quoted spread is 7.28% based on NYSE indicator quotes and 15.37% based on off-NYSE quotes. Again, these results provide support for our conclusions based on effective spreads, as reported in Table 6.

Overall, the results in Table 6 suggest that off-NYSE trading during NYSE halts comes at a significant cost. Market quality is significantly worse during the halt than during comparable non-halt periods both in terms of execution costs and volatility. In addition, the high execution costs appear largely to reflect profits to informed traders rather than compensation to liquidity providers. Traders who wish to use off-NYSE venues during NYSE halts must therefore consider the trade-off between the value of their information or their liquidity needs and the costs associated with off-NYSE trades during this period.

[21] The mean ratio of price impact to effective spread is significantly affected by outliers. To limit the effects of these outliers, we truncate the distribution at the 5th and 95th percentiles before calculating the mean ratio. This truncation has no impact on the remaining variables or on the median ratio.

[22] The results from these robustness tests are available from the authors.

Table 7
Order flow and trade activity on INET. The table reports average halt-period values on halt and non-halt days for measures of order submissions, executions, and cancelations on INET. The non-halt days include the 15 days prior to and 15 days after the halt. The halt sample includes 820 order imbalance delayed openings on the NYSE from 2002 through 2005 with at least one halt-period INET trade, with results for halts with 10 or more INET trades in Panel A and results for halts one to nine INET trades in Panel B. The halt period is defined from 9:30 a.m. through the reopening NYSE quote. Results are provided separately for buy and sell orders and for positive and negative return halts.

Variable	Positive return halts				Negative return halts			
	Buy		Sell		Buy		Sell	
	Halt period	Non-halt periods	Halt period	Non-halt periods	Halt period	Non-halt periods	Halt period	Non-halt periods
Panel A – Halts with at least 10 INET Trades (N = 173)								
Orders submitted	158.00	128.47***	163.43	125.30***	148.79	130.39**	137.39	131.97*
Shares submitted (000)	100.88	43.82***	94.41	48.90***	188.05	58.00***	111.74	63.06***
Order size	638.25	341.10***	577.86	390.32***	757.57	445.00***	813.11	477.94***
Shares executed/shares submitted (%)	16.25	4.27***	17.36	3.83***	8.50	5.15	14.31	4.74***
Shares canceled/shares submitted (%)	78.23	95.49***	68.20	96.91***	88.66	98.13*	69.25	97.32***
Panel B – Halts with One to Nine INET Trades (N = 647)								
Orders submitted	17.66	55.54**	55.87	54.36	10.93	39.98**	22.61	42.47**
Shares submitted (000)	10.88	20.03**	33.08	21.89**	12.14	16.15	17.26	18.20
Order size	598.75	351.58***	574.77	389.89***	937.90	388.67***	718.82	411.96***
Shares executed/shares submitted (%)	7.44	3.40**	2.45	3.11**	7.28	4.73*	5.12	4.20*
Shares canceled/shares submitted (%)	88.65	96.27***	93.26	94.64	70.69	94.84***	87.81	93.62**

* Significance at the 10% levels, based on a test of whether means are equal across halt and non-halt periods.
** Significance at the 5% levels, based on a test of whether means are equal across halt and non-halt periods.
*** Significance at the 1% levels, based on a test of whether means are equal across halt and non-halt periods.

7. Order flow and liquidity on the INET ECN

The results in the previous sections suggest that informed traders utilize off-NYSE venues during NYSE halts and that their trades provide information to the market. These findings point to a shift in either the composition of traders or in the trading strategies utilized on off-NYSE venues during NYSE halts. In this section, we use data from the INET ECN to provide a more detailed analysis of order flow characteristics on off-NYSE venues during NYSE halts.[23] As a starting point, we analyze submissions, executions, and cancelations through INET during the halt period and during comparable periods on non-halt days. Second, we analyze the impact of this activity on the state of the INET limit order book before during and after NYSE halts.

Table 7 provides mean values for several INET order flow and trade activity variables during NYSE halts and comparable periods on non-halt days. The sample includes 820 halts with at least one halt-period INET trade. Results for halts with 10 or more INET trades are shown in Panel A and results for halts with one to nine INET trades are shown in Panel B. As in the previous analysis, non-halt days are defined as the 15 days prior to and 15 days following the day of the halt. Results are provided separately for buy and sell orders and for positive and negative return halts.

As expected, the most significant shifts in order flow characteristics are observed in the sample of active halts (Panel A). Halt-period order submissions, defined as total marketable plus non-marketable

[23] INET was one of the primary off-NYSE venues during our sample period. In the sample of halts with at least one INET trade, INET trades account for 39.2% of total off-NYSE trades and the correlation between INET trades and total off-NYSE trades is 0.90. Interestingly, 63 of the cases with no off-NYSE trades identified in TAQ do have halt-period trades reported in the ITCH database. Further investigation of these trades suggests that they are reported to the tape late with condition code 'Z'. This suggests that the off-NYSE trades identified in TAQ may be understated.

order submissions, are significantly higher than normal in terms of both number of orders and total volume.[24] These results hold for both buy and sell orders and for both positive and negative return halts. For example, positive return halts exhibit an average of 158 buy-side order submissions reflecting 101 thousand shares, compared to averages of 128 orders and 44 thousand shares during comparable periods on non-halt days. Halt-period order size is also significantly larger than on non-halt days. Thus, order characteristics appear to shift significantly on both the buy and sell sides during NYSE halts.

In addition to the shift in order characteristics, halts are associated with a significant increase in execution rates and a significant decrease in cancelation rates. For example, an average of 7.4% of submitted buy order volume is executed during positive return halts, nearly double the rate of 3.4% during comparable periods on non-halt days. At the same time, 88.7% of halt-period buy order volume is canceled during the halt, compared to a cancelation rate of over 96% during similar periods on non-halt days. These patterns may reflect an increase in order aggressiveness or a decrease in the use of "fleeting orders" during halts (see, for example, Hasbrouck and Saar (2009)).

While the most significant shifts in order flow characteristics are observed for active halts, several similar patterns are evident for inactive halts (Panel B). First, while the number of orders submitted during halts tends to be significantly lower than normal, order size is significantly larger than normal on both the buy and sell sides for both positive and negative halts. Second, with the exception of sell orders for positive halts, execution rates tend to be higher than normal and cancelation rates are lower than normal. Overall, the results in Table 7 are consistent with a significant shift in either the composition of traders or in the trading strategies utilized on the INET ECN during NYSE halts.

If at least some informed traders react to halt-related information, it should be reflected in their order placement relative to pre- and post-halt prices. To address this, we reconstruct the limit order book for each stock at various points in time on the halt day by incorporating all orders submitted and removing all orders executed or canceled prior to the time of interest. Using this method, we estimate the state of the limit book at 30 min intervals from 7:00 to 9:30 a.m. and from the reopening time to the close of trading. We also estimate limit book snapshots at 1-min intervals for the first four minutes and the last four minutes of the halt. This results in 18 order book snapshots for each halt. To summarize the state of the limit order book, we calculate the cumulative depth at price increments from $0.10 to $5.00 away from the reopening NYSE quote midpoint.[25] In addition, we provide separate results for the subsamples of halts with zero halt-period INET trades, one to nine INET trades, and 10 or more INET trades.

The evolution of the limit order books around positive and negative return halts is illustrated in Figs. 3 and 4, respectively. In general, the figures show a substantial buy imbalance in the INET book prior to and during positive return halts and a substantial sell imbalance prior to and during negative return halts.[26] For all categories of halts, both bid and ask depth appear to increase during and after the halt. In addition, depth fills in on both sides of the book at all price increments around the reopening quote midpoint, resulting in reduced imbalances following the halt. This suggests that INET order flow is informative with respect to the reopening NYSE price and provides additional evidence of the use of off-NYSE venues by informed traders during NYSE halts.

Comparing the subsamples in Panels A, B, and C, we see that those halts with the highest levels of INET trading are also associated with the highest levels of pre- and post-halt liquidity on INET. In fact, for positive (negative) return halts, the subsample of halts with zero INET trades is associated with

[24] One important feature of the INET ECN is the non-display option that allows traders to place hidden orders. These hidden orders may be useful to traders who wish to place a large order without revealing their full trading interest or without the risk of front running (See, for example, Bessembinder et al., 2009, De Winne and D'Hondt, 2007, and Chakrabarty and Shaw, 2008). One disadvantage of the INET data is that hidden order submissions are not identified. As a result, our measures of order submissions and limit order book depth will be understated. The data do allow us to identify trades executed against hidden orders. In unreported results, we estimate the ratio of hidden order execution volume to total execution volume and find that this ratio is significantly higher than normal on both the buy and sell sides for positive halts and on the sell side for negative halts. Unfortunately, the lack of data on hidden order submissions makes it difficult to draw conclusions regarding the use of hidden orders during trading halts.

[25] To further analyze the informativeness of limit order placements, we estimated depth relative to the pre-halt NYSE quote midpoint. The results are consistent with informed order flow on INET and show that INET limit order placement has moved away from the pre-halt NYSE price even prior to 9:30.

[26] The conclusions are similar if we define the post-halt reference quotes either one hour after the halt or at the close of trading.

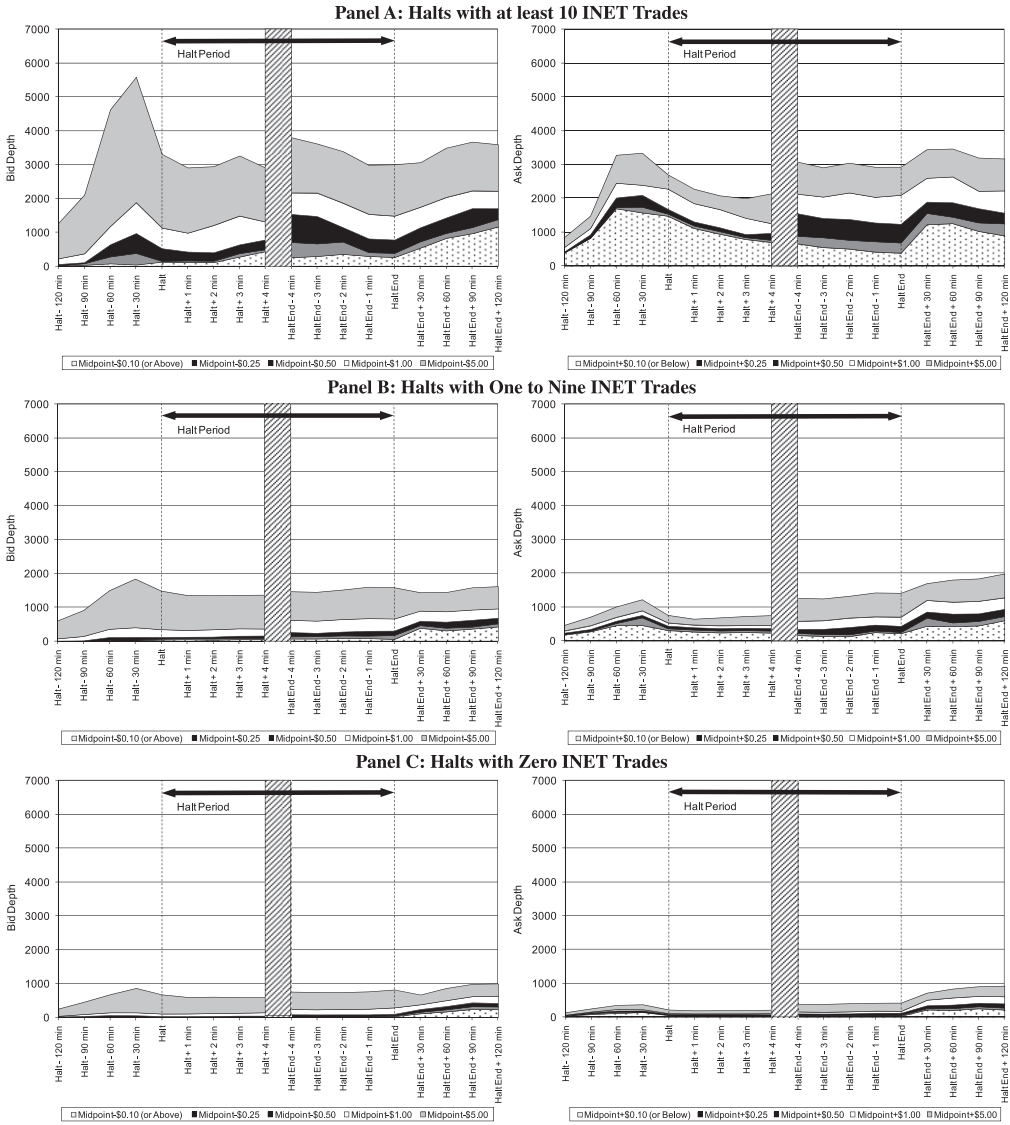

Fig. 3. Limit Order Book Depth Relative to the Reopening Midpoint for Positive Return Halts. The figure plots INET limit order book depth before, during, and after trading halts at various price increments from the reopening midpoint, with bid and ask depth shown separately. The sample includes 1064 order imbalance delayed openings on the NYSE from 2002 through 2005 for which the halt-period return is positive. Panel A provides results for halts with at least 10 INET trades. Panels B and C provide results for halts with one to nine INET trades and halts with zero INET trades, respectively.

only 214 (191) shares of bid (ask) depth, on average.[27] These results are consistent with our earlier finding that off-NYSE trading is limited by the amount of available liquidity on off-NYSE venues.

Overall, the results in this section point to a significant shift during NYSE halts in either the composition of traders using INET or the trading strategies employed on INET. While a portion of this in-

[27] The INET limit order book can be very thin and even one-side in many cases. For example, 10.9% of the sample halts have zero depth on both sides of the INET limit order book throughout the halt and an additional 32.5% of sample halts have zero depth on one side of the book.

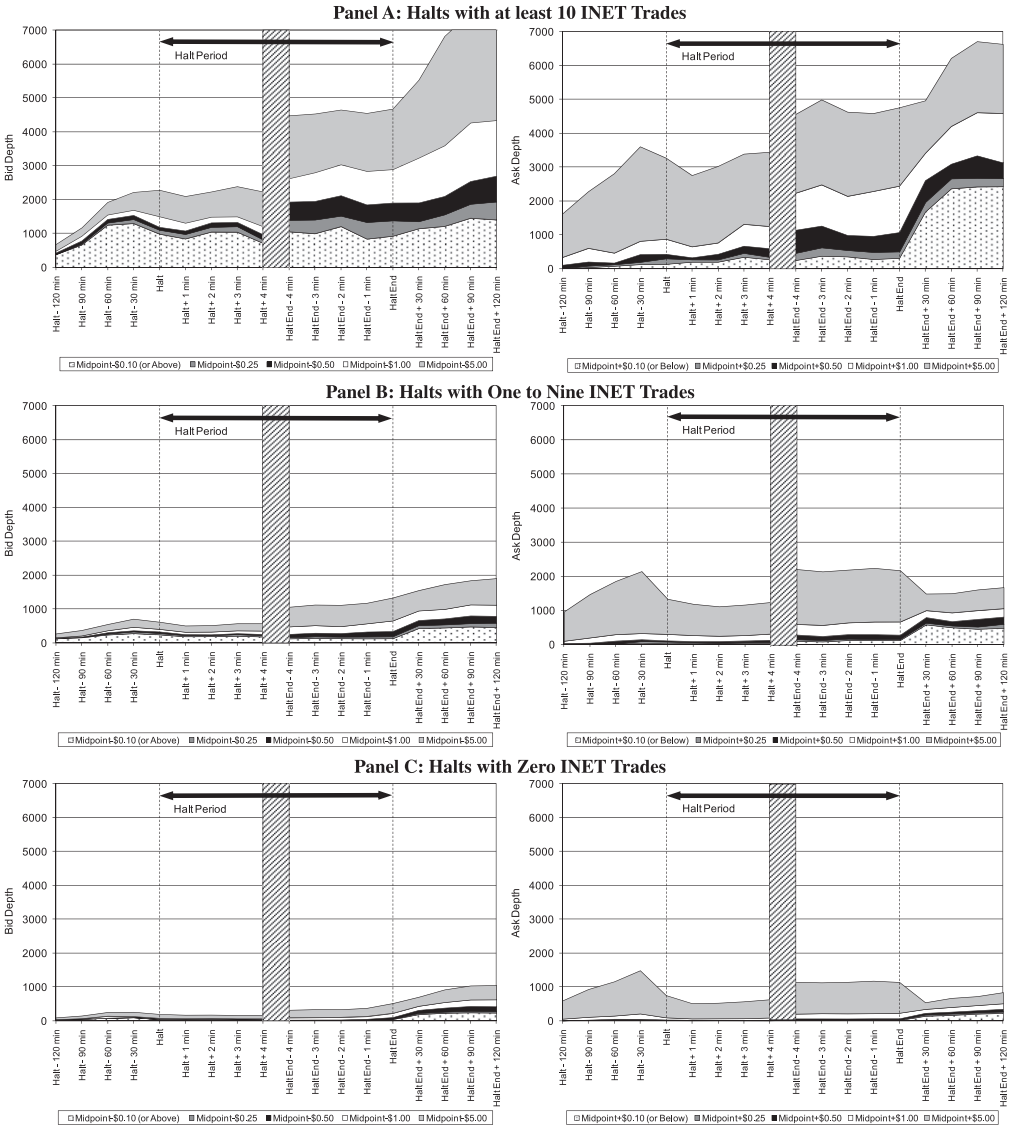

Fig. 4. Limit Order Book Depth Relative to the Reopening Midpoint for Negative Return Halts. The figure plots INET limit order book depth before, during, and after trading halts at various price increments from the reopening midpoint, with bid and ask depth shown separately. The sample includes 1397 order imbalance delayed openings on the NYSE from 2002 through 2005 for which the halt-period return is negative. Panel A provides results for halts with at least 10 INET trades. Panels B and C provide results for halts with one to nine INET trades and halts with zero INET trades, respectively.

creased activity likely reflects liquidity needs during NYSE halts, the evidence suggests that informed traders are active on INET, especially in the most liquid stocks.

8. Summary and conclusions

As markets become increasingly fragmented, one important concern is how to coordinate price discovery across multiple venues during extreme information or liquidity events. While many exchanges

make use of market-wide circuit breakers and/or individual security trading halts, the issues associated with coordinating these halt mechanisms across venues are not well understood. The difficulties associated with coordination were highlighted by the "flash crash" on May 6, 2010 and the subsequent regulatory response. As a starting point in addressing these issues, we analyze the costs and benefits of continued trading on alternative venues when the main market calls a halt.

We focus on the sample of order imbalance delayed openings on the NYSE from 2002 through 2005. During these non-regulatory halts, which make up the vast majority of NYSE halts, other venues are allowed to continue trading. This allows us to examine the extent to which market participants utilize off-NYSE trading venues to circumvent NYSE halts and the factors that drive halt-period off-NYSE trading. We find that the use of off-NYSE trading venues during NYSE halts varies significantly across stocks, but has increased substantially over time. Off-NYSE trading is more likely during halts involving large stocks and for stocks with high levels of off-NYSE trading during normal periods. Off-NYSE trading also increases with the magnitude of the halt return and with limit book depth on off-NYSE venues. Thus, informational motives appear to be a factor in determining the extent of off-NYSE trading during halts, but this trading is limited by the level of available liquidity.

We also test whether off-NYSE trades provide significant price discovery during NYSE halts and lead to more efficient post-halt prices. Our results suggest that the first trade accounts for an average of 70% of the total halt-period return, and both the magnitude and efficiency of price discovery increase with subsequent off-NYSE trades. We also find that NYSE specialists incorporate information from off-NYSE trades, as well as additional sources of information, when setting the reopening price. Consistent with prior studies, we find evidence of significant increases in volume and volatility after NYSE halts. However, after controlling for the endogeneity of off-NYSE trading, we find that off-NYSE trading is negatively related to abnormal post-halt volatility and bid-ask spreads. These results suggest that halt-period off-NYSE trades lead to more efficient post-halt prices. Thus, off-NYSE trading venues appear to provide a source of both liquidity and price discovery during NYSE market closures.

Our results suggest that the ability to continue trading during NYSE halts may provide significant benefits to the market. However, this trading comes at a significant cost: effective spreads on off-NYSE venues are as much as 10 times higher during halts than during comparable periods on non-halt days and volatility is three to five times higher. Further, the majority of this spread reflects price impact from informed trades rather than compensation to liquidity providers. These results are consistent with informed traders who use off-NYSE venues to trade against uninformed liquidity traders. Thus, any potential information gains from allowing off-NYSE trading during NYSE halts must be weighed against the investor protection concerns that have been a primary motivation for the implementation of halts. We expect these issues to gain importance as U.S. markets become more fragmented and as globalization of securities trading increases.

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