Informed Option Trading: Evidence from Data Breaches

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Abstract

This paper investigates the information content of options trading before data breach announcements. I document abnormal implied volatility (IV) skew in the days leading up to the announcements. This measure captures the relative expensiveness of put options and predicts the post-announcement returns of the stocks. The finding is robust to a placebo test and a propensity score matched sample. Moreover, the predictive power of IV skew is stronger when the option market is more liquid relative to the stock market, and when the underlying stock underperforms prior to the announcements. Overall, the results confirm the information content of data breach announcements and suggest the presence of informed option trading before such events.

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1 INTRODUCTION

Cybersecurity has emerged as a focal point of interest over the past decade, reflecting the investing public's reliance on the security and dependability of information and communication technologies, systems, and networks. A central manifestation of cybersecurity risk is the data breach, defined as the unauthorized access, disclosure, or theft of sensitive or confidential information. Such incidents may involve personal records, financial data, or intellectual property, and they impose significant operational and reputational costs on affected firms and their stakeholders. By 2023, the global average cost of a data breach reached $4.45 million, with the average cost in the United States escalating to $9.48 million—the highest globally [1]. These figures underscore the significant financial implications of data breaches and indicate the potential for notable market responses to cybersecurity incidents. In light of these issues, the Securities and Exchange Commission (SEC) provided interpretive guidance in February 2018 to public companies regarding the disclosure of cybersecurity risks and incidents [2]. By 2023, the SEC had implemented regulations mandating the disclosure of material cybersecurity incidents through Form 8-K, along with the periodic reporting of a registrant's cybersecurity risk management, strategy, and governance practices in annual reports.

Data breaches, as a form of realized cybersecurity risk, pose a significant negative impact on firms' equity value and shareholder wealth (Akey et al., 2023; Kamiya et al., 2021). On the other hand, unlike other material corporate events, data breaches are unscheduled and less predictable by public investors. Despite the importance and financial implications associated with data breaches, it remains to be answered whether there is informed trading before these events become public. Prior research reveals informed trading on cybersecurity events in the stock market (Lin et al., 2020b; Wang et al., 2022). However, there is a lack of evidence of whether there is informed trading in the option market around data breach announcements. Given the advantages of higher leverage and lower trading costs associated with options (Easley et al., 1998), it is plausible that informed traders might exploit their information advantage in the option market before the data breaches become public information.

To formally test for informed option trading prior to data breach announcements, I employ the implied volatility (IV) skew that measures the relative expensiveness of out-of-the-money puts to at-the-money calls (Xing et al., 2010). In essence, a higher IV skew indicates greater demand for put options, reflecting traders' negative views on

[1] Cost of Data Breach Report 2023, available at: https://www.ibm.com/reports/data-breach
[2] https://www.sec.gov/files/rules/interp/2018/33-10459.pdf

the underlying stock. Thus, if pre-announcement IV skew predicts post-announcement stock returns, it provides evidence of informed trading in the options market. The results show that abnormal IV skew one week before announcements significantly predicts cumulative abnormal returns around the event. Moreover, the predictive power is stronger when the stock has underperformed prior to the breach and when the options are relatively more liquid than the underlying stock.

One potential concern is that the predictive relation between IV skew and future stock returns may simply reflect the general patterns documented in prior studies. For instance, Bali and Murray (2013) find a significantly negative relation between IV skewness and subsequent stock returns. To address this concern, I conduct a placebo test by assigning pseudo announcement dates to the sample firms. This test shows that the relationship between abnormal IV skew and future abnormal stock returns does not exist in the placebo sample. For additional robustness, I also employ the Propensity Score Matching (PSM) method to pair sample firms making data breach announcements (treatment group) with control firms, matched on SIC code, market capitalization, total assets, leverage, and put option trading volume. In the pooled sample with both treatment firms and control firms, I find the predictability of abnormal IV skew only exists for the treatment firms.

This paper contributes to two strands of literature. First, it contributes to the literature on informed trading. Prior research has documented informed option trading ahead of major corporate events such as takeovers (Augustin et al., 2019; Chan et al., 2015), earnings announcements (Jin et al., 2012), share repurchases (Qing, 2016), auditor changes (Zhang, 2018a), and credit rating adjustments (Zhang, 2019), etc. I extend this line of literature by examining informed option trading in the context of data breach announcements. Unlike scheduled corporate events, data breaches are typically unpredictable and non-routine, reducing the role of pre-event rumors and market anticipation. This setting therefore provides a cleaner environment to study whether option traders exploit private information, highlighting the materiality of data breaches as an emerging corporate event with financial significance. Second, this paper contributes to the growing literature on cybersecurity and financial markets. Prior studies have shown evidence of informed stock trading before data breach disclosures (Lin et al., 2020a; Wang et al., 2022). Research on informed option trading, however, has produced mixed evidence when relying on volume-based measures of trading activity (Mitts & Talley, 2019; Piccotti & Wang, 2023). By employing implied volatility skew—a price-based proxy less subject to the noise of trading volume—this paper provides new evidence on the informational role of option markets around cybersecurity events.

The remainder of the paper is organized as follows. Section 2 discusses the related literature and develops hypotheses. Section 3 describes data and variables. Section 4 reports the main results and additional findings. Section 5 concludes.

2 Literature Review and Hypothesis Development

Information security issues have become increasingly important in the recent decade, and the implications of data breaches on financial markets have received considerable attention. For instance, Spanos and Angelis (2016) provide a comprehensive review of the impact of information security events on the stock market and report that most studies find statistically significant effects. More recent evidence shows that firms experiencing data breaches face economically meaningful losses: Lending et al. (2018) document an average abnormal return of -3.5% over one year, while Kamiya et al. (2021) show that cyberattacks negatively affect not only the targeted firms but also their industry peers. In addition, Akey et al. (2023) find that data breaches damage corporate reputation and reduce both equity and brand value.

Unlike typical corporate events such as earnings announcements or mergers, data breaches are unanticipated and not the result of deliberate firm decisions. Their idiosyncratic nature makes them a particularly compelling setting to study informed trading. Prior research highlights evidence of opportunistic behavior in equity markets: Lin et al. (2020b) show that insiders avoided significant losses by selling shares ahead of breach announcements, and Wang et al. (2022) document abnormal increases in short-selling costs around such events. These findings raise the natural question of whether informed traders also exploit private information in the options market, where forward-looking features may provide even greater opportunities for anticipatory trading.

The informational role of option markets has been widely established in the literature. A large body of research demonstrates that unusual options trading activity can predict future stock returns, particularly in the period leading up to major corporate events. Prior studies document informed option trading ahead of takeovers (Augustin et al., 2019; Chan et al., 2015), earnings announcements (Jin et al., 2012), share repurchases (Qing, 2016), auditor changes (Zhang, 2018a), and credit rating adjustments (Zhang, 2019), among others. More broadly, Pan and Poteshman (2006) and Cao et al. (2005) provide evidence of abnormal options market activity preceding earnings an-

nouncements and takeover bids, underscoring that option trading conveys predictive information about future stock price movements. Collectively, this literature highlights the options market as a rich source of forward-looking information regarding corporate events and firm value.

Despite this extensive literature, studies of informed option trading around data breaches remain limited. To the best of my knowledge, Mitts and Talley (2019) report evidence of informed trading up to 16 months prior to breach disclosures—though such early activity, in many cases preceding the breach itself, is difficult to reconcile. In contrast, Piccotti and Wang (2023) find that option volume and open interest lack predictive power for future returns, instead pointing to the put-to-call ratio as a potential predictor of cumulative abnormal returns. However, both studies rely heavily on volume-based measures, which may not capture the informational content embedded in option prices.

To address this gap, my study adopts implied volatility skew as a price-based measure of informed option trading. Put options, typically seen as bets against a firm's stock, increase in value when the stock price declines. Given the adverse impact of data breaches on stock prices, as documented by Lending et al. (2018) and Kamiya et al. (2021), it is reasonable to expect abnormal pricing activity in the options market prior to such announcements. If informed traders exploit private information, these activities should manifest as elevated IV skew that forecasts post-announcement stock returns. This leads to the following null hypothesis:

H_0: Option market trading activity does not predict future stock returns around data breach announcements.

3 Data

The sample used to test the null hypothesis is constructed from Audit Analytics, Compustat, the Center for Research in Security Prices (CRSP), and OptionMetrics IvyDB. Information on data breaches—including affected companies, announcement dates, and types of attacks—comes from the Audit Analytics Cybersecurity database, which documents 614 events between 2005 and 2023. Due to data availability, the analysis focuses on the period 2012–2022, covering roughly 88% of the full database. Table 1 reports the annual distribution of data breach incidents during this period, categorized by data type. The number of breaches rises consistently over time, peaking at 83 in 2021. In total, the sample includes 542 breaches across eleven years, providing a com-

prehensive basis for examining the financial implications of cybersecurity incidents.

Table 1: Data Breach by Year

Data Type	Payment	Identity	Other	Undisclosed	Total
2012	2	3	20	0	25
2013	7	1	18	0	26
2014	12	4	13	0	29
2015	8	3	11	0	22
2016	6	3	21	0	30
2017	15	5	25	2	47
2018	30	7	33	3	73
2019	21	8	41	3	73
2020	16	8	32	16	72
2021	20	8	45	10	83
2022	23	3	24	12	62
2012–2022	**160**	**53**	**283**	**46**	**542**

Note: The Audit Analytics Cybersecurity database contains the disclosures and impacts of data breaches affecting public companies registered with the SEC, as disclosed in SEC filings, state documents, and press releases.

First, I use the CRSP database to compute abnormal returns around data breach announcements. For an announcement on day t, I calculate the cumulative abnormal return (CAR) from day t to t+2. Abnormal return is defined as the difference between the actual return and the expected return estimated using the market return proxied by the value-weighted CRSP index.[3]

Next, I construct a measure that captures the relative expensiveness of put options using OptionMetrics. Following Xing et al. (2010), I calculate the implied volatility (IV) skew as the difference in implied volatility between out-of-the-money put options and near-the-money call options for the same underlying stock. Abnormal IV Skew is defined as the average daily IV skew over [*t–5, t–1*] minus the average daily IV skew over [*t–15, t–6*], consistent with prior literature.[4]

To control for stock performance prior to data breach announcements, I introduce two measures of pre-event stock returns. *Return_PreMonth* is the compounded buy-and-hold return over the one-month period leading up to the announcement, while *Return_PreYear* is the compounded buy-and-hold return over the one-year period before the event. These measures provide a baseline of stock performance prior to the announcement. Additionally, firm fundamentals are obtained from Compustat. Following Zhang (2018a), I control for several key firm-level variables: *Market Cap* (log

[3]The results are similar when using the Fama and French (1993) three-factor model to calculate abnormal returns.

[4]See, for example, Zhang (2018a, 2018b).

of market capitalization on the event day), *Market-to-Book* (log of the ratio of equity market value to book value), *Intraday Volatility* (average ratio of the absolute daily open-close price difference to the opening price, calculated over the 20 days before the event), *Dividend Yield* (log of one plus the annual dividend per share divided by the year-end closing price), *Leverage* (log of one plus the total liabilities-to-assets ratio), and *Cash Holdings* (log of one plus the ratio of cash and short-term investments to total assets).

To measure the liquidity of the option market relative to the stock market, I calculate the average bid-ask spread for both the options and the underlying stocks. For each option, the bid-ask spread is the ratio of the difference between the best offer price and the best bid price to the midpoint of the two. For each firm-day, the option bid-ask spread is averaged across all contracts with nonzero trading volume. This average option bid-ask spread, computed over the seven trading days prior to the data breach announcement, captures options market liquidity. The average stock bid-ask spread is computed analogously. The *Liquidity Ratio* is then defined as the ratio of the average option bid-ask spread to the average stock bid-ask spread. By construction, a lower liquidity ratio indicates higher relative liquidity in the options market.

Table 2 reports summary statistics of the key variables in the sample. Notably, the mean CAR around data breach announcements is -0.651%, and the median is -0.319%. Further tests show that the mean CAR of -0.651% is significantly negative, with a t-statistic of -2.91. These results indicate that, on average, the stock market reacts negatively to data breach announcements, consistent with expectations and the findings in previous literature.

4 Empirical Results

4.1 Predictability of Informed Options Trading

To test whether option trading is informed prior to data breach announcements, I first perform a baseline regression of the cumulative abnormal return, *CAR*, on the pre-announcement abnormal IV skew. I then include firm-level and stock-level variables to control for firm and stock characteristics. To control for unobserved heterogeneity across industries and over time, I include industry and year fixed effects by adding indicator variables for each industry and event year. The results are shown in Table 3.

As Model (1) shows, the abnormal IV skew significantly and negatively predicts

Table 2: Summary Statistics

Variable	Mean	SD	5%ile	25%ile	Median	75%ile	95%ile
CAR(%)	-0.651	3.846	-6.137	-2.305	-0.319	1.495	4.354
Abnormal IV Skew	0.000	0.035	-0.037	-0.011	0.001	0.011	0.039
Return_PreMonth(%)	2.145	10.086	-11.025	-2.657	1.633	5.807	17.506
Return_PreYear(%)	27.461	51.564	-26.294	2.475	18.779	38.578	104.032
Market Cap	17.230	2.418	14.147	15.520	16.953	18.540	20.854
Intraday Volatility	0.012	0.007	0.005	0.007	0.011	0.015	0.025
Dividend Yield	0.014	0.016	0.000	0.000	0.012	0.022	0.038
Market-to-Book	-1.288	0.989	-2.958	-1.741	-1.219	-0.739	0.052
Cash Holding	0.130	0.119	0.015	0.037	0.089	0.188	0.391
Leverage	0.522	0.162	0.290	0.450	0.513	0.606	0.693
Option b-a Spread	0.465	0.377	0.135	0.222	0.340	0.562	1.514
Stock b-a Spread	0.030	0.023	0.010	0.016	0.023	0.033	0.091
Liquidity Ratio	18.261	14.259	6.056	10.051	15.646	21.932	40.274

Note: This table reports summary statistics for variables around cybersecurity breach disclosures. *CAR* is the cumulative abnormal return from day t to $t+2$, calculated as the difference between actual returns and expected returns using the CRSP value-weighted index. *Abnormal IV Skew* is the average implied volatility skew over $[t-5, t-1]$ minus the average over $[t-15, t-6]$, following Xing et al. (2010). *Return_PreMonth* and *Return_PreYear* are the compounded buy-and-hold returns over the one-month and one-year periods before the disclosure. *Market Cap* is the log of market capitalization on the event day. *Market-to-Book* is the log ratio of equity market value to book value. *Intraday Volatility* is the average ratio of the absolute daily open–close difference to the opening price over the 20 days before the event. *Dividend Yield* is the log of one plus annual dividend per share over the year-end closing price. *Leverage* is the log of one plus the ratio of total liabilities to assets. *Cash Holding* is the log of one plus the ratio of cash and short-term investments to assets. *Option bid–ask spread* is the relative difference between the best offer and bid prices averaged across options with nonzero trading volume over the seven days before the event. *Stock bid–ask spread* is the same measure for the stock market. The *Liquidity Ratio* is the ratio of option market liquidity to stock market liquidity.

CAR, the cumulative abnormal return around the data breach announcements. This negative relationship persists across Models (2) and (3), even after including control variables such as prior stock returns (*Return_PreMonth* and *Return_PreYear*), *Market Cap*, *intraday volatility*, *Market-to-book* ratio, *dividend yield*, *cash holding*, *leverage*, and fixed effects for year and industry. The impact is not only statistically but also economically significant; a one standard deviation increase in abnormal IV skew results in a 0.55% decrease in *CAR*, aligning closely with the sample's mean *CAR* and exceeding its median.

4.2 Placebo Test with Pseudo Events

An important concern in identifying informed trading is whether the predictive relation between abnormal IV skew and post-announcement returns reflects genuine information about data breaches, or merely captures a broader return predictability documented in prior studies. For example, Bali and Murray (2013) show that option-implied skewness exhibits a significantly negative predictive relation with future stock returns in the cross-section, independent of event settings. To disentangle event-specific informativeness from general option market dynamics, I conduct a placebo

Table 3: Cross-sectional Regression of CAR on Abnormal IV Skew

Model	(1)	(2)	(3)
Abnormal IV Skew	-24.05**	-24.83***	-25.45***
	(-2.56)	(-3.01)	(-2.63)
Return_PreMonth		-7.75**	-6.11*
		(-2.17)	(-1.67)
Return_PreYear		-2.48**	-2.72**
		(-2.39)	(-2.15)
Market Cap		0.38**	0.48**
		(2.16)	(2.35)
Intraday Volatility		-14.00	32.40
		(-0.17)	(0.42)
Dividend Yield		-43.89	-47.96*
		(-1.49)	(-1.73)
Cash Holding		3.37	1.41
		(1.20)	(0.46)
Leverage		-0.38	-2.51
		(-0.12)	(-0.78)
Market-to-book		0.30	0.19
		(0.91)	(0.47)
Year and Industry FE	×	×	✓
N	382	294	294
Adjusted R^2	0.0474	0.1610	0.2095

Note: This table reports cross-sectional regressions of cumulative abnormal return (*CAR*) on abnormal implied volatility skew. *CAR* is the cumulative abnormal return from day t to $t+2$, calculated as the difference between actual returns and expected returns using the CRSP value-weighted index. *Abnormal IV Skew* is the average implied volatility skew over $[t-5, t-1]$ minus the average over $[t-15, t-6]$ (Xing et al., 2010). *Return_PreMonth* and *Return_PreYear* are the compounded buy-and-hold returns over the one-month and one-year periods before the disclosure. Firm controls include *Market Cap*, *Market-to-Book*, *Intraday Volatility*, *Dividend Yield*, *Cash Holding*, and *Leverage*. Year and industry fixed effects are included where indicated. Robust t-statistics are in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

test using randomly assigned pseudo-announcement dates.Specifically, for each firm in the sample, I generate fictitious event dates within the sample timeline, preserving the distribution of real event frequencies across years. Using this pseudo-event sample, I re-estimate the cross-sectional regressions in Table 3, including the same independent and control variables. If the predictive power of abnormal IV skew were simply capturing the broader patterns identified by Bali and Murray (2013), similar results should appear in the placebo setting.

As reported in Table 4, abnormal IV skew has no significant relation with cumulative abnormal returns around fictitious events. This finding confirms that the observed predictability is unique to actual data breach announcements and not an artifact of background stock–option return comovements. The placebo test therefore reinforces the interpretation that option traders selectively exploit private information ahead of data breach disclosures.

Table 4: Placebo Test with Pseudo Events

Model	(1)	(2)	(3)
Abnormal IV Skew	4.64	-5.38	-11.96
	(0.23)	(-0.42)	(-1.00)
Return_PreMonth		6.72	2.69
		(1.73)	(0.57)
Return_PreYear		-2.05*	-2.24
		(-1.73)	(-1.31)
Market Cap		-0.24	-0.20
		(-0.93)	(-0.79)
Intraday Volatility		19.27	-86.64
		(0.36)	(-1.34)
Dividend Yield		73.27*	73.48*
		(1.94)	(1.83)
Cash Holding		-0.32	5.61
		(-0.10)	(1.00)
Leverage		2.80	8.14**
		(0.84)	(2.09)
Market-to-book		0.05	1.17*
		(0.11)	(1.75)
Year and Industry FE	×	×	✓
N	382	294	294
Adjusted R^2	0.0008	0.0904	0.1199

Note: *CAR* is the cumulative abnormal return from day t to $t+2$, calculated using the CRSP value-weighted index. *Abnormal IV Skew* is the average implied volatility skew over $[t-5, t-1]$ minus that over $[t-15, t-6]$ (Xing et al., 2010). *Control* variable includes *Return_PreMonth* and *Return_PreYear* as buy-and-hold returns over the prior month and year, *Market Cap* as the log of market capitalization on the event day, *Market-to-Book* as the log equity market-to-book ratio, *Intraday Volatility* as the average absolute open–close difference scaled by opening price over the 20 days before the event, *Dividend Yield* as the log of one plus annual dividends over year-end price, *Leverage* as the log of one plus liabilities-to-assets, and *Cash Holding* as the log of one plus cash and short-term investments to assets. Robust t-statistics in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels.

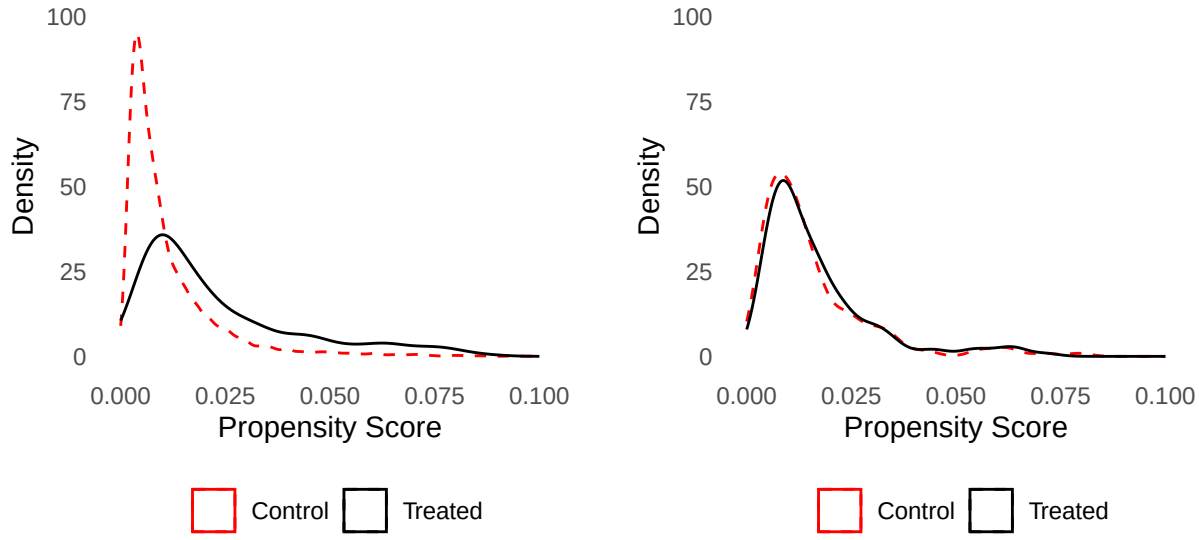
4.3 Propensity Score Matching (PSM)

To further strengthen the robustness of the predictive power of abnormal IV skew, I employ a propensity score matching (PSM) framework. The intuition behind PSM is to construct a control group of firms that are observationally similar to treatment firms (those disclosing data breaches), thereby mitigating selection bias in estimating treatment effects (Rosenbaum & Rubin, 1983). Following Mitts and Talley (2019), I match each sample firm experiencing a data breach with a control firm that has not disclosed a breach but is comparable in observable characteristics. Specifically, firms are matched on industry (SIC code), market capitalization, leverage, and average put option trading volume. Among the full CRSP universe of firms without breach disclosures, I successfully match 165 treatment-control pairs. Figure 1 illustrates the density distributions of propensity scores before and after matching. Post-matching, the treatment and control groups display nearly identical propensity score distributions, suggesting balanced covariates across groups. This balance reduces concerns that dif-

ferences in option trading dynamics are mechanically driven by firm fundamentals rather than breach-related information.

For empirical implementation, each control firm is assigned a pseudo announcement date identical to its matched treatment firm's actual disclosure date. A dummy variable, *Real*, equals one for treatment firms and zero for control firms. I then re-estimate the cross-sectional regressions (as in Table 3), including a dummy variable *Real* and its interaction with abnormal IV skew as explanatory variables. The results confirm that the predictive power of abnormal IV skew is concentrated among treatment firms, providing further evidence that the observed option trading patterns are tied to data breach events rather than general firm characteristics or random timing.

Figure 1: PSM Matching



Panel A: Before Matching

Panel B: After Matching

This figure shows the propensity score distribution of the entire sample before and after the matching. Panel A displays the propensity score density distribution for the treatment group and the unmatched group before matching. Panel B displays the density distribution of propensity scores for treated group and control group after matching.

The results of the cross-sectional regressions employing propensity score matching are reported in Table 5. The standalone abnormal IV skew is statistically insignificant across all model specifications, whereas the interaction terms between abnormal IV skew and the *Real* dummy exhibit statistical significance. This indicates that abnormal IV skew predicts abnormal returns for real data breach announcements but not for pseudo announcements for control firms. In essence, the predictability of abnormal IV skew is solely attributable to actual firms with data breaches.

Table 5: Robustness Check with Propensity Score Matched Sample

Model	(1)	(2)	(3)
Abnormal IV Skew	13.84	15.70	17.93*
	(1.61)	(1.52)	(1.76)
Abnormal IV Skew*Real	-37.89***	-38.35***	-43.63***
	(-2.98)	(-3.27)	(-3.54)
Real	0.28	-0.53	-0.38
	(0.58)	(-1.02)	(-0.74)
Return_PreMonth		-5.18*	-4.41
		(-1.76)	(-1.43)
Return_PreYear		-2.21**	-3.00***
		(-2.53)	(-2.86)
Market Cap		0.44***	0.52***
		(3.08)	(3.41)
Intraday Volatility		5.28	44.31
		(0.08)	(0.64)
Dividend Yield		-6.51	-5.79
		(-0.53)	(-0.45)
Cash Holding		2.75	0.08
		(1.32)	(0.03)
Leverage		-1.10	-2.74*
		(-0.56)	(-1.27)
Market-to-book		0.18	-0.03
		(0.71)	(-0.08)
Year and Industry FE	×	×	✓
N	277	239	239
Adjusted R^2	0.0349	0.1085	0.1651

Note: *CAR* is the cumulative abnormal return from day t to $t+2$, calculated using the CRSP value-weighted index. *Abnormal IV Skew* is the average implied volatility skew over $[t-5, t-1]$ minus that over $[t-15, t-6]$ (Xing et al., 2010). *Real* is an indicator that equals one for treatment firms and zero for control firms from propensity score matching. *Control* variable includes *Return_PreMonth* and *Return_PreYear* as buy-and-hold returns over the prior month and year, *Market Cap* as the log of market capitalization on the event day, *Market-to-Book* as the log equity market-to-book ratio, *Intraday Volatility* as the average absolute open–close difference scaled by opening price over the 20 days before the event, *Dividend Yield* as the log of one plus annual dividends over year-end price, *Leverage* as the log of one plus liabilities-to-assets, and *Cash Holding* as the log of one plus cash and short-term investments to assets. Robust t-statistics in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels.

4.4 Impact of Pre-announcement Momentum

Next, I examine how the predictive power of abnormal IV skew is affected by the degree to which information is already incorporated into stock prices prior to the data breach announcement. The intuition is that the informational advantage of option traders depends on how much private information remains unreflected in the stock market. When informed traders choose to exploit their private information in the equity market, pre-event stock returns will already embed part of the forthcoming news. As a result, fewer informed traders will resort to the options market, reducing the information content of options trading and weakening its predictive power. This conjecture is consistent with Roll et al. (2010), who show that the predictability of relative options trading volume declines when pre-event stock returns are high. To test this

hypothesis, I augment the regression models with the cumulative abnormal return during the three trading days preceding the data breach announcements, denoted as *PreCar*, and its interaction with abnormal IV skew. The results, reported in Table 6, show that abnormal IV skew retains a negative and significant coefficient, while the interaction with *PreCar* is positive. This suggests that the predictive power of abnormal IV skew is stronger when the stock underperforms in the pre-announcement window, consistent with the notion that option traders' informational advantage is larger when less information has already been impounded into stock prices. These findings provide indirect evidence that the option market serves as a complementary venue for incorporating information not yet fully reflected in the equity market.

Table 6: Impact of Pre-announcement Momentum

Model	(1)	(2)	(3)
Abnormal IV Skew	-18.08***	-20.36***	-20.23***
	(-3.06)	(-3.04)	(-2.86)
Abnormal IV Skew*PreCAR	7.27***	5.90***	5.65***
	(5.71)	(4.10)	(3.80)
PreCAR(%)	0.13**	0.16**	0.16**
	(2.05)	(2.22)	(2.18)
Return_PreMonth(%)		-3.77	-3.22
		(-1.57)	(-1.30)
Return_PreYear(%)		0.16	0.28
		(0.35)	(0.54)
Market Cap		0.06	0.06
		(0.60)	(0.67)
Intraday Volatility		-98.01	-98.69
		(-1.62)	(-1.58)
Dividend Yield		-19.23	-23.94
		(-0.77)	(-1.63)
Cash Holding		1.81	1.29
		(0.88)	(0.55)
Leverage		0.76	0.48
		(0.38)	(0.20)
Market-to-book		0.17	0.15
		(0.71)	(0.55)
Year and Industry FE	×	×	✓
N	318	292	292
Adjusted R^2	0.1233	0.1370	0.1411

Note: *CAR* is the cumulative abnormal return from day t to $t+2$, calculated using the CRSP value-weighted index. *Abnormal IV Skew* is the average implied volatility skew over $[t-5, t-1]$ minus that over $[t-15, t-6]$ (Xing et al., 2010). *PreCAR* is the cumulative abnormal returns during the three days time window preceding the data breach event disclosures. *Control* variable includes *Return_PreMonth* and *Return_PreYear* as buy-and-hold returns over the prior month and year, *Market Cap* as the log of market capitalization on the event day, *Market-to-Book* as the log equity market-to-book ratio, *Intraday Volatility* as the average absolute open–close difference scaled by opening price over the 20 days before the event, *Dividend Yield* as the log of one plus annual dividends over year-end price, *Leverage* as the log of one plus liabilities-to-assets, and *Cash Holding* as the log of one plus cash and short-term investments to assets. Robust t-statistics in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels.

4.5 Impact of Option Liquidity

Easley et al. (1998) suggest that informed trading in the options market is influenced by its liquidity compared to the stock market's liquidity. Specifcially, when the options market is more liquid than the stock market, informed traders are more likely to trade in the options market to take advantage of high leverage and low cost. Consequently, options trading becomes more informative under these conditions. Therefore, it is anticipated that the effectiveness of informed options trading measures in predicting stock returns increases with the relative liquidity of the options market compared to the stock market.

To test the hypothesis, I define the liquidity ratio as the liquidity comparison between the options and stock markets, measured through the bid-ask spread. The bid-ask spread, for each option, is the ratio of the price difference between the highest bid and lowest offer to their midpoint, averaged across all options with non-zero trading volumes. The study focuses on the average bid-ask spread from seven days before the data breach announcement as the liquidity measure for the options market, with the stock market's liquidity similarly calculated. A lower liquidity ratio signals higher relative liquidity in the options market, potentially enhancing the informativeness of options trading.

With the liquidity ratio and its interaction with abnormal IV skew as additional independent variables, similar regressions are conducted. The results, as shown in Table 7, shows that abnormal IV skew as a standalone varialbe significantly and negatively predicts *CAR*. More importantly, its interaction with liquidity ratio is significant and positive. This indicates that the inverse relationship between abnormal IV Skew and *CAR* intensifies when the options market is more liquid relative to the stock market. These findings affirm the hypothesis that the predictive power of abnormal IV skew on stock returns is enhanced in a relatively more liquid options market.

Table 7: Impact of Option Liquidity

Model	(1)	(2)	(3)
Abnormal IV Skew	-29.53***	-58.85***	-58.21***
	(-2.95)	(-5.19)	(-4.90)
Abnormal IV Skew*Liquidity_Ratio	0.84	1.21**	1.39**
	(1.43)	(2.08)	(2.38)
Liquidity_Ratio	-0.01	-0.04**	-0.05***
	(-0.97)	(-2.31)	(-2.86)
Return_PreMonth		-4.20*	-2.68
		(-1.86)	(-1.15)
Return_PreYear		-1.09**	-0.87*
		(-2.57)	(-1.87)
Intraday Volatility		-176.64***	-181.90***
		(-4.45)	(-4.19)
Market Cap		0.05	0.05
		(0.45)	(0.49)
Dividend Yield		-27.32*	-30.73**
		(-1.89)	(-2.12)
Cash Holding		3.69*	2.11
		(1.73)	(0.88)
Leverage		1.69	-1.13
		(0.83)	(-0.46)
Market-to-book		0.46**	0.17
		(1.96)	(0.59)
Year and Industry FE	×	×	✓
N	316	290	290
Adjusted R^2	0.1439	0.2513	0.2905

Note: *CAR* is the cumulative abnormal return from day t to $t+2$, calculated using the CRSP value-weighted index. *Abnormal IV Skew* is the average implied volatility skew over $[t-5, t-1]$ minus that over $[t-15, t-6]$ (Xing et al., 2010). *Liquidity Ratio* is the ratio of *Option bid–ask spread* to *Stock bid–ask spread*, where *Option bid–ask spread* is the relative difference between best offer and bid prices, averaged across traded options over the seven pre-event days and *Stock bid–ask spread* defined analogously. *Control* variable includes *Return_PreMonth* and *Return_PreYear* as buy-and-hold returns over the prior month and year, *Market Cap* as the log of market capitalization on the event day, *Market-to-Book* as the log equity market-to-book ratio, *Intraday Volatility* as the average absolute open–close difference scaled by opening price over the 20 days before the event, *Dividend Yield* as the log of one plus annual dividends over year-end price, *Leverage* as the log of one plus liabilities-to-assets, and *Cash Holding* as the log of one plus cash and short-term investments to assets. Robust t-statistics in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels.

5 CONCLUSION

This article looks into the informativeness of options trading by exploring the correlation between cumulative abnormal returns around data breach announcements and preceding informed options trading. Employing abnormal IV skew as a measure of informed options trading, I establish a negative and statistically significant relationship between pre-announcement abnormal IV skew and abnormal returns post-announcements. These findings provide evidence that informed options trading predicts upcoming announcement-induced stock returns. Given that IV skew is tailored to capture option traders' overall pessimistic outlook on the underlying stock, the observed significant predictability of abnormal IV skew is consistent with findings from studies that market reactions to data breaches tend to be predominantly negative.

Moreover, the predictive power of abnormal IV skew is stronger when the options market exhibits greater liquidity compared to the underlying stock market. This predictive power is also amplified when the information to be disclosed has already been incorporated in the stock market, indicating a complementary relationship between option trading and stock trading. The main results are robust to a placebo test using fake announcement dates and a propensity score matched sample that combines treatment and control firms. Overall, the results suggest that informed options traders possess private information about forthcoming data breach announcements and exploit such information in the option market.

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