Shorting in Broad Daylight: Short Sales and Venue Choice*

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ABSTRACT

Using a novel database on venue short sales and market design characteristics, we ask: Where do short sellers exploit their information advantage? Exchange short sales comprise a larger proportion of trading and are more informative about future prices than dark pool short sales, particularly in the presence of short-lived information. Our results indicate that short sellers value the immediacy of exchanges over the lower transaction costs of dark pools, as predicted by Zhu (2014). When examining market design characteristics, we find that dark pools offering VWAP crossing attract more short sales while those offering block trading attract fewer short sales.

JEL classification: G1, G10.

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The idea that short sellers are rational, well informed investors is widely supported in the financial economics literature.[1] While extant research examines which types of short sellers are the most informed (e.g., Boehmer, Jones, and Zhang (2008)) and how short sellers obtain their information advantage (e.g., Karpoff and Lou (2010) and Engelberg, Reed, and Ringgenberg (2012)), we contribute to the understanding of short selling by asking: Where do short sellers exploit their information advantage?

To address this question, we construct a novel panel of short sales from individual stock exchanges and from an enhanced version of the FINRA Trade Reporting Facilities (TRF) that includes activity reported by individual dark pools. These data allow us to comprehensively examine short selling at the trading venue level. Furthermore, regulatory filings allow us to examine how short selling relates to market mechanisms across trading venues.

Economic differences between exchanges and dark pools can be central to a short seller's choice of trading venue. Exchange orders can be submitted to execute immediately even if the resulting execution prices fall outside of the prevailing National Best Bid and Offer (NBBO). In contrast, dark pools are required to match orders at prices within the NBBO.[2] While this approach can lead to lower bid-ask spread costs, if no match within the NBBO exists, then no trade will take place. This induces a trade-off

[1]Miller (1977); Harrison and Kreps (1978); Duffie, Garleanu, and Pedersen (2002); and Hong, Scheinkman, and Xiong (2006) show that when short sellers are constrained, prices will diverge from fundamentals and Diamond and Verrecchia (1987) show that short sellers are predominantly informed because they cannot use their sale proceeds. Asquith, Pathak, and Ritter (2005); Desai, Krishnamurthy, and Venkataraman (2006); Diether, Lee, and Werner (2009); and Christophe, Ferri, and Hsieh (2010) among others empirically find that short sales are informative about future prices and negative corporate events.

[2]Rule 611 of Regulation NMS requires this, but several exceptions are made (e.g., inter-market sweep orders).

for short sellers between transaction costs and the probability of immediate trade.[3]

Zhu (2014) formalizes this intuition in a model of venue choice that allows both informed and liquidity traders to trade on exchanges and dark pools. The model posits that since informed traders trade in the same direction as each other, crowding the "heavy" side of the market, they face a higher execution risk in the dark pool relative to uninformed traders. Consequently, the model predicts that exchanges will be relatively attractive to informed traders and dark pools will be relatively attractive to uninformed traders.

Consistent with this idea, we find that short sales comprise a larger proportion of exchange trading than of dark pool trading. Short sales comprise 45.68% of a stock's exchange volume and 37.04% of a stock's dark pool volume on average.[4] Furthermore, although all venue short sales are informative about future prices, exchange short sales are the most informative. Specifically, using the methodology of Boehmer, Jones, and Zhang (2008) and Engelberg, Reed, and Ringgenberg (2012), we find that heavily shorted stocks underperform lightly shorted stocks over the next 20 days by an average of 0.89% on exchanges, versus 0.53% on dark pools. These 20 trading day returns correspond to annualized returns of 10.70% for exchanges and 6.41% for dark pools. Over horizons of 30 minutes, two hours, and one trading day, respective post-exchange short sale returns are 0.32, 0.83, and 1.50 basis points lower than their dark pool counterparts. The

[3]Ye (2010) finds that observed bid-ask spread costs in dark pools are 20% lower than on exchanges and that dark pool orders have a fill rate of 4% in NYSE stocks, while fill rates for exchange orders are significantly higher. In another sample, Tuttle (2013) estimates a dark pool fill rate of 0.69%.

[4]We also examine a subsample of short sales classified as "marketable" using the approach of Comerton-Forde, Jones, and Putnins (2017) and find that results are qualitatively similar: short sales classified as "marketable" comprise 17.64% of a stock's exchange trading volume and a statistically distinguishable 13.11% of a stock's off-exchange trading volume on average.

average post-short sale return pattern over a horizon of one trading day corresponds to an annualized return difference of 3.78%.

We also shed light on a tension in the extant theoretical literature. When considering venue choice in the presence of short-lived information, Zhu (2014) and Hendershott and Mendelson (2000) provide differing predictions. Zhu (2014) predicts that a shorter information horizon can cause more aggressive use of the dark pool by informed traders. Such a horizon makes delay more appealing for liquidity traders, driving up exchange spreads. Therefore, informed traders will use the dark pools more aggressively to save on the spread. This prediction differs from that of Hendershott and Mendelson (2000), who predict that a shorter information horizon means that informed traders are even more likely to send orders to exchanges.

Using corporate news as episodes of short-lived information, we test these unique comparative statics. Our empirical approach is similar to those of Christophe, Ferri, and Angel (2004) and Engelberg, Reed, and Ringgenberg (2012). We find that exchange short sale ratios increase by a cumulative 4.62% from their unconditional level over the two days prior to unscheduled negative corporate events, while dark pool short sales ratios do not increase. Furthermore, we find that on news release days, exchange short sales are up to 4.39 times more informative about future prices compared to other days, while dark pool short sale informativeness does not increase. These findings are consistent with the prediction of Hendershott and Mendelson (2000) that increases in informed short selling associated with short-lived information occur on exchanges rather than dark pools.

Our unique empirical setting permits us to study how dark pool design may impact the ability of short sellers to exploit their informational advantage. Dark pools differ from

one another across several attributes of market design, including the availability of block trading, the availability of discrete time crossing, the degree of pre-trade transparency, availability of counterparty restrictions, and the availability of volume weighted average price (VWAP) crossing. Theory of market design provides predictions with regard to how each of these characteristics will affect the venue choice of short sellers.

For example, Seppi (1990) predicts that block trading is preferred by traders who can credibly signal that their trades are not information-motivated when facing the trade-off between trading a limited number of shares as a block at a good price and potentially trading many round lots at less favorable prices. Thus, block trading should not be associated with an increased proportion of informed short sales volume. We find that offering block trading is associated with 34.65 percentage points lower short sale ratios. In other words, our findings are consistent with the prediction of Seppi (1990).

Furthermore, Madhavan (2002) makes the point that VWAP pricing is the primary price benchmark of institutional order execution algorithms. Thus, we expect institutional short sales to be attracted to venues that provide VWAP crossing. We find that offering trading at a VWAP is associated with 16.43 percentage points higher short sale ratios. In other words, our findings are consistent with the Madhavan (2002) view of institutional short sales. Our findings exploiting differences in market design are consistent with theoretical predictions regarding informed trade.

Overall, our results indicate that short sellers exploit their information advantage relatively more on exchanges than dark pools, as predicted by Zhu (2014). This is particularly the case when information is short-lived, as predicted by Hendershott and Mendelson (2000). Furthermore, motivated by theory of market design, we examine the mechanism choice of short sellers across dark pools, and we find that venues offering

VWAP crossing attract more short sales while venues offering block trading attract fewer short sales.

The balance of this paper proceeds as follows: Section 1 develops our hypotheses. Section 2 details the data collection. Section 3 presents our empirical methodology and results. Section 4 contains concluding remarks.

1. Hypothesis development

Zhu (2014) predicts that exchanges are relatively more attractive to informed traders and dark pools are relatively more attractive to uninformed traders. This leads us to our first hypothesis:

Hypothesis 1 *Short sales comprise a greater proportion of exchange trading than of dark pool trading.*

This hypothesis rests against the null hypothesis that short sales comprise the same proportion of exchange and dark pool trading.

The literature shows that some short sales are more informed than others (for example, see Boehmer, Jones, and Zhang (2008), who examine the relative informativeness of short sales by account type). Using the logic of Zhu (2014), a natural hypothesis emerges. Short sales executed on exchanges should be more informative about future prices than short sales executed on dark pools. This is our second hypothesis:

Hypothesis 2 *Exchange short sales are more informative than dark pool short sales about future prices.*

This hypothesis rests against the null hypothesis that exchange and dark pool short sales are equally informative about future prices.

Short-lived information can also affect venue choice. In the presence of short-lived information, Zhu (2014) predicts that informed traders can use dark pools more aggressively to save on bid-ask spread costs, whereas Hendershott and Mendelson (2000) predict that informed traders will all use exchange orders for their higher probability of trade. Our next hypothesis examines the unique comparative statics of these models in order to resolve this apparent tension:

Hypothesis 3a *Dark pools exhibit increased short sales and short sale informativeness around periods of short-lived information.*

Hypothesis 3b *Exchanges exhibit increased short sales and short sale informativeness around periods of short-lived information.*

Hypothesis 3a is consistent with Zhu (2014), whereas Hypothesis 3b is consistent with Hendershott and Mendelson (2000). These hypotheses rest against the null hypothesis that there is no increase in short sales or short sale informativeness in either venue during periods of short-lived information.

It is important to note that these hypotheses are relative in nature, as theory suggests that some informed trade will occur in dark pools (see Zhu (2014)).

2. Data

2.1. Venue-level trading

We obtain exchange-level short sales directly from individual stock exchanges.[5] Trades and short sales in 24 dark pools are collected from an enhanced version of the FINRA TRF.[6,7] As in Diether, Lee, and Werner (2009) and Engelberg, Reed, and Ringgenberg (2012), among others, these data detail short position opening trades. We do not observe the "covering" trades of short sellers. In line with the literature, we remove short sales marked as exempt from the alternative uptick rule and short sales executed outside of regular trading hours. Using TAQ, we calculate exchange trading volume after removing trades with a price less than zero or a correction indicator other than zero.

2.2. Dark pool categories

We further disaggregate dark pool short sales using two approaches. We first apply a data-driven approach, classifying dark pools based on the percentage of trades executed inside of the NBBO and average trade sizes. Second, we use regulatory filings to identify the mechanisms of each dark pool.

Millisecond timestamps for trading in two dark pools are not available, so we classify the remaining 22 into block dark pools (4), midpoint dark pools (7), and non-midpoint

[5]NYSE Arca provides only daily short sale totals. National Stock Exchange (NSX) trade-level short sale data are missing for January 2014, so daily short sale totals are used. The Chicago Board Stock Exchange (CBSX) stopped providing short sale data on its website after June 2011.

[6]As of the second calendar quarter of 2014, these dark pools comprise 85% of dark pool volume reported to FINRA.

[7]These data do not permit us to observe whether the broker or customer is choosing the venue. While the execution venue of a short sale can reflect the discretion of the customer and broker, we treat the ultimate execution venue as the short seller's choice.

dark pools (11). Block dark pools are characterized by larger trade sizes. Midpoint dark pools are characterized by a high relative proportion of trades inside of the NBBO and non-midpoint dark pools are characterized by a low relative proportion of trades inside of the NBBO compared to midpoint dark pools.[8]

We also disaggregate dark pools based on market design characteristics according to their regulatory filings, allowing for relatively idiosyncratic deviations from the standard dark pool design suggested by Zhu (2014), among others. This classification approach involves algorithmically searching each filing for key terms associated with each mechanism as well as manually reading each filing.[9] We discuss these characteristics in Section 3.5.

2.3. Corporate news releases

RavenPack provides a database of corporate news releases accompanied by analytics. These data contain a timestamp and relevance score for each news release, where a score of zero means that the entity was passively mentioned while a score of 100 means that the entity was prominent in the news story. RavenPack also classifies news releases as scheduled or unscheduled. We study categorized Dow Jones Newswire press releases, full articles, news flashes, and hot news flashes. As in Engelberg, Reed, and Ringgenberg

[8]Block dark pools, midpoint dark pools, and non-midpoint dark pools host 0.57%, 3.86%, and 8.88% of trading volume, respectively while 87.18%, 57.83%, and 33.08% of their respective trades are inside of the NBBO, respectively. The category averages of venue average trade sizes of block, midpoint, and non-midpoint dark pools are 9,702 shares, 247 shares, and 183 shares, respectively. Return predictability results for block dark pools are not reported because they do not host trading in enough stocks on a given day to compute statistics.

[9]Specifically, we search each filing for the following terms: "scheduled", "block", "discrete", "cross", "session", "match", "filter", "pool club", "counterparty", "group", "exclude", "IOI", "conditional", "display", "lit", "indication", "volume weighted average price", "VWAP", "average", "peg", "midpoint", and "NBBO".

(2012), if a story is released after 16:00:00, then we mark the following trading day as the event day. To alleviate concerns of multicollinearity, we remove events in a given stock that occur within 15 calendar days of another news event after presenting descriptive statistics. Similarly to von Beschwitz, Keim, and Massa (2015), we examine only stories with a relevance score of 100. RavenPack also provides novelty scores in order to link multiple stories that cover the same event. As in Engelberg, Reed, and Ringgenberg (2012), we examine news releases with a novelty score of 100 in order to remove redundant releases. We exclude categories with fewer than 999 stories in the sample. We remove categories of stories relating to market activity, such as the "technical analysis", "prices", and "trading" categories. We also remove stories regarding "insider-trading" because they cluster in time and would result in significant overlap. We remove stories regarding "revenues" and "investor relations" because they are in close proximity to earnings announcements. Following Engelberg, Reed, and Ringgenberg (2012), we present results based on the event day market reaction, as it reflects a divergence from the market's prior expectations.[10]

2.4. Quotes and prices

We use Center for Research in Security Prices (CRSP) daily stock data for U.S. listed common stocks. NBBO midquote returns are computed from TAQ.[11] We also obtain NBBOs from the consolidated tape in order to classify dark pools. NBBO records that correspond to locked or crossed markets are excluded.

[10]Results are qualitatively similar when news is signed with RavenPack's sentiment score derived from natural language processing.

[11]Following Comerton-Forde, Jones, and Putnins (2017), we inspect end-of-minute NBBO midquotes that represent a 20% log return from their previous level and manually remove them if they are spurious.

We construct a matched sample, considering stocks that trade in both dark pools and exchanges. The final database spans the period of August 2012 through June 2014 and contains 3,148 securities.

2.5. Descriptive statistics

Table 1 presents stock-level summary statistics.

<Insert Table 1>

Panel A presents the mean, median, and standard deviation for each of the following during the sample period: average stock market capitalization, book value to market value, price, number of novel news events per stock-day, and the percentage of trading volume executed in dark pools. Panel B presents the stock-level mean, median, and standard deviation for trading volume and short sale volume in each trading venue type. Panel C presents the number of news events in the sample by category, from a total of 11 categories. This panel suggests that a broad range of corporate event types are covered, many of which have been studied individually in the financial economics literature.

3. Results

3.1. Where do shorts trade?

We test Hypothesis 1, which states that short sales comprise a greater proportion of exchange trading than of dark pool trading. Panel A of Table 2 presents statistics for

stock-level venue short sale ratios, defined as short sale volume divided by total volume, by venue.

<Insert Table 2>

Exchange short sales represent 45.68% of a stock's exchange trading volume on average. Short sales executed in dark pools represent 37.04% of a stock's dark pool trading volume on average. Dark pool short sale ratios and their exchange counterparts are statistically distinguishable at the 1% level. Though relatively simple, the fact that there is a greater proportion of short selling on exchanges is clear evidence supporting our key conjecture: as in Zhu (2014), short sellers exploit their information advantage on exchanges rather than dark pools.

The magnitudes of these short sale ratios are comparable to those of Comerton-Forde, Jones, and Putnins (2017), who study a panel of NASDAQ and NYSE exchange short sales. However, these magnitudes are larger than those of previous samples (see Boehmer, Jones, and Zhang (2008), among others). This finding could be consistent with both reduced shorting constraints (see Hanson and Sunderam (2014)) and increased high-frequency trading in equity markets (see Hendershott, Jones, and Menkveld (2011)). However, in Panel B, aggregate short sale ratios do not monotonically sort with stock-day cancel/trade ratios (a proxy of high-frequency trading; see Hendershott, Jones, and Menkveld (2011)). When we sort by stock-month aggregate short sale ratios, average stock-month short interest ratios (SIR) increase monotonically. In other words, we find that the short sales ratios in our sample follow a pattern similar to short interest ratio and a pattern different than high-frequency trading.

Panel C shows contemporaneous correlations, first-order autocorrelations, and cross-autocorrelations of the daily venue short sale ratio measures. We compute contemporaneous Spearman rank cross-sectional correlations each day and report time-series average correlations. Exchange and dark pool short sale ratios have a correlation of 0.438. Auto and cross-autocorrelations are computed as cross-sectional averages of stock-level auto and cross-autocorrelations of exchange and dark pool short sale ratios. As in Boehmer, Jones, and Zhang (2008), the venue shorting measures are persistent, with average daily autocorrelations and cross-autocorrelations ranging from 0.19 to 0.39. These correlations are statistically distinguishable from zero at the 5% level.

Overall, these results suggest that short sellers choose to exploit their information advantage on exchanges rather than dark pools.

3.2. Where are shorts most informed?

Asquith, Pathak, and Ritter (2005); Boehmer, Jones, and Zhang (2008); Diether, Lee, and Werner (2009); and Engelberg, Reed, and Ringgenberg (2012) find that heavily shorted stocks underperform lightly shorted stocks, indicating that short sellers are good at relative valuation. In this section, we test Hypothesis 2 and examine the relative informativeness of venue short sales about future prices.

We first adopt a calendar-time portfolio approach used in Jegadeesh and Titman (1993) to measure cross-sectional differences in trading venue short sales and future returns. As in Boehmer, Jones, and Zhang (2008) and Engelberg, Reed, and Ringgenberg (2012), we sort stocks daily into quintiles based on the previous day's venue type short sale ratio and hold the portfolio for 20 days. We control for systematic risk and momentum with the standard Carhart (1997) time series regression. Raw returns and Carhart

alphas of trading venue short sale portfolios are reported in Table 3.

<Insert Table 3>

Both short sale types are informative about future price moves, but exchange short sales are significantly more informative than dark pool short sales. Heavily shorted stocks in dark pools underperform corresponding lightly shorted stocks by 0.53% over the subsequent 20 trading days (or 6.41% annualized). This difference is more pronounced on exchanges: heavily shorted stocks underperform lightly shorted stocks by 0.89% (10.70% annualized). Furthermore, the difference-in-differences between dark pools and exchanges is 4.29%, which is statistically significant at the 1% level. These results confirm the prediction of Zhu (2014) and Hypothesis 2 that exchange short sales are more informative than dark pool short sales about future price moves.

Turning to the venue characteristic splits, we find that the long-short alphas for midpoint and non-midpoint dark pools are 0.29% and 0.55%, respectively. This suggests that midpoint dark pools, which most closely resemble the dark pool design suggested by Zhu (2014), have less informed short selling than other venue types. These results further confirm Hypothesis 2 and the prediction of Zhu (2014).[12]

To examine the relative informativeness of venue short selling while controlling simultaneously for stock characteristics and correlations, we employ a variant of the Fama-MacBeth (1973) procedure. Our approach is similar to those of Boehmer, Jones, and Zhang (2008) and Engelberg, Reed, and Ringgenberg (2012). Specifically, we estimate

[12]Results are qualitatively similar when equal-weighted portfolios are used and are available upon request.

daily cross-sectional regressions where each observation of the dependent variable is either the raw return or the 20-day cumulative Daniel, Grinblatt, Titman, and Wermers (DGTW) (1997) characteristic-adjusted return of stock i starting on day $t+1$ (one day after measuring shorting activity). Observations of the independent variables are stock-day venue type short sale ratios on day t. We take the time series mean of daily parameter estimates. Specifications with raw returns as the dependent variable include size and book to market controls. We standardize all explanatory variables to have a zero mean and unit variance each day, so coefficients can be interpreted as the association between returns and a one standard deviation change in the explanatory variable. Results appear in Table 4.

<Insert Table 4>

Both dark pool and exchange short sales are informative about future price moves. According to specifications 7 and 8, a one standard deviation increase in exchange short sales implies a 0.28% lower return over the following month while a one standard deviation increase in dark pool short sales implies a 0.23% lower return. In specification 11, we compare exchange short sales with dark pool short sales by including both in the same specification. We confirm the superior incremental informativeness of exchange short sales, with a coefficient estimate of -0.22%, over dark pool short sales, with a coefficient estimate of -0.12%. In unreported tests, we find that exchange short sale estimates are statistically distinguishable from their dark pool counterparts at the 5% level.

By employing our venue design characteristics, we can see that there is a difference between midpoint and non-midpoint dark pools. In specification 12, when we include

both midpoint and non-midpoint dark pools, the estimate for short sales in midpoint dark pools becomes statistically insignificant (coefficient of -0.02%, *t*-statistic of -1.23), while the coefficient for non-midpoint dark pools remains significant (coefficient of -0.11%). Even so, exchange short sales estimates are statistically distinguishable from their midpoint and non-midpoint dark pool counterparts at the 5% level.

These results suggest that short sales in midpoint dark pools, which most closely resemble the dark pool in Zhu (2014), do not contain any incremental informativeness about future prices. The results confirm Hypothesis 2, that exchange short sales are more informative than dark pool short sales.

Following Comerton-Forde, Jones, and Putnins (2017), we also examine the intraday informativeness of venue short sales. Due to data limitations, we randomly select a size-stratified sample of 439 stocks, roughly half of which are NYSE listed and half are NASDAQ listed over the September 2012 through June 2014 period.[13]

Using the approach of Comerton-Forde, Jones, and Putnins (2017), we aggregate short sales over five-minute intervals, and we weight returns by short dollar volume to measure the relationship between venue short sales and future returns. Figure 1 presents average post-short sale excess returns for horizons of up to one trading day.[14]

<Insert Fig. 1>

[13]The list of stratified tickers is available upon request.

[14]Comerton-Forde, Jones, and Putnins (2017) note that de-meaning returns across all sample stocks for a given interval is equivalent to using excess returns vs. the market as the dependent variable, thereby accounting for relative rather than raw stock price behavior, and that dollar weighting better reflects the actual performance of short sellers. Results are quantitatively similar when trades are weighted equally, with raw returns, and with one-minute sampling frequency, and are available upon request.

Exchange (gray dashed line) and dark pool (black solid line) short sales are both informative about future price moves. However, exchange post-trade returns are lower than dark pool post-trade returns. As before, the visual evidence using intraday data is consistent with the prediction of Zhu (2014), and Hypothesis 2, that exchange short sales are more informative than dark pool short sales about future price moves.

In order to determine statistical significance, we employ a technique used in Comerton-Forde, Jones, and Putnins (2017). In this regression, the level of observation for the dependent variable is post-short sale returns. There will be two return observations for each interval, one corresponding to each venue type. Observations are weighted by venue type short sales volume. We regress returns on an indicator variable that is equal to one if dark pool returns are being measured, and zero otherwise. This makes exchange returns the base case. We include stock fixed effects.

This regression allows us to test for differences between the exchange and dark pool return patterns seen in Figure 1. Specifically, in Table 5, the indicator variable *dark pool* captures differences in return predictability across the venues.

<Insert Table 5>

Panel A presents results for all dark pools. After one trading day, exchange cumulative post-trade returns are 1.501 basis points (3.78% annualized) lower than their dark pool counterparts, consistent with the idea that short sales are more informative on exchanges than on dark pools. This pattern is relatively consistent for longer intervals. Exchange cumulative post-trade returns are statistically distinguishable from their dark

pool counterparts at the 10% level for 30 minute intervals and at the 5% level for longer intervals. Consistent with the literature, these post-trade patterns indicate contrarian trading. Avramov, Chordia, and Goyal (2006) and Diether, Lee, and Werner (2009) argue that contrarian traders are rational and trade to profit from the deviation of prices from fundamentals.

In Panel B, we separate dark pools into midpoint and non-midpoint dark pools, with qualitatively similar results. Midpoint dark pools are the least informative about future returns. Taken together, these results indicate that exchange short sales are more informative than dark pool short sales, and especially midpoint dark pools, further confirming Hypothesis 2.

Biais, Hillion, and Spatt (1995) and Menkveld, Yueshen, and Zhu (2017) show that trading volume is persistent, and that trading can be correlated across venues. To allow for these possibilities, we follow Comerton-Forde, Jones, and Putnins (2017) by employing the Hasbrouck (1991) information content of trade framework. Specifically, we separately estimate the following system for each stock in calendar-time over the period:

$$\begin{aligned} x_t^{EX} &= \mu^{EX} + \sum_{i=1}^{20} \phi_i^r r_{t-i} + \sum_{i=1}^{20} \phi_i^{EX} x_{t-i}^{EX} + \sum_{i=1}^{20} \phi_i^{DP} x_{t-i}^{DP} + \epsilon_t^{EX} \\ x_t^{DP} &= \mu^{DP} + \sum_{i=1}^{20} \theta_i^r r_{t-i} + \sum_{i=1}^{20} \theta_i^{EX} x_{t-i}^{EX} + \sum_{i=1}^{20} \theta_i^{DP} x_{t-i}^{DP} + \epsilon_t^{DP} \\ r_t &= \mu^{r_t} + \sum_{i=1}^{20} \lambda_i^r r_{t-i} + \sum_{i=1}^{20} \lambda_i^{EX} x_{t-i}^{EX} + \sum_{i=1}^{20} \lambda_i^{DP} x_{t-i}^{DP} + \epsilon_t^{r_t}, \end{aligned} \tag{1}$$

where variables x^{EX} and x^{DP} denote exchange and dark pool dollar short sale volume, respectively, and r_t is the excess log NBBO-midquote return at time t. This Vector autoregression (VAR) is estimated with five-minute data and 20 lags of each variable.[15]

Figure 2 shows average impulse response of returns to short sale volume shocks. The magnitude of each volume shock is set to be a one standard deviation increase in short sales volume. Return responses are presented for horizons of up to one trading day.

<Insert Fig. 2>

The figure shows that return response profiles are different for exchange volume shocks versus dark pool volume shocks. In Panel A, post-exchange volume shock returns are generally negative. On the other hand, in Panel B, post-dark pool volume shock returns are generally positive, and statistically different from zero starting immediately.[16] When examining the difference between venues, we find that return responses are 1.83 basis points (4.61% annualized) lower after exchange volume shocks than those of their dark pool counterparts after one trading day. In unreported tests, we find that this difference is statistically significant at the 5% level for the one-day horizon. These results further confirm Hypothesis 2, that exchange short sales are more informative than dark pool short sales about future price moves, this time looking at an intraday scale.

[15]We also estimate this system using the BIC minimizing lag lengths, as well as with one-minute sampling frequency, and find similar results. Results are available upon request. We do not estimate this system in trade-time due to data availability.

[16]Comerton-Forde, Jones, and Putnins (2017) comment that while this result might initially seem inconsistent with results showing that short sellers possess superior information over longer holding horizons, information can take more than one day to be impounded in prices.

In summary, our results form a consistent picture. Consistent with Hypothesis 2 and the prediction of Zhu (2014), exchange short sales are more informative than dark pool short sales about future prices.

3.3. Venue short sale informativeness and information horizon

Theory suggests that short sellers' choice of venue may change if information is short-lived. Following Christophe, Ferri, and Angel (2004) and Christophe, Ferri, and Hsieh (2010), we use imminent corporate events as a setting of short-lived information. In order to examine Hypothesis 3, and how short-lived information affects venue choice, we follow Engelberg, Reed, and Ringgenberg (2012) and present equally weighted long-short quintile portfolios. Portfolios are formed as in Table 3, by conditioning on venue short sales alone, and venue short sales on news days, where short sales are measured on the day prior to the news release.[17] Figure 3 shows the cumulative percentage returns of these portfolios.

<Insert Fig. 3>

A clear pattern emerges: short sale informativeness increases on news days for exchanges, and short sale informativeness does not increase on news days for dark pools. In other words, in the presence of short-lived information, short selling on exchanges is particularly informative: the long-short portfolio conditioning on exchange short sales

[17]Due to data availability, we study a distinct set of news releases in a more recent sample than Engelberg, Reed, and Ringgenberg (2012).

and news yields annualized returns of 24.72% over the sample relative to annualized returns of 10.91% for portfolio conditioned on exchange short sales alone.

In Table 6, we control for stock characteristics and correlations, by expanding upon the Fama-MacBeth (1973) analysis shown in Table 4. We include a news day indicator variable and interactions between venue short sales and the news day indicator variable to statistically test whether exchange or dark pool short sales' informativeness increases around corporate news events. Results appear in Table 6.

<Insert Table 6>

The interaction term for exchange short sales on news days in specifications 4 and 6 indicates that exchange short sales are 2.07 to 4.39 times more informative about the cross-section of future price moves on news days compared to other days, while dark pool short sale informativeness does not increase on these days. In unreported results, estimates for the exchange short sale and news interaction are statistically distinguishable from their dark pool counterparts at the 5% level. This result confirms Hypothesis 3b and is consistent with the prediction of Hendershott and Mendelson (2000).

3.4. Venue short sale timing

Our empirical setting allows us to further test the prediction of Hendershott and Mendelson (2000), which suggests that informed traders will increasingly use exchanges in the presence of short-lived information, against that of Zhu (2014), which suggests that informed traders can use dark pools more aggressively. We examine where short sellers

trade around unscheduled corporate news events in order to understand which prediction is a better match for our empirical setting.

We use a difference-in-differences approach similar to that of Engelberg, Reed, and Ringgenberg (2012), where we vary the timing of the dependent variable relative to the news event for the five days around the news release day. We include *exchange*, which is an indicator variable equal to one if the dependent variable is an exchange stock-day short ratio and zero otherwise, making the base case dark pool short sale ratios. The *news* indicator variable is equal to one if a news event occurs and zero otherwise. The interaction term measures the incremental response of exchange short sale ratios, relative to the response of dark pool short sale ratios, on news days. Diether, Lee, and Werner (2009) find that in addition to predicting future returns, short sales respond to prior returns. Consequently, we include two lags for percentage returns in addition to stock-month fixed effects.

Baruch, Panayides, and Venkataraman (2017) argue that trading surrounding scheduled news events reflects belief heterogeneity, while unscheduled news events provide a better setting of informed trade. Similarly, Sarkar and Schwartz (2009) find that unscheduled corporate news announcements are preceded by relatively more one-sided trading (consistent with adverse selection) compared to scheduled macroeconomic announcements. Consequently, our events of interest are unscheduled news events and unscheduled negative news events. There are 13,776 total scheduled events and 10,394 total unscheduled events in our sample. Results appear in Table 7.

<Insert Table 7>

Panel A shows that dark pool short sale ratios and exchange short sale ratios both increase on the day before a negative news release. Panel B shows that both of these ratios increase preceding scheduled negative news, though the increase is larger in magnitude for dark pool short sale ratios.[18] As mentioned above, the literature posits that unscheduled news provides the best sample of events for examining informed trading. Panel C shows that exchange short sale ratios increase by a cumulative 2.113% (4.62% relative to the stock-level mean) over the two days preceding negative unscheduled news events, while dark pool short sale ratios do not increase. This result is consistent with the prediction of Hendershott and Mendelson (2000). Together, these results confirm Hypothesis 3b, that exchanges exhibit increased shorting activity and informativeness about future price moves prior to news releases.

3.5. Dark pool mechanisms

Our unique database allows us to examine variation in dark pool market design. We exploit this variation to examine the connection between market design and short sales. Since the mechanisms are stable through time, we examine short sale ratios both unconditionally and around the sample of news events in a manner similar to Table 7.

Using the disaggregated dark pool data, we regress stock-venue-day short sale ratios, defined similarly to those in Table 7, on market design indicator variables equal to one if a dark pool has a design characteristic and zero otherwise. We also include a news indicator that is equal to one if an unscheduled negative news event occurs on the following day and zero otherwise. We then interact the news event indicator with the

[18] In unreported tests, we confirm that the increase in exchange short sale ratios is statistically significant.

market design indicators. The coefficients of interest are the mechanism indicators and interactions. As in Table 7, we include two lagged returns as controls and stock-month fixed effects. Exchange short sale ratios are the base case.

The first mechanism design characteristic that we consider is *block*, which designates dark pools that offer block trading. Seppi (1990) provides a prediction that block trading is preferred by traders who can credibly signal that their trades are not information-motivated. Thus, according to Seppi (1990), the presence of *block* should not increase the fraction of short sales volume.

Scheduled designates dark pools that offer a scheduled cross in addition to a continuous cross. Du and Zhu (2017) model the implications of trade frequency and find that when information arrives at scheduled time intervals, the optimal trading frequency cannot be higher than the frequency of new information. Within our context, we expect unscheduled news to arrive at random times. Given this experimental structure, we should not expect short sellers to be attracted to venues that host a scheduled cross.

Poolclub designates dark pools that allow traders to choose entities with which to trade. This would allow some traders to avoid trading with those whom they think are informed. At the same time, this may reduce the probability of trade for informed traders. This idea suggests that informed short sellers may not be able to trade on venues that have the *poolclub* feature.

Non-display designates dark pools that display no order or quote information aside from the prices and quantities of trade executions. Baruch (2005), like others, models pre-trade transparency and finds that when more detailed information on the limit order book is displayed, the resulting competition benefits liquidity takers. Mixed evidence exists as to whether liquidity takers are informed (see Baruch, Panayides, and

Venkataraman (2017), among others).

$VWAP$ designates dark pools that offer matching at a volume-weighted average price. VWAP pricing is the primary price benchmark of order execution algorithms for investors with longer holding horizons (see Madhavan (2002)). Thus, VWAP pricing may have more to do with whether a short seller is institutional than with whether a short seller is informed. In other words, we would expect institutional short sellers to be attracted to venues that allow VWAP pricing. Results appear in Table 8.

<Insert Table 8>

Each column corresponds to a different specification. We find that three dark pool design characteristics relate to informed short selling in our sample. In specifications with stock-month fixed effects, offering trading at a VWAP is associated with 16.43 percentage point higher short sale ratios on non-news days and a 2.89% increase on news days relative to the dark pool stock-level mean. In contrast, consistent with Seppi (1990), we find that hosting block trading is associated with a statistically significant 34.65 percentage point lower short sale ratios unconditionally, while offering poolclub trading is associated with a 4.11% decrease on news days relative to the dark pool stock-level mean.

4. Conclusion

Prior research shows that short sellers are informed, but little is known about where short sellers exploit their information advantage. This paper seeks to examine this question

by constructing a novel panel of short sales at the trading venue level.

Consistent with the prediction of Zhu (2014), we find that short sales comprise a larger proportion of exchange trading than of dark pool trading. Furthermore, using several approaches, we find that exchange short sales are more predictive of future prices than are dark pool short sales.

Using corporate news events as episodes of short-lived information, we find that exchange short sale ratios increase from their unconditional levels over the two days prior to unscheduled negative corporate events, while dark pool short sale ratios do not increase. Furthermore, we find that exchange short sales are more informative about the cross-section of future prices on news days as compared to other days, while dark pool short sale informativeness does not increase. These findings are consistent with the prediction of Hendershott and Mendelson (2000) that increases in informed trade take place on exchanges when information is short-lived.

We exploit the additional richness of our database in order to better understand short-sellers' venue choice. Our database contains information regarding specific dark pool mechanisms (e.g., block trading, continuous vs. discrete time crossing, pre-trade transparency, and other characteristics). Consistent with Madhavan (2002), we find that offering trading at a volume-weighted average price (VWAP) is associated with short sales comprising a larger proportion of order flow. In contrast, consistent with Seppi (1990), we find that hosting block trading is associated short sales comprising a smaller proportion of order flow.

More broadly, our results provide a novel link between market design and informed trade. Furthermore, the results have implications for our understanding of the interaction between informed trade and the horizon of information (see Holden and Subrah-

manyam (1992), among others). Specifically, we provide novel evidence on the venue and mechanism choice of informed traders in the presence of short-lived information when weighing trade-off between immediacy and transaction costs.

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Table 1: Summary statistics

The database contains 1,343,458 stock-day observations over the period spanning August 2012 through June 2014 and includes 3,148 securities. Panel A provides stock-level summary statistics. *Market capitalization*, *book to market*, and *price* are stock-level sample averages. *Novel news events per stock-day* is a count of news events per stock-day. *Dark pool vol./total vol.* is total dark pool volume divided by total trading volume. Panel B provides stock-level trading volume statistics. *Exchange short vol.* is total exchange short sale volume. *Exchange vol.* is total exchange trading volume. *Dark pool vol.* is total dark pool trading volume. *Dark pool short vol.* is total dark pool short volume. Panel C contains summary statistics on the frequency of events occurring in each news category.

Panel A: Stock statistics

Variable	Mean	Median	Std. dev.
Market capitalization (mm)	\$5,018	\$721	21,243
Book to market	0.696	0.588	0.560
Price	\$32	\$20	\$63
Novel news events per stock-day	0.060	0.044	0.090
Dark pool vol./total vol.	13.1%	13.8%	4.6%

Panel B: Shorting flow statistics

Variable	Mean	Median	Std. dev.
Exchange short vol. (mm shares)	162	29	595
Exchange vol. (mm shares)	301	61	1038
Dark pool vol. (mm shares)	62	14	209
Dark pool short vol. (mm shares)	28	5	107

Panel C: News categories

Category	N
Acquisitions and mergers	4564
Analyst ratings	12420
Assets	1683
Credit	1426
Credit ratings	5405
Dividends	3060
Earnings	22834
Equity actions	5814
Labor issues	6023
Partnerships	999
Products and services	6765

Table 2: Trading venue short sale ratios

This table presents venue short sale ratio statistics. Panel A presents stock-level short sale ratio statistics. *Exchange short vol./exchange vol.* is total exchange short sale volume divided by total exchange trading volume. *Dark pool short vol./dark pool vol.* is total dark pool short sale volume divided by total dark pool trading volume. Signifier *** indicates that *exchange short vol./exchange vol.* is statistically distinguishable from its dark pool counterpart at the 1% level. Panel B presents descriptive sorts for short sale ratios aggregated across all venues. Stocks are sorted into quintiles based on short sale ratios and average stock characteristics are computed. Trade/cancel is the average stock-day trade to cancellation ratios obtained from SEC MIDAS for each quintile. *SIR* is the average stock-month ratio of short interest to shares outstanding obtained from NASDAQ and Compustat for each quintile. Panel C presents venue short sale ratio correlations. *Contemporaneous correlation* is time series average contemporaneous Spearman rank cross-sectional correlation of *Exchange short vol./exchange vol.* and *Dark pool short vol./dark pool vol.* Cross-sectional averages of stock-by-stock autocorrelations and cross-autocorrelations of *Exchange short vol./exchange vol.* and *Dark pool short vol./dark pool vol.* are also presented.

Panel A: Venue short sale ratio statistics

Variable	Mean	Median	Std. dev.
Exchange short vol./exchange vol.	45.68%	48.09%	9.92%
Dark pool short vol./dark pool vol.	37.04%	37.22%	10.10%
Difference	8.64%***		

Panel B: Total short sale ratio descriptive sorts

Short sale ratio quintile	*Trade/cancel*	*SIR*
1 (Least shorted)	4.07%	1.34%
2	4.62%	3.19%
3	4.62%	4.45%
4	4.58%	5.51%
5 (Most shorted)	4.45%	6.95%

Panel C: Venue short sale ratio correlations

Contemporaneous correlation		0.438
Autocorrelations and cross-autocorrelations	$Exchange_{t-1}$	$Dark\ pool_{t-1}$
$Exchange_t$	0.390	0.207
$Dark\ pool_t$	0.187	0.294

Table 3: Portfolio raw returns and Carhart alphas based on venue short sale ratios

This table presents portfolio raw returns and Carhart (1997) alphas from regressions that examine the performance of value-weighted portfolios based on stock-day venue short sale ratio measures. Results are presented for quintile portfolios formed on the stock-day ratio of exchange short volume to exchange volume (*exchange*), total dark pool short volume to total dark pool volume (*all dark pools*), midpoint dark pool short volume to midpoint dark pool volume (*midpoint*), and non-midpoint dark pool short volume to non-midpoint dark pool volume (*non-midpoint*). After forming portfolios each day, value-weighted portfolios are held for the subsequent 20 trading days. This process repeats each trading day, so that each trading day's portfolio return is an average of 20 different portfolios, with 1/20 of the portfolio rebalanced each day. Daily calendar-time returns and Carhart (1997) four-factor alphas are reported in percent multiplied by 20 to reflect an approximate monthly return, with t-statistics based on the daily time series presented in parentheses.

	Exchange		*All dark pools*		*Midpoint*		*Non-midpoint*	
Portfolio	Return	Alpha	Return	Alpha	Return	Alpha	Return	Alpha
1 (least shorted)	2.429	0.764	2.123	0.412	1.985	0.239	2.122	0.420
2	1.919	0.223	1.681	-0.021	1.573	-0.109	1.750	0.044
3	1.591	-0.089	1.688	-0.006	1.751	0.055	1.623	-0.067
4	1.644	-0.078	1.628	-0.099	1.641	-0.089	1.639	-0.088
5 (most shorted)	1.640	-0.128	1.656	-0.122	1.730	-0.050	1.659	-0.134
Long-short	0.789	0.891	0.467	0.534	0.254	0.288	0.463	0.554
		(5.72)		(4.28)		(2.01)		(4.45)
Difference with exchange long-short				0.357		0.603		0.338
				(2.85)		(4.13)		(2.56)

Table 4: Cross-sectional relation between monthly percentage returns and venue short sale ratios

This table presents the results of Fama-MacBeth (1973) regressions examining the relation between returns and stock-day venue short sale ratios. Each column corresponds to a different specification. For each model, we estimate daily cross-sectional regressions, calculate the time series mean of the daily coefficient estimates, and obtain *t*-statistics using Newey-West (1987) standard errors with 20 lags. Dependent variables are raw returns and the Daniel, Grinblatt, Titman, and Wermers (1997) adjusted returns over the subsequent 20 trading days. *Exchange* is stock-day ratio of exchange short volume to exchange volume on the current day. *All dark pools*, *midpoint dark pools,* and *non-midpoint dark pools* are the stock-day ratios of dark pool type short volume to dark pool type volume on the current day, respectively. Specifications with raw returns as the dependent variable include size and book to market controls. Explanatory variables are standardized to have a mean of zero and unit variance each day and *t*-statistics are presented in parentheses.

	Dependent Variable											
	Raw returns (%)						DGTW adjusted returns (%)					
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Intercept	2.241	2.211	2.214	2.213	2.231	2.233	0.192	0.147	0.146	0.147	0.182	0.183
	(3.89)	(3.80)	(3.81)	(3.81)	(3.87)	(3.87)	(4.55)	(3.94)	(3.91)	(3.93)	(4.33)	(4.37)
Exchange	-0.262				-0.195	-0.202	-0.281				-0.217	-0.223
	(-4.12)				(-3.11)	(-3.22)	(-4.76)				(-3.67)	(-3.79)
All dark pools		-0.221			-0.129			-0.228			-0.124	
		(-5.39)			(-5.26)			(-6.55)			(-5.63)	
Midpoint dark pools			-0.116			-0.021			-0.126			-0.019
			(-5.17)			(-1.30)			(-5.84)			(-1.23)
Non-midpoint dark pools				-0.186		-0.106				-0.199		-0.105
				(-5.61)		(-3.92)				(-6.46)		(-4.48)
Adj. R^2	1.42%	1.35%	1.31%	1.35%	1.46%	1.46%	0.14%	0.07%	0.03%	0.06%	0.17%	0.20%

Table 5: Post venue short sale cumulative returns measured through varying post-trade horizons

This table presents regression estimates for price impact regressions, where the dependent variable is the midquote post-trade excess cumulative log returns measured in basis points over various post-trade horizons. Venue short sales are aggregated into five-minute intervals and weighted by dollar volume. *Dark pool*, *midpoint dark pools*, and *non-midpoint dark pools* are indicator variables that take the value of one for all dark pool short sales, midpoint dark pool short sales, and non-midpoint dark pool short sales, respectively, making the base case post-exchange short sale returns. Log returns are de-meaned by the average return across all stocks over each horizon. Stock fixed effects are included. Standard errors are clustered by five-minute interval. Signifiers ***,** , and * indicate statistical significance for a coefficient estimate at the 1%, 5%, and 10% level, respectively. This result is based on a stratified sample of 439 stocks during September 2012 through June 2014.

Panel A: All dark pools

	Post-short sale horizon							
	5 minutes		30 minutes		2 hours		1 trading day	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Intercept (*Exchange*)	0.433***		0.373		−0.515		−3.863***	
Dark pool	−0.027	−0.007	0.274*	0.322**	0.712***	0.830***	1.378***	1.501***
Stock fixed effects	N	Y	N	Y	N	Y	N	Y

Panel B: By dark pool type

	Post-short sale horizon							
	5 minutes		30 minutes		2 hours		1 trading day	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Intercept (*Exchange*)	0.433***		0.373		−0.515		−3.863***	
Midpoint dark pool	−0.023	0.013	0.372*	0.410**	1.261***	1.290***	2.865***	2.585***
Non-midpoint dark pool	−0.017	−0.009	0.261*	0.300*	0.560***	0.688***	0.980***	1.217***
Stock fixed effects	N	Y	N	Y	N	Y	N	Y

Table 6: Venue short sale informativeness and news arrival

This table presents the results of Fama-MacBeth (1973) regressions examining the relation among returns, short sales by type of trading venue, and news events. For each model, we estimate daily cross-sectional regressions, calculate the time series mean of the daily coefficient estimates, and obtain t-statistics using Newey-West (1987) standard errors with 20 lags. Each column corresponds to a different specification. Dependent variables are raw returns and the Daniel, Grinblatt, Titman, and Wermers (1997) adjusted returns over the subsequent 20 trading days. *Exchange* is stock-day ratio of exchange short volume to exchange volume on the current day. *Dark pool* is stock-day ratio of dark pool short volume to dark pool volume on the current day. *News* in an indicator variable that equals one if a corporate news release occurs on the day that returns are first measured and zero otherwise. Size and book to market controls are included in specifications with raw returns as the dependent variable. Continuous explanatory variables are standardized to have a mean of zero and unit variance each day and t-statistics are presented in parentheses.

	Dependent Variable					
	Raw returns (%)			DGTW adjusted returns (%)		
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Intercept	2.156	2.157	2.156	0.138	0.139	0.139
	(3.95)	(3.95)	(3.95)	(3.07)	(3.10)	(3.08)
Exchange	-0.189		-0.141	-0.205		-0.161
	(-2.90)		(-2.11)	(-3.11)		(-2.39)
Dark pool		-0.167	-0.118		-0.173	-0.110
		(-6.04)	(-5.70)		(-6.09)	(-5.43)
News	0.102	0.097	-0.088	0.105	0.107	-0.118
	(1.04)	(0.97)	(-0.39)	(1.14)	(1.15)	(-0.47)
Exchange × *News*	-0.206		-0.498	-0.219		-0.545
	(-1.84)		(-1.75)	(-1.99)		(-1.71)
Dark pool × *News*		0.107	0.152		0.162	0.190
		(1.16)	(1.15)		(1.24)	(1.36)
Adj. R^2	1.29%	1.17%	1.33%	0.24%	0.09%	0.28%

Table 7: Venue short sale ratios surrounding news events

This table presents the results of panel data regressions that examine venue short sale ratios surrounding news events. In each panel, we examine five separate regressions that vary the timing of the dependent variable relative to the news event to examine venue short sale ratio changes around news events. For example, $t-2$ indicates that two days before a news event, the news release indicator variable is equal to one. In each regression, the dependent variable is the stock-day venue short sale ratio (in percent). The independent variables of interest are *news*, an indicator variable that takes the value of one for the news day of interest and zero otherwise; another indicator variable that equals one if exchange short sale ratios are being considered (*exchange*), making dark pool trading the base case, and zero otherwise; and the interaction term of *news* and *exchange*. $Return_{t-1}$ and $Return_{t-2}$ are one and two day lagged percentage stock returns, respectively. Panel A presents results for all news events, Panel B presents results for scheduled news events, and Panel C presents results for unscheduled news events. We define a news event as negative if the news announcement day return is in the bottom quintile of returns for that day. All regressions include stock-month fixed effects. Standard errors are clustered by stock and day. Coefficients of interest are presented for panels after Panel A. Signifiers ***,** , and * indicate statistical significance for a coefficient estimate at the 1%, 5%, and 10% level, respectively.

Panel A: All news, all events					
	$t-2$	$t-1$	t	$t+1$	$t+2$
$Return_{t-1}$	0.307^{***}	0.307^{***}	0.307^{***}	0.307^{***}	0.307^{***}
$Return_{t-2}$	0.126^{***}	0.126^{***}	0.126^{***}	0.126^{***}	0.126^{***}
Exchange	4.352^{***}	4.356^{***}	4.347^{***}	4.365^{***}	4.361^{***}
News	-0.477^{***}	0.244	-0.881^{***}	-0.567^{***}	-0.069
Exchange × *News*	0.513^{**}	0.296	0.787^{***}	-0.250	-0.004
N	2,538,884	2,538,884	2,538,884	2,538,884	2,538,884
$Adj.R^2$	21%	21%	21%	21%	21%
Panel A1: All news, negative events					
News	-0.577^{**}	0.807^{***}	-2.423^{***}	-0.935^{***}	0.022
Exchange × *News*	0.498	0.008	0.923^{***}	-0.460	0.455
Panel B: Scheduled news, all events					
News	-0.261	0.883^{***}	-0.669^{***}	-0.632^{**}	0.177
Exchange × *News*	0.011	-0.532^{*}	0.106	-0.895^{***}	-0.622^{**}
Panel B1: Scheduled news, negative events					
News	-0.514	1.318^{***}	-1.919^{***}	-0.923^{**}	0.344
Exchange × *News*	0.083	-0.859^{**}	0.041	-0.995^{**}	0.338
Panel C: Unscheduled news, all events					
News	-0.761^{***}	-0.556^{***}	-1.110^{***}	-0.504^{**}	-0.389^{*}
Exchange × *News*	1.181^{***}	1.358^{***}	1.671^{***}	0.686^{***}	0.828^{***}
Panel C1: Unscheduled news, negative events					
News	-0.716^{*}	-0.122	-3.376^{***}	-0.888^{**}	-0.603
Exchange × *News*	1.315^{***}	1.636^{***}	2.630^{***}	0.586	0.707^{***}

Table 8: Dark pool design and short sale ratios

This table presents the results of regressions of stock-venue-day short sale ratios on market design indicator variables that are equal to one if a dark pool has a certain characteristic and zero otherwise, news event indicator variables that are equal to one if an unscheduled negative news event occurs on the following day and zero otherwise (*news*), and their interaction terms. Exchange stock-day short sale ratios are the base case. *Block* is an indicator variable equal to one if a dark pool hosts block trading and zero otherwise. *Scheduled* is an indicator variable equal to one if a dark pool hosts a scheduled cross and zero otherwise. *Poolclub* is an indicator variable equal to one if a dark pool allows traders to filter potential counterparties and zero otherwise. *Non-display* is an indicator variable equal to one if a dark pool does not disseminate any non-trade order related information and zero otherwise. *VWAP* is an indicator variable equal to one if a dark pool offers crossing at a volume-weighted average price and zero otherwise. Each column corresponds to a different specification. Stock-month fixed effects are included and t-statistics obtained from standard errors clustered by venue are in parentheses.

	Dependent variable: venue short sale ratio			
Variable	(1)	(2)	(3)	(4)
Intercept	44.17		44.17	
	(13.59)		(13.59)	
Block	−34.93	−34.65	−34.92	−34.65
	(−5.73)	(−5.71)	(−5.73)	(−5.71)
Scheduled	−6.40	−6.44	−6.39	−6.43
	(−0.49)	(−0.50)	(−0.49)	(−0.50)
Poolclub	−2.99	−3.92	−2.99	−3.91
	(−0.02)	(−0.79)	(−0.65)	(−0.79)
Non-display	3.80	3.64	3.80	3.64
	(0.87)	(0.83)	(0.87)	(0.83)
VWAP	16.40	16.43	16.40	16.43
	(2.28)	(2.29)	(2.28)	(2.29)
$Return_{t-1}$	0.31	0.31	0.31	0.31
	(10.52)	(11.48)	(10.52)	(11.49)
$Return_{t-2}$	0.12	0.12	0.12	0.12
	(5.87)	(7.54)	(5.87)	(7.55)
News			2.43	1.50
			(3.19)	(2.97)
Block × *News*			−1.48	−1.32
			(−2.40)	(−1.67)
Scheduled × *News*			−0.81	−0.76
			(−1.23)	(−1.09)
Poolclub × *News*			−1.88	−1.52
			(−2.56)	(−2.94)
Non-display × *News*			−0.37	−0.24
			(−0.52)	(−0.34)
VWAP × *News*			1.05	1.07
			(2.12)	(2.11)
Stock-month fixed effects	N	Y	N	Y
Observations	16307682	16307682	16307682	16307682
Adj R^2	3.43%	8.13%	3.43%	8.13%

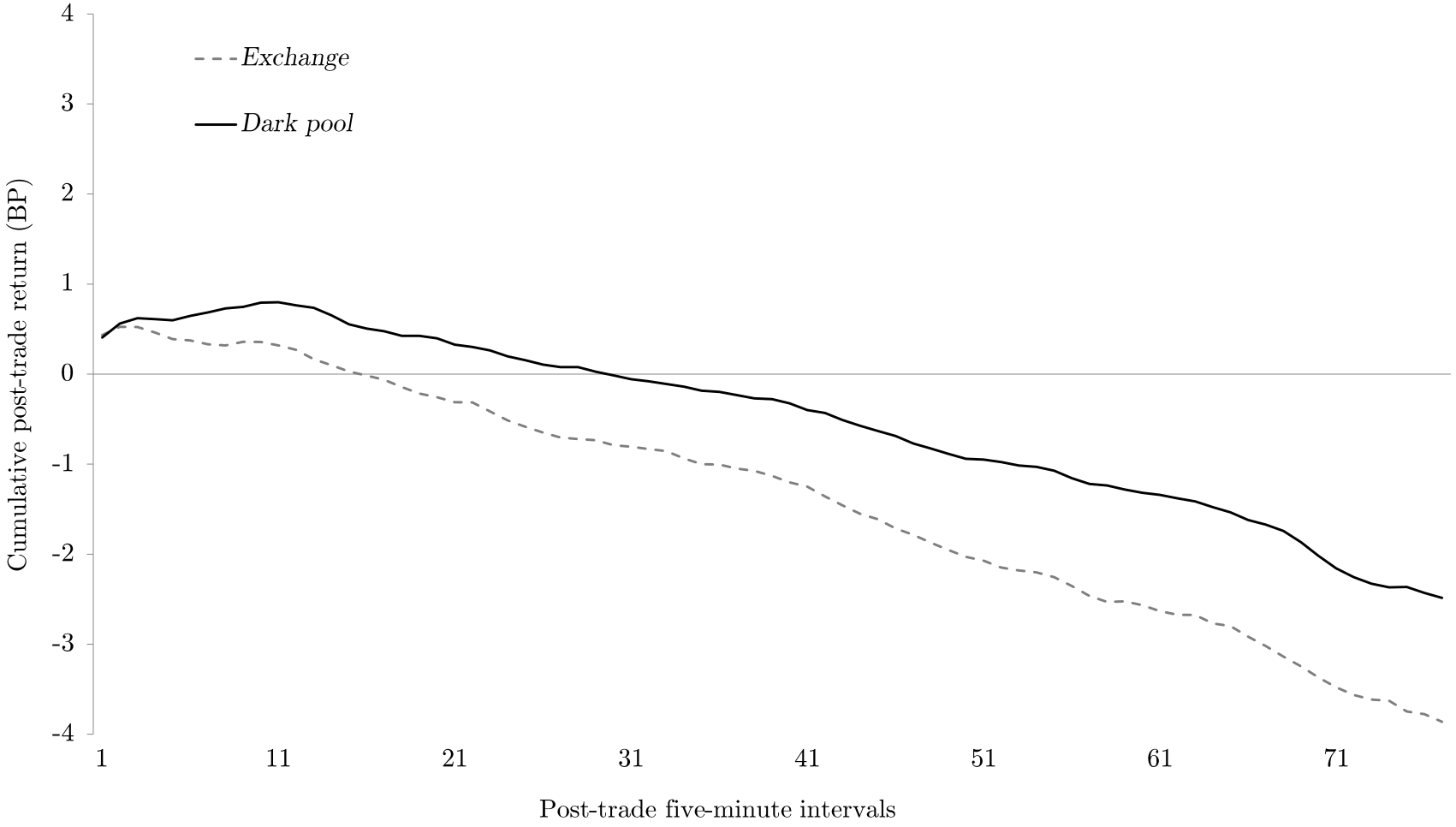

Figure 1: Average cumulative midquote returns after venue short sales. This figure presents average cumulative NBBO midquote returns (in basis points) after *exchange* (gray dashed line) and *dark pool* (black solid line) short sales. Returns are excess log-returns (de-meaned by the average return across all stocks over each horizon) and venue-stock-level dollar short sale volume is aggregated into five-minute intervals. The horizontal axis is the number of five-minute intervals following short sales and the vertical axis is the cumulative return of the short sales.

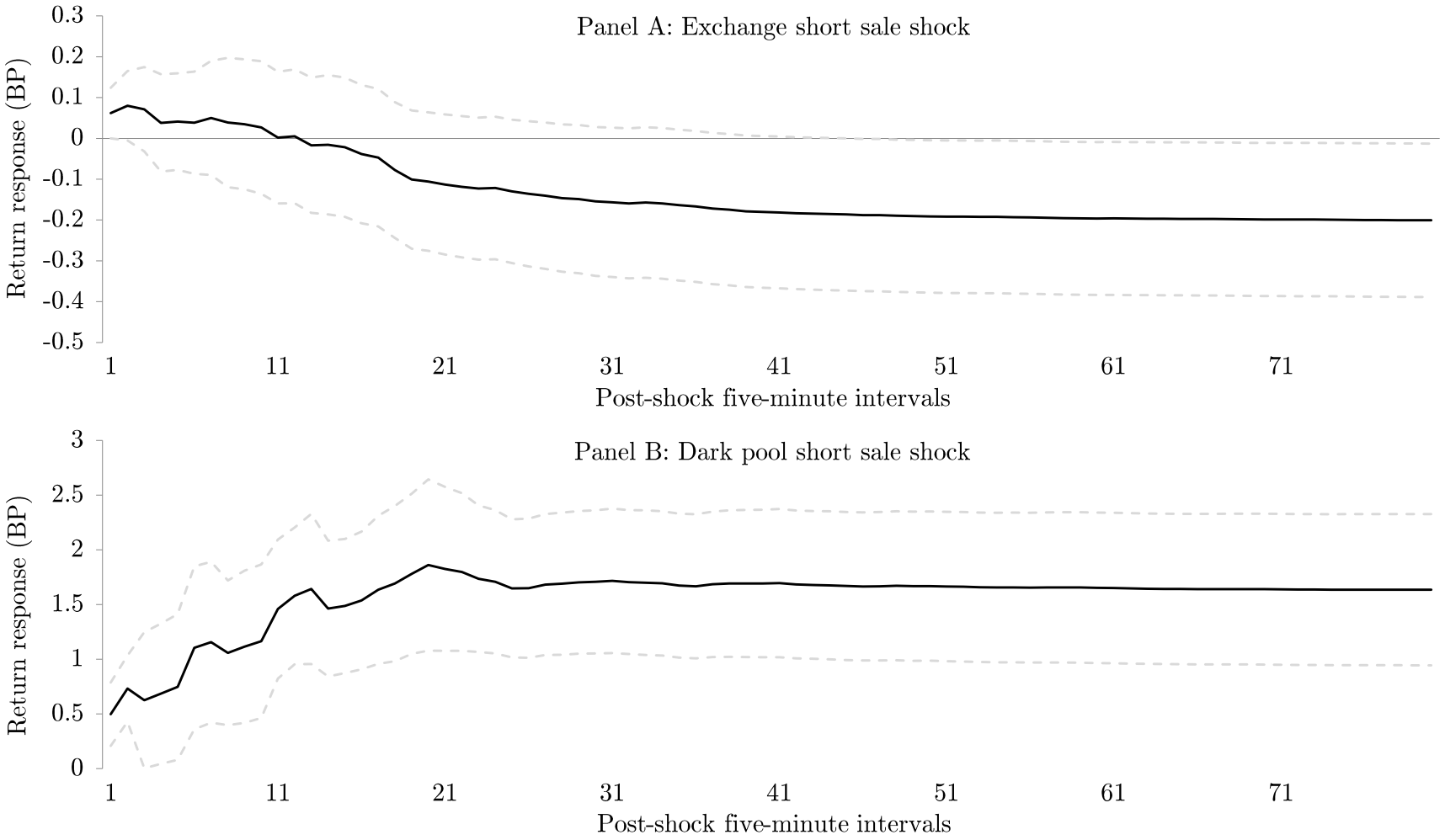

Figure 2: Impulse response of returns to short sale volume shocks. This figure presents equally weighted cumulative impulse response functions of NBBO midquote returns (in basis points) to *exchange* short sale (Panel A, black solid line) and *dark pool* short sale (Panel B, black solid line) shocks, respectively. Returns are excess log-returns (de-meaned by the average return across all stocks over each horizon) and venue-stock-level dollar short sale volume is aggregated into five-minute intervals. The horizontal axis measures the number of five-minute intervals following a short sale shock. The vertical axis measures cumulative return responses after short sale shocks. The magnitude of each short sale shock is set equal to that of a one standard deviation unanticipated exchange short sale shock. Gray dashed lines represent 90% confidence intervals.

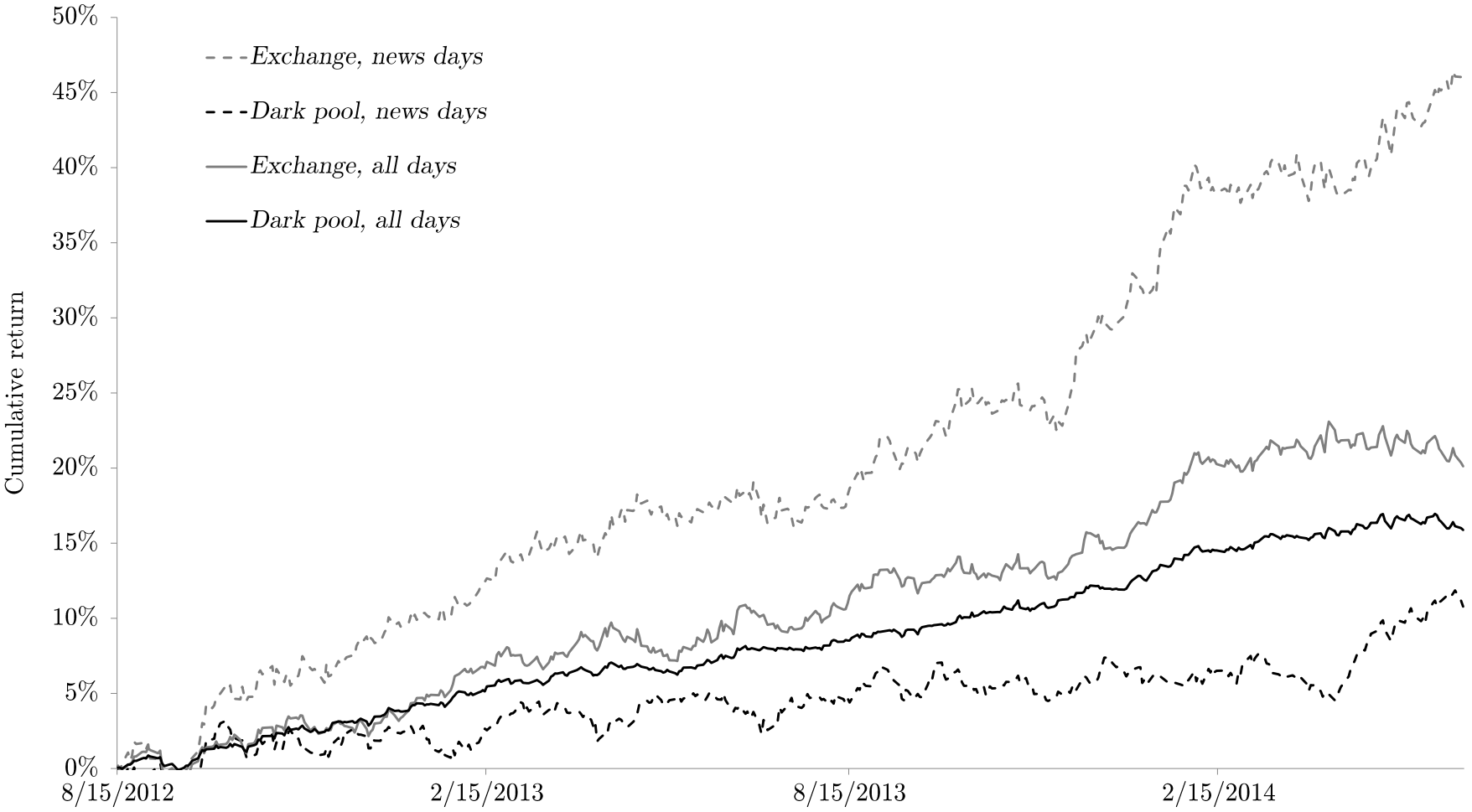

Figure 3: Cumulative long-short portfolio returns conditioning on venue short sale ratios and news events. This figure presents cumulative percentage returns from quintile long/short portfolios formed by conditioning on stock-day venue short sale ratios alone, *exchange, all days* (gray solid line) and *dark pool, all days* (black dashed line) and on venue short sale ratios the day prior to a corporate news release, *exchange, news days* (gray dashed line) and *dark pool, news days* (black dashed line). These equal-weighted portfolios are then held for 20 days. This process repeats each trading day, so that each trading day's portfolio return is an average of 20 different portfolios, with 1/20 of the portfolio rebalanced each day.