Short-selling before data breach

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Abstract

This study examines whether short sellers detect firm-level data breaches. Using proprietary daily lending data and unique data-breach data, we investigate whether short-selling anticipates corporate data breaches, and whether the short-selling ex-ante would benefit investors by improving market liquidity and price efficiency or cost investors by extracting rent from investors as they undertake the price. First, we document that the level of short-selling constraints when data breaches publicly revealed. Both borrowing costs and utilization fee jump. In addition, short interest increases. The results are robust using propensity score matching (PSM) techniques. Second, on a cross-sectional basis, our results show that the level of short-selling activities predict the cumulative abnormal returns (CARs) around data breaches. The results of event studies show the evidence that cumulative abnormal returns (CARs) are significant around firm-level data breaches. The CARs are also consistent across different types of data breach. Further, we test the market impact of the short selling. We find that short-selling activities improve market liquidity and market efficiency. The evidence is robust using different measures for market liquidity and price efficiency. Overall, our study provides strong evidence that short sellers exploit prior knowledge of data breaches and help improve overall market efficiency.

Keywords: informed trading, short-selling, data breach, cumulative abnormal returns, market liquidity and price efficiency

1. Introduction

In this study, we examine public-company announcements of data breaches and analyze how short sellers detect and respond to the events. We find that short sellers/arbitrageurs anticipate data breaches based on prior information advantage. In addition, the short selling predicts the cumulative abnormal returns around data breaches. While short sellers trade ahead of public investors, their trading activities actually facilitate price discovery and improve market efficiency. Using proprietary daily lending data and a novel dataset of corporate data breaches involving publicly traded companies, we find strong empirical evidence of significant market abnormalities in the equity lending market. The level of short selling loan fee, loan utilization rate, and short interest all increase around the event date. The contribution of our study is three-fold. First, our study contributes to a growing literature in finance and accounting studies on data breaches and cyberattacks. Second, our study contributes to a literature on informed trading in securities lending markets. Making use of proprietary daily lending data assists us to identify trading abnormalities days and weeks leading up to data breaches. The unique focus allows us to investigate the underlying market effects. Finally, our study facilities the discussion whether short selling facilities price discovery and improve market efficiency. We provide evidence to support the proposition in the setting of data breaches.

Our analysis proceeds as follows. Section 2 discusses related literature and develops testing hypotheses. Section 3 describes the sample, data sources and descriptive statistics. Section 4 presents main empirical results. Section 5 conducts robust tests and sensitivity analyses. Section 6 concludes.

2. literature review and hypotheses development

2.1. Literature Review

Our study is related to three major strands of academic literature. The first strand is literature on data breaches and cyberattacks in finance and accounting. So far, vast majority of existing studies in data breaches are focus on legal and technical aspects. For example, from legal perspective, frequently asked research questions include the harms and consequences of data breaches, mitigation of the cases, and improvement of data breach laws. In addition, technical aspect of data breaches tends to center on the information system risk and incident prevention. Surprisingly however, few studies have attempted to examine the market activity around data breaches, particularly how market participants interact with each other in the event of data breaches. Our study attempts to fill the void by investigating the role of short sellers. Consensus tends to agree that, unlike other investors, short sellers are usually sophisticated and well informed. The data breach events provide an ideal setting for us to examine how short sellers interact with the events. For example, Bianchi and Tosun (2019) studies the short-term and long-term market effect from the first-time data breaches. They find that the daily excess returns drop, trading volume increases, and liquidity deteriorates upon data breaches within short event windows. In the long term, data breaches affect firms polices including dividend payouts, R&D expenses, and CEO pay. In the same vein, Akey, Lewellen, and Liskovich (2018) finds that negative effect of data breaches in both short-term and long-term. Interestingly, those firms suffering from data breaches in fact increase investment in corporate social responsibilities (CSR) investments in respond to a negative reputation shock. By the same token, Amir, Levi, and Livne (2018) studies firms incentive on cyber-attacks disclosure. They find that withheld cyber-attacks are associated with a decline of approximately 3.6% in equity values in the month the attack is discovered, and disclosed attacks with a substantially lower decline of 0.7%. They provide evidence that managers tend to withhold information on the more severe attacks. Lin, Sapp,

Ulmer, and Parsa (2018) studies insider trading within the data breach firms. They find statistically significant evidence of opportunistic insider trading, with insiders save the cost due to their timely selling in the three months prior to the announcement of a cybersecurity breach. Interestingly, they estimate that the bulk of this opportunistic trading tends to occur 55 to 72 days before the public announcement. One of the closest studies is from Mitts and Talley (2018). Their study finds evidence that arbitrageurs can and do obtain early notice of impending breach disclosures, and that they are able to profit from such information. They employ at the money (ATM) equity put options on the common stock of the data-breach firms in the main tests. They study, however, does not directly test the market liquidity and price efficiency after the data breach events. Our study complements their study and sheds addition light on the role short sellers plays in overall market efficiency.

The second strand of literature that our study relates to is short selling surrounding corporate events. In microstructure models (Kyle, 1985; Glosten and Milgrom, 1985), informed traders are privately informed about the securitys intrinsic value and act on the prior knowledge before information is reveal publicly. We posit that, without violating any securities laws and insider regulations, in the event of data breach, informed traders are able to gain information advantage and trade more efficient than public. A large literature has investigated short-selling activities surrounding a spectrum of major corporate events. For example, Berkman, McKenzie, and Verwijmeren (2016) find that pre-announcement short sellers are able to predict announcement day returns for firms private placement deals. The effects are especially strong when hedge funds are involved and when the number of buyers is high. Liu and Wu (2014) and Mitchell, Pulvino, and Stafford (2004) both examine the short-selling activity around firm mergers. They find similar evidence of arbitrage short-selling around merger announcement. Massoud, Nandy, Saunders, and Song (2011) find evidence that short-selling among hedge fund borrowers prior to public announcements of both loan originations and loan amendments. Christophe, Ferri, and Hsieh (2010) find that abnormal levels of short-selling within the three days before analyst downgrades are publicly

announced and that the pre-announcement abnormal short-selling is significantly related to the subsequent share price reaction to the downgrades. Henry and Koski (2010) show that, around seasoned equity offerings (SEOs) issue dates, higher levels of pre-issue short-selling are significantly related to larger issue discounts for non-shelf-registered offerings. KARPOFF and LOU (2010) find that abnormal short interest increases steadily in the 19 months before the misrepresentation is publicly revealed, particularly when the misconduct is severe. Their study indicates that short sellers anticipate the eventual discovery and severity of financial misconduct. LASSER, WANG, and ZHANG (2010) and Christophe, Ferri, and Angel (2004) both find evidence of abnormal short-selling in pre-earnings announcement. Data breach cases are similar yet different from many of those corporate events. On one hand, data breaches are firm-level events. Based on market efficient hypotheses, market participants are able to access the information at the same time while the cases are revealed to the market. On the other hand, however, data breaches do not come from firm decisions. In addition, the relative rarity makes these cases more independent and idiosyncratic. The theoretical foundation and empirical results from other studies have motivated us to develop our hypothesis. To our best knowledge, we are among the first to examine the short-selling around data breach. Fortunately, the proprietary daily lending data allows us to conduct powerful tests in this particular setting.

Our study also relates to the studies on price discovery and market efficiency. Boehmer and Wu (2013) find that stock prices are more accurate when short sellers are more active. Intraday informational efficiency of prices improves with greater shorting flow.

2.2. Main hypotheses

H1: Short-selling activity increases around data breaches.

H2: Short-selling activity predicts cumulative abnormal returns around data breaches.

H3: short-selling facilitates price discovery and improves market liquidity and market efficiency.

3. Data and results

3.1. Data breaches data

We obtain the data of announced corporate data breaches from Privacy Rights Clearing house (PRC) over the period 2005 to 2018. PRC provides the data-breach announcement date, the name of the firm, the type of data breach and the description of events. The types of data breach include CARD (Payment Card Fraud), HACK (Hacking or Malware), INSD (Insider), PHYS (Physical Loss), PORT (Portable Device), STAT (Stationary Device), DISC (Unintended Disclosure) and UNKN (Unknown). PRC reported 8804 data breaches made public since 2005. After ruling out private firms and matching with daily short-selling data, we finally have 704 data-breach events and 486 unique firm.

3.2. Daily short-selling data

We use a proprietary dataset of equity lending supply and loans from Markit Securities Finance Buy Side Analytics Data Feed. Markit collects lending information from many of the largest custodians (125 of them) and prime brokers (32 of them) in the securities lending industry. The data cover more than 85% of the securities lending market. The complete daily security-level data is available starting from July 2006. The equity lending database includes several variables from the equity loan market. The primary interest are shares borrowed (Short Interest), the active quantity of shares available to be borrowed (Loan Supply), the active utilization rate (Utilization), the weighted average loan fee across all shares currently on loan (Loan Fee).

3.3. Firm level data

We obtain daily stock prices and volumes from CRSP, annual fundamentals data from COMPUSTAT, quarterly institutional ownership data from Thomson Reuters Institutional (13f). The fundamental measures include Return on Asset (ROA), total debt divided by total

asset (Leverage), firm size (Size), book-to-market ratio (BM). The daily trading measure is stock trading volume (VOL) and a dummy variable for NASDAQ stocks (NASDAQ). Ownership is the total number of quarterly shares held by institutions.

3.4. Measure of market liquidity and price efficiency

We use various measures to examine the market liquidity and price efficiency. The first measure is firm-level liquidity using two proxies. The second measure is based on short selling patterns lending supply and loan fee. The third measure relies on option trading dynamics.

3.5. Descriptive statistics

Table 1 reports the detailed descriptive statistics of some key variables from the study. The statistics are based on the (-30, -1) event window. ABSS measures the abnormal short-selling. The mean and median of ABSS are 0.08 and -0.13, respectively. The opposite sign of mean and median value for ABSS is a little surprising, the distribution of which seems to be quite skewed. ABVOL measures the abnormal trading volume. Not surprisingly, the mean and median are 0.09 and 0.04, respectively. DCBS is Daily Cost of Borrow Score - a relative measure of borrow cost constructed by Markit. It ranges from 1 (least expensive to borrow) to 10 (most expensive to borrow). The mean and median is 1.24 and 1, respectively. Utilization is the value of assets on loan from beneficial owners (beneficial owner value on loan) divided by the total lendable assets (beneficial owner inventory value), expressed as a percentage. Utilization measures the relationship between demand and supply and provides an insight into how the interplay of demand and supply affects stock price movements. The calculation is short value divided by short supply. The mean of utilization is 14.66% and 6.11%, respectively. Loan fee is the annualized borrowing fee. Rebate is the annualized rebate fee. The mean and median for short interest are 0.03 and 0.04, respectively. The reminder of the table is based on firm-level characteristics. ROA measures the return on

assets indicating the profitability of the firms. The mean and median is 0.05 and 0.04, respectively. We use natural log of market value for size measure. Leverage measures the sample firms' debt level. BM reports book-to-market ratio. Nasdaq is a dummy variable. Nasdaq equals to one if the firm is listed on Nasdaq exchange and zero otherwise. VOL measures the average trading volume. Ownership measures the institutional ownership.

Table 2 reports the Pearson pairwise correlation among short selling related variables. We can observe a few interesting patterns in the table. As expected, there is a strong correlation between the DCBS and loan fees, rebate (negative sign), short interest, utilization (all P value ¡.0001). As mentioned, Daily Cost of Borrow Score (DCBS) is a relative measure of borrow cost constructed by Markit. It ranges from 1 (least expensive to borrow) to 10 (most expensive to borrow). In addition, short interest is positively associated with utilization and abnormal short volume (both P value <.0001). Also, while abnormal short selling does not appear to strongly associate with DCBS, fee, and rebate, it is positively associated with utilization and abnormal short volume (both P value <.0001). Overall, our statistics match the patterns previously documented in the literature.

4. Main empirical results

Methodologically, we implement an event study, a set of multivariate regressions analyses, as well as a set of Difference-in-Difference (DiD) analyses. Using event study, we present the significant negative cumulative abnormal returns (CARs) around the data breach events. The negative CARs tend to be consistent across various types of data breaches. In addition, the results from multivariate regressions provide direct evidence that short sellers can and do predict the event day negative returns based on their prior knowledge of potential incidents. Further, the DiD approach identifies targeted firms and control firms and allows us to drill down to the trading activities for data breach firms. It assists us further disentangle the interaction between short sellers and data breach firms.

4.1. Characteristics of short selling surrounding data breaches

Figure 1 presents the short selling activities around data breach event dates. Figure 1a plots the LendableValue and ValueOnLoan amount. To provide the dynamics of short supply for the firms, we rely on the field of LendableValue from Markit, which measures the value of stock inventory, available to lend. This lendable supply captures the shares made available for lending by investors with long positions in the stock. To estimate short value, we rely on the field of ValueOnLoan from Markit, which measures the total value of stock on loan/borrowed. While, in reality, equity loans are borrowed for different purposes including short-selling, convertible bond arbitrage and dividend-tax arbitrage strategies (see Aggarwal et al. 2015), vast majority of the stock on loans are undertaken as a tool of shorting. Thus, equity value on loan is a good measure of short-selling activity.

Figure 1b plots the short selling Utilization rate. Taken together, loan utilization rate, daily borrowing costs (DCBS) and loan fee provide insight to the short sale lending. Utilization measures the value of assets on loan from lenders divided by the total lendable value. In other words, utilization captures the percentage of lendable shares that are actually on loan. Utilization measures the relationship between demand and supply and provides an insight into how the interplay of demand and supply affects stock price movements. It is calculated as: Utilization = LenderValueOnLoan / LendableValue.

Figure 1c plots the Indicative Fee and Indicative Rebate, respectively. Loan fee/Indicative Fee provides a direct measure of the expensiveness of borrowing shares. Markit defines loan fee as expected borrow cost, in fee terms, for a hedge fund on a given day. The calculation uses both borrow costs between agent lenders and prime brokers as well as rates from hedge funds to produce an indication of the current market rate. Loan fee is not necessarily the actual rate but rather an indication of the estimated standard market cost. Loan fees are set in two different ways, depending on the collateral type. Since cash collateral is most dominant form of collateral in the U.S. Market, the loan fee is defined as the difference between the risk-free interest rate and rebate rate. The rebate rate is the portion of interest rate on the

collateral the borrower receives. Rebate rate received by the borrower = general collateral rate lending/loan fee). Under typical circumstances, loan fee is inversely associated rebate rate.

Figure 1d plots DCBS score. DCBS is assigned for each firm on a daily basis based on the lending fees from the previous seven days.

We further examine the short selling activities during several windows including (-5, -1), (-1, 1), (1, 5), (-10, -1), (-20, -1), (1, 10), and (1, 20). Table 3 summarizes the results. Panel A reports the mean value and Panel B reports the median value. Following Henry and Koski (2010), ABSS(t) = SSVOL(t) / AVESS - 1, and ABVOL(t) = VOL(t) / AVEVOL - 1. The benchmark period is from day -70 to day -30 relative to the data-breach date. ShortInterest is the number of shares short from Markit divided by shares outstanding from the CRSP (Muravyev, Pearson, and Pollet, 2018). What seems to be puzzling to us is that, while DCBS, utilization, loan fee, and rebate all tend to be much higher days leading to the data breach, two relative measures ABSS and ABVOL tend to be much higher post event date.

In order to investigate what drives the results, we further decompose the data breach cases into 8 different types. Table 4 reports the results. The categories of data breaches include CARD (Payment Card Fraud), HACK (Hacking or Malware), INSD (Insider), PHYS (Physical Loss), PORT (Portable Device), STAT (Stationary Device), DISC (Unintended Disclosure) and UNKN (Unknown).

To make more sense of short-selling activities, we employ propensity-score matching (PSM) method to ensure that treatment and control firms are as similar as possible. Following Mitts and Talley (2018), we employ PSM method to select control firms by one-to-one matching on 1) 4-digit SIC industry code (i.e. an indicator for each), 2) log of market capitalization, 3)log of total assets, 4) log of net income, and 5) log of total liability. ATTACK is equal to 1 for attacked firms and equal to 0 for control firms; PRE is equal to one prior to corporate data-breach announcements and equal to zero after the announcement dates. The daily short-selling measures are from pre-30 day to post-30 day relative to the announcement

dates. Table 5 shows the results of Difference-in-Difference (DiD) regression results. Panel A shows the results of ValueOnLoan, LendableValue, DCBS, Fee, and Rebate. Panel B shows the results of Utilization, ShortInterest, ABSS, and ABVOL.

4.2. Is short-selling predictive of cumulative abnormal returns?

We conduct a host of event studies to examine the Cumulative Abnormal returns (CAR) surrounding a data breach case. Table 6 reports the CARs based on the CRSP value-weighted returns. N-P Ratio is the number of negative CARs versus the number of positive CARs.

We conduct multivariate regression analysis. Table 7 reports the results. Dependent variable is the CARs of window (0,+1d), The measures of short selling activity include ABSS, ABVOL, DCBS, Utilisation, Fee, Rebate and ShortInterest under the window (-10d,-1d). The control variables are return on asset (ROA), firm size (Size), total debt to total asset (Leverage), book-to-market ratio (BM), trading volume (VOL), institutional ownership (Ownership) and the dummy variable for NASDAQ stocks (NASDAQ).

4.3. Market activities, liquidity and price efficiency

To measure stock price efficiency after data breach, we use three measures. The first measure is firm-level liquidity using two proxies. The second measure is based on short selling patterns lending supply and loan fee. The third measure relies on option trading dynamics. Similar to Gormley, Kaplan, and Verma (2019), we use two proxies for firm-level liquidity including the average ratio of the daily absolute return to the dollar trading volume on that day (commonly known as the Amihud (2002) illiquidity measure) and closing bid-ask spreads scaled by share price. Consistent with Saffi and Sigurdsson (2011), lending supply has a significant impact on efficiency and on the distribution of returns. Stocks with limited lending supply and high loan fees are associated with low price efficiency. We find that, after data breach, there is an increase in lending supply leads to both an increase in price efficiency and decrease in skewness (daily return distribution and standard deviation) and a

lower frequency of extreme negative returns. Our pricing efficiency measures adopted from Saffi and Sigurdsson (2011) are based on general stock return characteristics, such as return standard deviation (Stdev), skewness (Skew), and kurtosis (Kurt).

5. Robust tests

5.1. Additional market efficiency measures

We use additional measures for market liquidity. We follow Buti et al. (2011) and Huszr and Prado (2019). These measures include daily average high and low price spread (HLspread), bid-ask spread (BAspread), and the natural logarithm of the high and low price spread and the bid-ask spread (e.g., LogBAspread and LogHLspread).

5.2. Interactions between public news, firm events, and short sellers return predictability

Following Boehmer, Duong, and Huszr (2018), using news data from Thomson Reuters News Analytics, we find that short sellers are skilled at processing public information contained in news, consistent with Engelberg, Reed, and Ringgenberg (2012). However, they also trade on return-predictive private information that goes beyond public information.

6. Conclusion

This study examines whether short sellers detect firm-level data breaches. Using proprietary daily lending data and unique data breach data, we investigate whether short-selling anticipates corporate data breaches, and whether the short-selling ex-ante would benefit investors by improving market liquidity and price efficiency or cost investors by extracting rent from investors as they undertake the price. First, we document that the level of short-selling constraints when data breaches publicly revealed. Both borrowing costs and utilization fee

jump. In addition, short interest increases. Second, on a cross-sectional basis, our results show that the level of short-selling activities predict the cumulative abnormal returns around data breaches. The results of event studies show the evidence that cumulative abnormal returns (CARs) are significant around firm-level data breaches. The CARs are also consistent across different types of data breach. Further, we test the market impact of the short selling. We find that short-selling activities improves market liquidity and price efficiency. The evidence is robust using different measures for market liquidity and price efficiency. Overall, our study provides strong evidence that short sellers exploit prior knowledge of data breaches and help improve market efficiency. Our study is subject to a few caveats. One caveat is that we cannot directly identify the channels that short sellers obtain the private information of subsequent data breaches. Further research needs to discuss the informed-trading channels and mechanisms. The other caveat is that we control for the size and types of data breach cases, we cannot quantify the severity of the case, especially non-monetary and reputational consequences. Its a difficult task given the uniqueness of each case and firm characteristics.

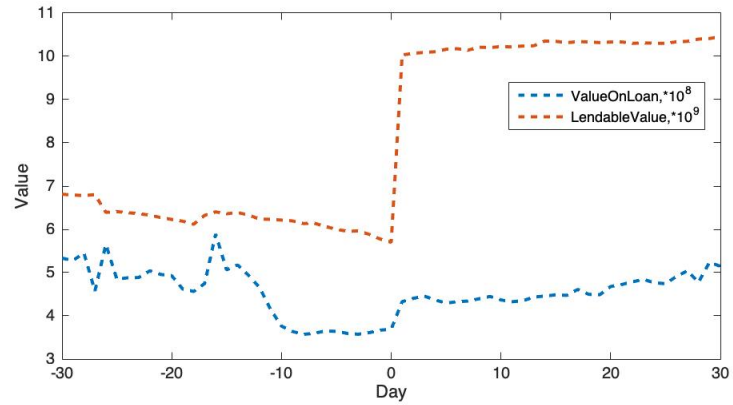
Table 1: Summary Statistics. ABSS is abnormal short selling; ABVOL is abnormal stock trading volume; DCBS is daily cost of borrow score; Utilisation is marked value of assets on loan from beneficial owners divided by the total lendable assets, expressed as a percentage; Fee is annualized loan fee; Rebate is annualized rebate fee; and ShortInterest is the average short supply value . ABSS, ABVOL, DCBS, Utilisation, Fee, Rebate and ShortInterest are under the window (-30d,-1d). Other relevant firm-level variables include ROA (return on asset), firm size (Size), total liabilities to total assets (Leverage), book-to-market ratio (BM), a dummy variable (NASDAQ), stock trading volume (VOL), and institutional ownership (Ownership).

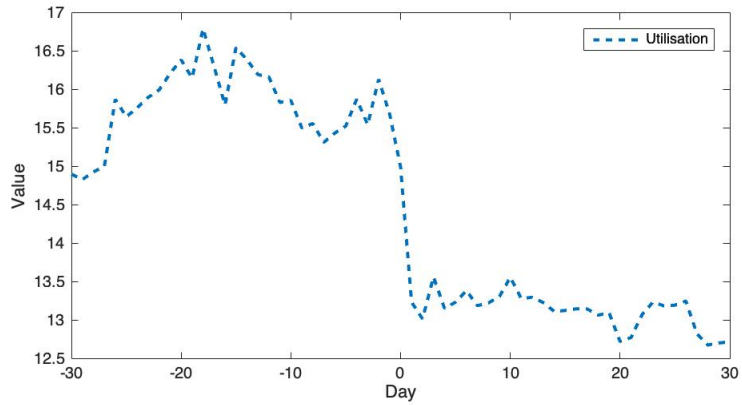
Variable	N	Mean	S.D.	Min	0.25	Mdn	0.75	Max
ABSS	440	0.08	0.88	-0.94	-0.36	-0.13	0.21	6.1
ABVOL	437	0.09	0.42	-0.86	-0.1	0.04	0.17	1.93
DCBS	440	1.24	1.05	1	1	1	1	10
Utilisation	438	14.66	19.1	0	2.14	6.11	19.81	93.07
Fee	440	0.01	0.05	0	0	0	0	0.59
Rebate	440	0.03	0.06	-0.59	0.05	0.05	0.05	0.05
ShortInterest	437	0.03	0.04	0	0	0.01	0.04	0.26
ROA	440	0.05	0.08	-0.63	0.01	0.04	0.08	0.87
Size	440	9.66	2.39	2.01	7.95	9.56	11.31	14.75
Leverage	436	1.91	1.39	0.94	1.16	1.57	1.98	16.13
BM	402	0.48	0.35	0.01	0.22	0.4	0.63	2.42
NASDAQ	440	0.32	0.47	0	0	0	1	1
VOL	440	13.13	50.56	0	0.89	2.65	8.6	638.71
Ownership	421	789.96	1311.33	0.03	62.86	240.51	735.35	6411.73

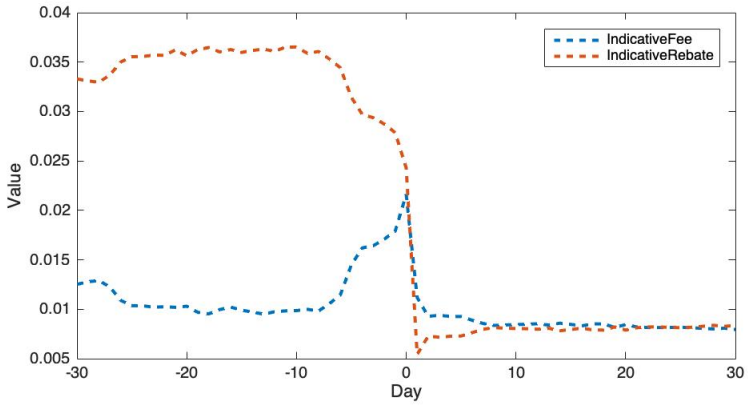
Table 2: Correlation. This table presents the Pearson Correlation among the measures of short selling activities. DCBS is daily cost of borrow score; Fee is annualized loan fee; Rebate is annualized rebate fee; ABSS is abnormal short selling; ShortInterest is the average short supply value; Utilisation is marked value of assets on loan from beneficial owners divided by the total lendable assets, expressed as a percentage; and ABVOL is abnormal stock trading volume.

	DCBS	Fee	Rebate	ShortInterest	ABSS	Utilisation	ABVOL
DCBS	1						
Fee	0.7996	1					
	(<.0001)						
Rebate	-0.7340	-0.8875	1				
	(<.0001)	(<.0001)					
ABSS	-0.0068	-0.0049	-0.0042	1			
	(0.2241)	(0.3788)	(0.4481)				
ShortInterest	0.2220	0.1566	-0.1423	0.0356	1		
	(<.0001)	(<.0001)	(<.0001)	(<.0001)			
Utilisation	0.5279	0.3658	-0.3110	0.0166	0.7019	1	
	(<.0001)	(<.0001)	(<.0001)	(0.0031)	(<.0001)		
ABVOL	-0.0016	-0.0063	-0.0655	0.2551	0.0331	0.0095	1
	(0.7783)	(0.2707)	(<.0001)	(<.0001)	(<.0001)	(0.0968)	

Fig. 1. Characteristics of short sellings. The short-selling activities include the marked value of assets on loan from beneficial owners (ValueOnLoan) from a, the total lendable assets (LendableValue) from a, Utilisation from b, the loan fee (IndicativeFee) from c, the rebate fee (IndicativeRebate) from c, and daily cost of borrow score (DCBS) from d.







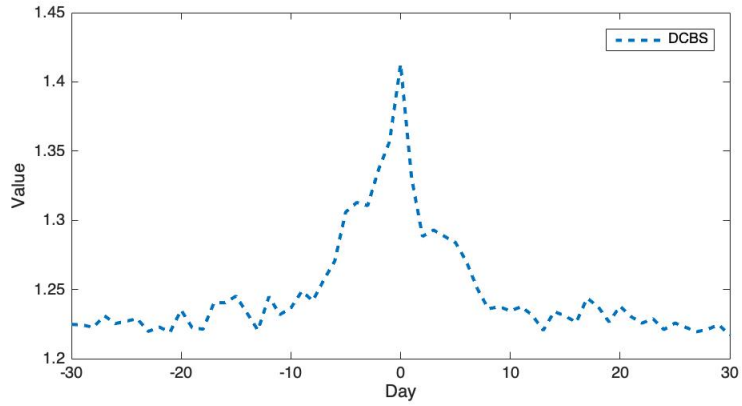


Table 3: Short selling activity around data-breach events. This table summarize measures of short selling activity for variance windows around the data-breach event date. Following Henry and Koski (2010), $ABSS_t = \frac{SSVOL_t}{AVESS} - 1$, $ABVOL_t = \frac{VOL_t}{AVEVOL} - 1$. The benchmark period is from day -70 to day -30 relative to the data-breach date. $ShortInterest$ is the number of shares short from Markit divided by shares outstanding from the CRSP (Muravyev, Pearson and Pollet, 2018).

Panel A: Mean							
	(-5,-1)	(-1,1)	(1,5)	(-10,-1)	(-20,-1)	(1,10)	(1,20)
DCBS	1.279***	1.302***	1.192***	1.246***	1.218***	1.184***	1.182***
	(24.96)	(29.92)	(32.91)	(27.00)	(28.27)	(33.67)	(34.07)
Utilisation	15.842***	14.453***	12.230***	16.253***	16.761***	12.271***	12.433***
	(17.62)	(20.17)	(15.19)	(18.17)	(18.37)	(15.39)	(15.87)
Fee	1.62%***	1.61%***	0.77%***	1.30%***	1.11%***	0.75%***	0.76%***
	(4.06)	(5.17)	(8.46)	(4.92)	(5.58)	(8.62)	(8.65)
Rebate	2.99%***	1.91%***	0.52%***	3.29%***	3.45%***	0.53%***	0.50%***
	(6.99)	(5.67)	(4.22)	(11.11)	(14.92)	(4.41)	(4.24)
ShortInterest	3.03%***	3.06%***	3.60%***	3.03%***	3.10%***	3.60%***	3.58%***
	(14.47)	(19.64)	(15.08)	(17.24)	(18.20)	(15.25)	(15.57)
ABSS	0.094	1.674***	4.759***	0.104*	0.168***	4.770***	4.599***
	(1.51)	(3.03)	(2.93)	(1.77)	(2.91)	(2.92)	(2.98)
ABVOL	0.203***	0.698***	1.642***	0.253***	0.170***	1.656***	1.590***
	(7.31)	(7.34)	(6.10)	(8.77)	(7.70)	(5.94)	(6.19)
Panel B: Median							
	(-5,-1)	(-1,1)	(1,5)	(-10,-1)	(-20,-1)	(1,10)	(1,20)
DCBS	1.276***	1.319***	1.194***	1.236***	1.205***	1.186***	1.185***
	(24.65)	(23.93)	(31.98)	(25.66)	(27.71)	(32.97)	(32.65)
Utilisation	15.548***	14.760***	12.135***	15.343***	15.695***	11.990***	12.032***
	(17.34)	(17.82)	(14.99)	(17.34)	(17.00)	(14.87)	(14.94)
Fee	1.66%***	1.79%***	0.77%***	1.23%***	0.94%***	0.76%***	0.76%***
	(3.93)	(4.00)	(8.37)	(4.71)	(5.77)	(8.37)	(8.32)
Rebate	2.96%***	2.79%***	0.52%***	3.39%***	3.68%***	0.53%***	0.53%***
	(6.60)	(5.87)	(4.16)	(11.69)	(18.89)	(4.32)	(4.30)
ShortInterest	2.99%***	2.73%***	3.59%***	2.82%***	2.86%***	3.59%***	3.61%***
	(14.36)	(16.97)	(14.99)	(16.99)	(16.73)	(15.05)	(15.22)
ABSS	0.076	0.228**	4.753***	0.059	0.047	4.800***	4.711***
	(1.23)	(2.33)	(2.94)	(1.03)	(0.85)	(2.92)	(3.02)
ABVOL	0.118***	0.143***	1.510***	0.045**	-0.022	1.413***	1.332***
	(4.98)	(4.04)	(5.56)	(2.37)	(-1.39)	(5.20)	(5.28)

Table 4: Short selling activity for different types of breach. The categories of data breaches include CARD (Payment Card Fraud), HACK (Hacking or Malware), INSD (Insider), PHYS (Physical Loss), PORT (Portable Device), STAT (Stationary Device), DISC (Unintended Disclosure) and UNKN (Unknown).

	CARD			DISC			HACK			INSD		
	(-5,-1)	(-1,+1)	(+1,+5)	(-5,-1)	(-1,+1)	(+1,+5)	(-5,-1)	(-1,+1)	(+1,+5)	(-5,-1)	(-1,+1)	(+1,+5)
DCBS	1.000	1.067***	1.175***	1.270***	1.345***	1.213***	1.513***	1.540***	1.310***	1.065***	1.092***	1.149***
	.	(20.57)	(8.89)	(10.39)	(11.21)	(16.10)	(11.87)	(14.65)	(14.03)	(22.70)	(26.86)	(17.36)
Utilisation	7.826***	9.813***	13.501***	14.035***	13.149***	11.054***	18.911***	16.554***	13.546***	13.015***	11.939***	9.978***
	(3.01)	(3.64)	(3.10)	(6.64)	(7.48)	(5.12)	(10.83)	(12.57)	(8.87)	(5.91)	(6.80)	(5.70)
Fee	0.42%***	0.49%***	0.65%***	1.94%	1.91%**	0.73%***	2.96%***	2.96%***	1.12%***	0.53%***	0.55%***	0.59%***
	(44.48)	(6.08)	(2.90)	(1.56)	(2.24)	(5.69)	(2.83)	(3.49)	(4.30)	(5.47)	(7.36)	(6.15)
Rebate	4.83%***	3.16%***	-0.24%	2.60%**	1.50%*	0.34%	1.10%	0.01%	-0.30%	4.50%***	3.14%***	0.36%
	(509.08)	(26.57)	-(0.69)	(1.98)	(1.64)	(1.60)	(0.99)	(0.02)	(-1.06)	(27.16)	(21.35)	(1.53)
ShortInterest	1.65%***	2.20%***	3.36%***	2.00%***	2.30%***	2.93%***	3.51%***	3.28%***	3.84%***	3.27%***	3.35%***	3.52%***
	(4.30)	(4.71)	(3.36)	(7.20)	(7.94)	(5.31)	(7.99)	(12.27)	(9.38)	(5.49)	(5.91)	(4.71)
ABSS	0.051	1.683**	4.832**	0.063	2.752	8.161	0.003	0.824***	2.291***	0.276	2.502	6.831
	(0.36)	(2.12)	(2.06)	(0.43)	(1.52)	(1.47)	(0.04)	(3.84)	(4.15)	(0.84)	(1.22)	(1.14)
ABVOL	0.360**	1.819	4.826*	0.119***	0.557***	1.208***	0.198***	0.580***	1.432***	0.042	0.968***	2.026**
	(2.38)	(1.55)	(1.72)	(2.63)	(3.96)	(3.82)	(4.04)	(4.55)	(3.05)	(0.67)	(2.95)	(2.51)
N	20	20	20	88	88	88	160	160	160	69	69	69

	PHYS			PORT			STAT			UNKN		
	(-5,-1)	(-1,+1)	(+1,+5)	(-5,-1)	(-1,+1)	(+1,+5)	(-5,-1)	(-1,+1)	(+1,+5)	(-5,-1)	(-1,+1)	(+1,+5)
DCBS	1.000	1.130***	1.227***	1.059***	1.081***	1.044***	1.813**	1.750**	1.531***	1.370***	1.244***	1.038***
	.	(18.25)	(8.40)	(28.01)	(28.63)	(25.60)	(2.23)	(2.49)	(3.08)	(9.00)	(12.95)	(42.98)
Utilisation	13.396***	15.726***	15.149***	15.118***	13.174***	10.888***	25.640***	23.872***	25.484***	17.076***	15.414***	11.644***
	(3.54)	(4.63)	(3.58)	(7.69)	(8.75)	(7.40)	(3.45)	(3.48)	(3.17)	(5.42)	(5.84)	(4.42)
Fee	0.41%***	0.64%***	0.81%**	0.49%***	0.55%***	0.48%***	2.64%	2.28%	1.57%	1.13%***	0.89%***	0.39%***
	(45.33)	(4.94)	(2.48)	(8.98)	(7.86)	(5.40)	(1.20)	(1.25)	(1.48)	(3.76)	(4.49)	(10.04)
Rebate	3.70%***	2.47%***	0.24%	4.74%***	3.89%***	2.26%***	2.61%	2.08%	0.92%	3.62%***	2.74%***	0.98%***
	(8.00)	(7.66)	(0.48)	(76.33)	(30.66)	(8.06)	(1.19)	(1.21)	(0.92)	(10.15)	(11.54)	(8.82)
ShortInterest	2.19%***	2.31%***	2.73%***	3.01%***	3.27%***	3.45%***	3.88%**	5.09%***	7.60%***	3.84%***	3.23%***	4.07%***
	(6.04)	(6.67)	(4.00)	(8.50)	(9.30)	(6.90)	(2.41)	(2.91)	(2.78)	(3.79)	(5.70)	(4.56)
ABSS	0.290	0.333*	0.722	0.099	0.379**	0.835**	-0.230**	0.151	0.930	0.152*	4.390	12.793
	(1.35)	(1.89)	(1.60)	(0.93)	(2.39)	(2.26)	(-2.18)	(0.46)	(1.16)	(1.64)	(1.27)	(1.30)
ABVOL	0.369	0.037	0.209	0.271***	0.425***	0.629***	0.315*	1.996	1.898*	0.313***	1.049***	3.490**
	(1.44)	(0.41)	(1.23)	(4.29)	(2.93)	(4.76)	(1.80)	(1.53)	(1.69)	(3.19)	(2.80)	(2.53)
N	23	23	23	86	86	86	8	8	8	52	52	52

Table 5: Difference-in-Difference Regressions. Following Mitts and Talley (2018), we employ PSM method to select control firms by one-to-one matching on 1) 4-digit SIC industry code (i.e. an indicator for each), 2) log of market capitalization, 3) log of total assets, 4) log of net income, and 5) log of total liability. ATTACK is equal to 1 for attacked firms and equal to 0 for control firms; PRE is equal to one prior to corporate data-breach announcements and equal to zero after the announcement dates. The daily short-selling measures are from pre-30 day to post-30 day relative to the announcement dates.

Panel A

	ValueOnLoan		LendableValue		DCBS		Fee		Rebate	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
ATTACK	0.216***	0.199***	7.802***	7.292***	-0.0707***	-0.0398***	-0.00163***	-0.000970***	0.00250***	0.00146***
	(17.81)	(15.77)	(40.75)	(43.07)	(-7.989)	(-4.217)	(-5.227)	(-2.787)	(6.648)	(3.538)
PRE	-0.0897***	-0.0833***	-3.549***	-3.432***	0.0124	0.0289***	0.000564*	0.000869**	0.0333***	0.0328***
	(-7.402)	(-6.493)	(-18.56)	(-19.94)	(1.401)	(3.005)	(1.808)	(2.452)	(88.48)	(78.04)
ATTACK*PRE	0.0926***	0.0636***	-3.098***	-3.571***	0.0754***	0.0679***	0.00272***	0.00270***	-0.00352***	-0.00299***
	(5.609)	(3.711)	(-11.91)	(-15.56)	(6.259)	(5.298)	(6.403)	(5.716)	(-6.868)	(-5.332)
ROA		0.338***		54.96***		0.0989		-0.0139***		0.0302***
		(3.479)		(42.04)		(1.361)		(-5.181)		(9.514)
SIZE		0.142***		3.990***		-0.0688***		-0.00158***		0.00178***
		(61.93)		(130.9)		(-40.24)		(-25.00)		(23.78)
Leverage		0.0673***		1.774***		0.0474***		0.000968***		-0.00268***
		(14.16)		(27.83)		(13.36)		(7.395)		(-17.25)
BM		-0.0662***		2.191***		0.0712***		-0.00149***		0.00134***
		(-4.368)		(10.84)		(6.242)		(-3.535)		(2.675)
Constant	0.562***	-0.799***	6.012***	-37.43***	1.033***	1.516***	0.00449***	0.0179***	0.0302***	0.0170***
	(22.82)	(-22.49)	(15.43)	(-78.71)	(57.48)	(57.09)	(7.085)	(18.25)	(39.54)	(14.68)
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj R-sqr	3.50%	13.00%	8.90%	39.30%	1.12%	6.66%	0.61%	2.97%	38.40%	33.60%
Observations	44,244	39,196	44,620	39,506	44,186	39,138	44,186	39,138	44,186	39,138

Panel B

	Utilisation		ShortInsterest		ABSS		ABVOL	
	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
ATTACK	-0.591***	-0.450***	8.26e-05	0.00412***	0.778***	1.029***	-1.099***	-1.176***
	(-27.19)	(-20.81)	(0.140)	(6.910)	(7.590)	(9.293)	(-23.30)	(-24.20)
PRE	0.583***	0.645***	-0.000282	-0.000504	-2.945***	-2.976***	-2.436***	-2.411***
	(26.46)	(28.87)	(-0.478)	(-0.832)	(-28.72)	(-26.40)	(-51.78)	(-49.04)
ATTACK*PRE	0.0486	-0.0396	-0.00380***	-0.00434***	-0.568***	-0.757***	1.368***	1.363***
	(1.629)	(-1.339)	(-4.751)	(-5.398)	(-4.063)	(-5.029)	(21.51)	(20.87)
ROA		-5.038***		-0.0866***		-11.63***		-5.578***
		(-30.07)		(-19.25)		(-13.63)		(-15.26)
SIZE		-0.302***		-0.00805***		-0.330***		0.201***
		(-75.73)		(-73.74)		(-16.42)		(22.76)
Leverage		-0.0131		-0.00112***		0.576***		0.204***
		(-1.608)		(-5.034)		(13.81)		(11.35)
BM		-0.157***		-0.000359		-2.104***		0.580***
		(-5.905)		(-0.504)		(-15.80)		(10.05)
Constant	1.839***	4.933***	0.0376***	0.118***	1.324***	4.462***	1.551***	-0.453***
	(41.28)	(80.63)	(31.84)	(71.04)	(6.350)	(14.30)	(16.46)	(-3.358)
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj R-sqr	11.90%	23.50%	2.67%	18.90%	7.21%	9.15%	6.49%	6.22%
Observations	43,397	38,405	41,556	36,842	44,244	39,196	41,815	37,067

t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6: Cumulative Abnormal returns (CAR) following a data breach under the windows, (0,+1d), (0,+5d) and (-1,+1d). This table reports the CARs based on the CRSP value-weighted average. N-P Ratio is the number of negative CARs versus the number of positive CARs. The categories of data breaches include CARD (Payment Card Fraud), HACK (Hacking or Malware), INSD (Insider), PHYS (Physical Loss), PORT (Portable Device), STAT (Stationary Device), DISC (Unintended Disclosure) and UNKN (Unknown).

Panel A: CARs	(0,+1)				(0,+5)				(-1,+1)			
	Mean	Median	N	N-P Ratio	Mean	Median	N	N-P Ratio	Mean	Median	N	N-P Ratio
Overall	-0.35%***	-0.18%	573	1.22	-0.46%**	-0.21%	573	1.15	-0.31%**	-0.30%	574	1.32
	(-2.59)				(-2.15)				(-2.06)			
Panel B: Type of Breach												
CARD	-1.34%	-0.44%	18	1.25	0.06%	0.53%	18	0.50	-0.95%	-0.17%	18	1.57
	(-1.60)				(0.05)				(-0.97)			
DISC	0.12%	-0.08%	96	1.18	0.09%	-0.49%	96	1.18	-0.24%	-0.41%	96	1.53
	(0.21)				(0.15)				(-0.40)			
HACK	-0.43%**	-0.11%	161	1.12	-0.67%	-0.03%	161	1.06	-0.46%*	-0.34%	161	1.27
	(-1.96)				(-1.33)				(-1.72)			
INSD	0.25%	0.15%	70	0.94	0.06%	0.18%	70	0.79	0.29%	0.12%	70	0.94
	(1.19)				(0.13)				(0.93)			
PHYS	-0.75%*	-0.31%	26	1.60	-0.29%	-0.20%	26	1.36	-1.02%**	-0.86%	26	2.25
	(-1.86)				(-0.44)				(-2.37)			
PORT	-0.39%**	-0.16%	129	1.26	-0.84%**	-0.50%	129	1.58	-0.15%	-0.16%	129	1.24
	(-2.11)				(-2.22)				(-0.75)			
STAT	-1.32%	-0.86%	13	1.60	-1.75%	-1.34%	13	1.60	-0.70%	-0.68%	14	1.80
	(-1.51)				(-1.41)				(-0.55)			
UNKN	-0.80%**	-0.66%	60	1.73	-0.55%	-0.38%	60	1.14	-0.50%	-0.34%	60	1.40
	(-2.09)				(-1.08)				(-1.21)			
Panel C: CARs	(-2,+1)				(-1,+2)				(-1,+3)			
	Mean	Median	N	N-P Ratio	Mean	Median	N	N-P Ratio	Mean	Median	N	N-P Ratio
Overall	-0.40%**	-0.32%	574	1.30	-0.26%	-0.22%	574	1.17	-0.31%	-0.23%	574	1.13
	(-2.31)				(-1.38)				(-1.48)			
Panel D: Type of Breach												
CARD	-1.45%	-0.63%	18	1.57	-0.06%	-0.60%	18	1.25	0.41%	-0.37%	18	1.57
	(-1.49)				(-0.07)				(0.29)			
DISC	-0.12%	-0.30%	96	1.23	-0.10%	-0.32%	96	1.23	-0.09%	-0.21%	96	1.09
	(-0.2)				(-0.17)				(-0.14)			
HACK	-0.46%	-0.51%	161	1.48	-0.37%	-0.04%	161	1.04	-0.52%	-0.11%	161	1.09
	(-1.48)				(-0.83)				(-1.10)			
INSD	-0.04%	-0.05%	70	1.06	0.35%	0.85%	70	0.75	0.29%	0.72%	70	0.75
	(-0.09)				(0.82)				(0.63)			
PHYS	-0.64%	-0.47%	26	1.17	-0.98%*	-0.45%	26	1.89	-1.00%	-0.83%	26	1.60
	(-0.98)				(-1.74)				(-1.51)			
PORT	-0.21%	-0.26%	129	1.30	-0.14%	-0.21%	129	1.19	-0.21%	-0.29%	129	1.15
	(-0.83)				(-0.58)				(-0.74)			
STAT	-0.79%	-0.12%	14	1.00	-1.41%	-0.54%	14	2.50	-0.99%	-0.38%	14	1.80
	(-0.64)				(-0.92)				(-0.56)			
UNKN	-0.96%**	-0.36%	60	1.31	-0.67%	-0.68%	60	1.73	-0.75%	-0.93%	60	1.40
	(-2.03)				(-1.54)				(-1.39)			

Table 7: Regression Analysis. Dependent variable is the CARs of window (0,+1d), The measures of short selling activity include ABSS, ABVOL, DCBS, Utilisation, Fee, Rebate and ShortInterest under the window (-10d,-1d). The control variables are return on asset (ROA), firm size (Size), total debt to total asset (Leverage), book-to-market ratio (BM), trading volume (VOL), institutional ownership (Ownership) and the dummy variable for NASDAQ stocks (NASDAQ).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
DCBS	-0.000673	-0.00243*										
	(-0.553)	(-1.686)										
Fee			-0.0417**	-0.0732***								
			(-2.014)	(-3.161)								
Rebate					0.0414**	0.0692***						
					(2.188)	(3.256)						
ABSS							-0.00108	-0.000441				
							(-0.788)	(-0.281)				
ShortInterest									0.0326	0.0730*		
									(0.917)	(1.873)		
Utilisation											-2.24e-06	0.000127
											(-0.0302)	(1.359)
ABVOL		-0.00330		-0.00318		-0.00316		-0.00403		-0.00420		-0.00485*
		(-1.242)		(-1.226)		(-1.218)		(-1.516)		(-1.614)		(-1.824)
ROA		0.00765		0.00159		-9.07e-05		0.0134		0.0172		0.0271
		(0.400)		(0.0836)		(-0.00476)		(0.709)		(0.910)		(1.205)
Size		0.000212		7.78e-05		0.000117		0.000528		0.000854		0.000767
		(0.192)		(0.0716)		(0.108)		(0.483)		(0.775)		(0.660)
Leverage		-0.000527		-0.000606		-0.000388		-0.000651		-0.000634		-0.000659
		(-0.438)		(-0.510)		(-0.326)		(-0.539)		(-0.529)		(-0.546)
BM		-0.00638		-0.00762		-0.00757		-0.00515		-0.00579		-0.00448
		(-1.250)		(-1.505)		(-1.498)		(-1.011)		(-1.144)		(-0.877)
VOL		-2.12e-05		-1.99e-05		-1.28e-05		-3.54e-05		-3.58e-05		-4.73e-05
		(-0.263)		(-0.250)		(-0.161)		(-0.440)		(-0.447)		(-0.582)
Ownership		-5.87e-07		-4.66e-07		-6.51e-07		-7.26e-07		-5.98e-07		-5.16e-07
		(-0.287)		(-0.231)		(-0.323)		(-0.353)		(-0.293)		(-0.251)
NASDAQ		0.00322		0.00216		0.00233		0.00347		0.00391		0.00324
		(0.897)		(0.602)		(0.654)		(0.962)		(1.090)		(0.894)
Constant	-0.00511	-0.00420	-0.00551	-0.00388	-0.00761	-0.00800	-0.00611	-0.0101	-0.00688	-0.0155	-0.00591	-0.0147
	(-0.660)	(-0.303)	(-0.725)	(-0.289)	(-0.997)	(-0.602)	(-0.800)	(-0.747)	(-0.895)	(-1.130)	(-0.771)	(-1.038)
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	431	370	431	370	431	370	431	370	428	370	428	368
Adj R-sqr	2.9%	5.8%	3.8%	7.7%	3.9%	7.9%	3.0%	5.0%	2.9%	6.0%	2.7%	5.6%

t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Appendix A. Definitions

Trading and Lending characteristics	**Definition**	**Source**
Cumulative Abnormal Return (CAR)	Market-adjusted cumulative abnormal return (CAR) in various windows around data breach event date	CRSP
ABSS	Abnormal short-selling in various windows around data breach event date	Markit and CRSP
ABVOL	Abnormal trading volume in various windows around data breach event date	CRSP
Utilization	Marked value of assets on loan from beneficial owners (beneficial owner value on loan) divided by the total lendable assets (beneficial owner inventory value), expressed as a percentage.	Markit
DCBS	Daily Cost of Borrow Score - a relative measure of borrow cost constructed by Markit. It ranges from 1 (least expensive to borrow) to 10 (most expensive to borrow)	Markit
Loan Fee	Annualized stock loan fee. This variable reflects the expected borrow cost.	Markit
Short Interest	Average short supply value	Markit and CRSP
Trading and Lending characteristics		
ROA	Return on assets, calculated as net income divided by total assets	Compustat
Leverage	Financial leverage, calculated as total debt divided by total assets	Compustat
Nasdaq	An indicator = 1 if the firm is listed on Nasdaq	CRSP
Firm size	Market value standardized by natural log	Compustat
BM	Book to market ratio	Compustat
VOL	Daily Trading volume	CRSP
Ownership	The quarterly data on institutional ownerships (before lockup expiration)	Thomson Reuters Institutional (13f)

References

Akey, P., Lewellen, S., Liskovich, I., 2018. Hacking Corporate Reputations. Working paper .

Amihud, Y., 2002. Illiquidity and stock returns: Cross-section and time-series effects. Journal of Financial Markets 5, 31–56.

Amir, E., Levi, S., Livne, T., 2018. Do firms underreport information on cyber-attacks? Evidence from capital markets. Review of Accounting Studies 1177–1206.

Berkman, H., McKenzie, M. D., Verwijmeren, P., 2016. Hole in the Wall: Informed Short Selling Ahead of Private Placements*. Review of Finance 21, 1047–1091.

Bianchi, D., Tosun, O. K., 2019. Cyber Attacks and Stock Market Activity ? Working Paper, University of Warwick .

Boehmer, E., Duong, T. X., Huszr, Z. R., 2018. Short covering trades. Journal of Financial and Quantitative Analysis 53, 723748.

Boehmer, E., Wu, J. J., 2013. Short Selling and the Price Discovery Process. The Review of Financial Studies 26, 287–322.

Christophe, S. E., Ferri, M. G., Angel, J. J., 2004. Short-selling prior to earnings announcements. The Journal of Finance 59, 1845–1876.

Christophe, S. E., Ferri, M. G., Hsieh, J., 2010. Informed trading before analyst downgrades: Evidence from short sellers. Journal of Financial Economics 95, 85–106.

Engelberg, J. E., Reed, A. V., Ringgenberg, M. C., 2012. How are shorts informed ? Short sellers , news , and information processing. Journal of Financial Economics 105, 260–278.

Glosten, L. R., Milgrom, P. R., 1985. Bid, ask and transaction prices in a specialist market with heterogeneously informed traders. Journal of Financial Economics 14, 71 – 100.

Gormley, T. A., Kaplan, Z., Verma, A., 2019. Can disclosure decrease price efficiency? Working paper .

Henry, T. R., Koski, J. L., 2010. Short Selling Around Seasoned Equity Offerings. The Review of Financial Studies 23, 4389–4418.

Huszr, Z. R., Prado, M. P., 2019. An analysis of over-the-counter and centralized stock lending markets. Journal of Financial Markets 43, 31–53.

KARPOFF, J. M., LOU, X., 2010. Short sellers and financial misconduct. The Journal of Finance 65, 1879–1913.

Kyle, A. S., 1985. Continuous auctions and insider trading. Econometrica 53, 1315–1335.

LASSER, D. J., WANG, X., ZHANG, Y., 2010. The effect of short selling on market reactions to earnings announcements*. Contemporary Accounting Research 27, 609–638.

Lin, Z., Sapp, T. R. A., Ulmer, J. R., Parsa, R., 2018. Insider Trading Ahead of Cyber Breach Announcements. Working Paper, Iowa State University .

Liu, T., Wu, J. J., 2014. Merger arbitrage short selling and price pressure. Journal of Corporate Finance 27, 36–54.

Massoud, N., Nandy, D., Saunders, A., Song, K., 2011. Do hedge funds trade on private information? Evidence from syndicated lending and short-selling . Journal of Financial Economics 99, 477–499.

Mitchell, M., Pulvino, T., Stafford, E., 2004. Price pressure around mergers. The Journal of Finance 59, 31–63.

Mitts, J., Talley, E. L., 2018. Informed Trading and Cybersecurity Breaches. Harvard Business Law Review, Forthcoming .

Muravyev, D., Pearson, N. D., Pollet, J. M., 2018. Understanding Returns to Short Selling Using Option-Implied Stock Borrowing Fees. Working paper, SSRN .

Saffi, P. A. C., Sigurdsson, K., 2011. Price Efficiency and Short Selling. The Review of Financial Studies 24, 821–852.