How Common is Insider Trading? Evidence from the Options Market☆

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Abstract

Option traders are considered among the most informed investors because their trades strongly predict future stock returns. We identify the source of their information edge using a quasi-exogenous shock to insider trading enforcement. With the arrest of Raj Rajaratnam, prosecutors launched an unprecedented campaign against insider trading making such trading much riskier. Before the arrest, the put-call ratio that aggregates information content of option trades earned a 0.24% weekly alpha among S&P 500 stocks. But this striking predictability suddenly disappeared shortly after Raj's arrest, as option investors refrained from trading on insider information. These results suggest that insider trading used to be prevalent in the options market and explain why option trades used to predict stock returns.

JEL Classification: G12, G13, G14

Keywords: Insider trading, informed trading, equity options, return predictability

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"A lot of people were found guilty of insider trading. The weapon of choice for insider traders through that period were options."

Dennis Davitt, Head of Derivative Trading at Credit Suisse, 2001-2009

1. Introduction

"U.S. charges billionaire Rajaratnam with insider trading" read the headline on a rainy morning of October 16, 2009, and Steven Fortuna, a cofounder of S2 Capital, was shocked by this news. He never met Raj Rajaratnam, but everyone knew Raj was a hedge fund superstar. This was big news because the prosecutors had not charged major investors with insider trading since the mid-1980s. What if Raj's arrest signaled a war against insider trading? If so, Fortuna could be in trouble. Suddenly, another morning flashed in his memory. On July 25, 2008, he got a call from a reliable source within Akamai Technologies and learned that the company was about to announce disappointing quarterly results. Fortuna immediately bought 2,000 put options and shorted Akamai stock. The stock price tanked after the earnings release on July 30, and his fund made $2.4 million on this trade.[2] Now after Raj's arrest, he must be extra careful and avoid making suspicious trades.

In this paper, we show that this anecdote is representative of how option investors responded to the biggest spike in insider trading enforcement in history. During this campaign that lasted from late 2009 to 2016, federal prosecutors racked up 93 convictions. Raj Rajaratnam was sentenced for 11 years, the longest ever prison sentence for insider trading.[3] SAC Capital, a prominent hedge fund, pleaded guilty and agreed to pay a $1.8 billion fine, the largest ever penalty related to insider trading. This unprecedented campaign was preceded by a relatively quiet period lasting almost 30 years.

This quasi-exogenous shock to insider trading enforcement helps us study two related research questions. First, how prevalent is illegal insider trading? The U.S. Securities and Exchange Commission (SEC) brought 51, 30, and 33 insider trading cases in 2018, 2019, and 2020, respectively. Perhaps, there is indeed little insider trading. Alternatively, prosecutors deploy their limited resources to focus only most promising cases. Detecting insider trading is hard because insiders, like other informed investors, usually hide their trades (e.g., Admati and Pfleiderer (1988),

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[2] See Securities and Exchange Commission (2009) and Department of Justice (2009) for more details on this case.

[3] See "How the Feds Pulled Off the Biggest Insider-Trading Investigation in U.S. History" by P. Hurtado and M. Keller in *Bloomberg* on 6/1/2016. The 13 other defendants in Raj's case received prison sentences averaging three years each. For comparison, Ivan Boesky was sentenced for 3.5 years in the second biggest insider war in 1980s.

Collin-Dufresne and Fos (2015)). Thus, the prosecuted cases could be the tip of the iceberg and may not represent typical insider trading. This selection bias poses a major challenge for studying illegal insider trading. To get around it, we study how investors respond to a sudden increase in the likelihood and severity of prosecution after Raj's arrest. The arrest should only affect illegal insider trading, but not other forms of informed trading.

Second, how do option investors, who are an important class of informed investors, obtain their information edge? We focus on option investors because many prior studies show that their trades strongly predict future stock returns (e.g., Easley, O'Hara, and Srinivas (1998), Pan and Poteshman (2006), Johnson and So (2010), Hu (2014), and Ge, Lin, and Pearson (2016)). This return predictability is typically interpreted as evidence of informed trading in options. Informed investors are attracted by high option leverage and lack of shorting constraints (Black (1975)). Also, large option bid-ask spreads discourage uninformed trading, while informed investors are less cost-sensitive. Investors can obtain information edge in two broad ways. First, they can analyze public data better than others. Second, they can obtain non-public information from corporate insiders, which is typically illegal to trade on. The current consensus is that given the risks of trading on insider information, informed trading on public information is likely more prevalent. Surprisingly, we find that insider trading used to be more prevalent.

We follow the pioneering approach of Pan and Poteshman (2006), who study informed trading by considering how the put-call ratio predicts stock returns. For a given stock and date, the put-call ratio is computed as the volume of put purchases divided by the volume of call purchases. Only purchases that open new option position are considered. Intuitively, buying a call (put) signals positive (negative) future stock returns. The ratio is computed separately for volume executed at the two largest options exchanges, the Chicago Board Options Exchange (CBOE) and the International Securities Exchange (ISE), from May 2005 to May 2017. We limit the sample to stocks in S&P 500 index because their options are liquid enough to attract institutional investors and because S&P 500 provides a consistent panel to compare return predictability over time.

We present several main results. The put-call ratio strongly predicts stock returns before Raj's arrest in October 2009. In portfolio sorts, the decile portfolios with the highest put-call ratio underperform the bottom decile portfolios by 0.24% next week, or 12.1% per year. The predictability is highly statistically significant with *t*-statistics of 3.8 for both the CBOE and ISE ratios. The annualized Sharpe ratios are high, 1.76 and 1.67. The abnormal returns barely change when we risk-adjust them with the four-factor Fama-French model that includes the momentum factor. The alphas remain stable pre-arrest including the 2008 financial crisis. Fama-MacBeth regressions control for standard return predictors and confirm the portfolio sort results.

These large alphas are puzzling. First, these abnormal returns exceed trading costs as S&P 500 stocks are very liquid and always easy to short. Second, the put-call ratio is by far the strongest return predictor in the cross-section of S&P 500 stocks. Out of several hundred known anomalies, only few generate significant alphas in the post-2003 period (Green, Hand, and Zhang (2017)), as market efficiency is improving. Most anomalies are concentrated in small-cap stocks, and none of them generate significant alpha among S&P 500 stocks (Hou, Xue, and Zhang (2020)). This fact is not surprising as S&P 500 stocks, like Microsoft, are always in investors' spotlight. Finally, informed investors earn even larger profits than is implied by these large alphas as a high put-call ratio can often be due to option buying by uninformed investors.

What do some option investors know to generate such an impressive alpha in mega-cap stocks? Perhaps, investors achieve an edge by analyzing public data. Alternatively, they can obtain private information from corporate insiders. Understandably, investors are secretive about which information generates alpha, so we infer this indirectly from the change in investors' behavior post Raj's arrest, a quasi-exogenous shock to insider trading enforcement.

Raj's arrest was a huge shock to the market – S&P 500 E-mini futures plunged by 0.6% within an hour after he was arrested at 6:20 am on October 16, 2009. The market dropped by another 0.6% by 10:00 am as Preet Bharara, U.S. Attorney for the Southern District of New York, announced that it was the largest insider trading case in history and finished with a warning. "It should be a wake-up call for every Wall Street trader who is even thinking about engaging in insider trading." As we show below, option investors internalized and responded to this message.

Strikingly, the return predictability by the put-call ratio abruptly disappeared shortly after Raj's arrest and remained so for the rest of the sample period. The alphas of the long-short strategy for CBOE and ISE ratios dropped from 0.24% and 0.23% per week pre-arrest to -0.04% and -0.01% post-arrest. The corresponding *t*-statistics drop from 3.8 and 3.8 to -1.8 and -0.6. Option volume from both exchanges suddenly stopped predicting stock returns. Fama-MacBeth regressions confirm the portfolio sort results. To better identify the effect, the difference-in-difference analysis compares alphas in two years pre- and post-arrest with the put-call ratio computed from close-buy trades as a control group. The diff-in-diff analysis confirms that the predictability suddenly disappears after the arrest.

We interpret the above results as evidence that Raj's arrest scared option investors, who refrain from option buying. Option trades suddenly lost their information content for future stock returns, which is consistent with the hypothesis that trading on insider information largely explains why option trades used to predict stock returns.

We further test the insider trading hypothesis. First, if insiders constitute a large enough share of option volume and then stop trading, then option volume will decline post-arrest. Indeed, open-buy volume from CBOE and ISE reaches the all-time high around Raj's arrest and subsequently declines, which we further confirm with panel regressions. Stock volume declined slightly post-arrest suggesting that at most few option insiders switched from options to stocks. Second, the return predictability is fully driven by option contracts with high embedded leverage, which are particularly attractive to informed investors. Finally, prosecuted insider cases are concentrated before important stock-specific news such as earnings and merger (M&A) announcements. We find that the put-call ratio predicts returns stronger for weeks that contain unscheduled news than for no-news weeks. But this stronger predictability prior to news disappeared post-arrest.

We study the consequences of the biggest campaign against insider trading. This event is akin to the 2008 financial crisis or the 2020 COVID pandemic. Raj's arrest was a huge shock that changed investor behavior. The sharp discontinuity in return predictability and trading volume helps alleviate some of the concerns about confounding effects. However, like other studies of uniquely significant events, we are limited to one event and thus cannot completely rule out all alternative explanations. Reassuringly, the results are very similar for the put-call ratios separately computed from CBOE and ISE option volume, which addresses many of the data-specific concerns.

We contribute to several literatures. First, a large literature documents that option investors are informed; see Augustin and Subrahmanyam (2020) for a review. We show that option volume suddenly and permanently stopped predicting stock returns after October 2009. More importantly, option investors' behavior indicates that their information edge came primarily from insider information. Had investors traded on legal public information, they would continue to trade despite the enforcement campaign. Cao, Chen, and Griffin (2005) and Augustin, Brenner, and Subrahmanyam (2019) study unsigned option volume and argue that some insider trading is likely prior to M&A news. We present a much stronger case for the insider trading hypothesis. First, our identification comes from a natural experiment that affects illegal insider trading but not legal informed trading. Second, our results are consistent with the hypothesis that informed trading in options was *entirely* driven by insider information, which we establish for the *entire* options market rather than important special cases such as M&A news.

Second, we contribute to the literature on illegal insider trading by showing that informed trading in one major market, options, was likely entirely driven by insider trading. Recently, Patel and Putniņš (2021) calibrate a structural model on the prosecuted insider cases and conclude that "prevalence of illegal insider trading in the stock market is at least four times greater than the number of prosecutions." In contrast, we focus on the options market, use a major exogenous shock for identification, and compare illegal insider trading to legal informed trading. We also contribute to the debate on whether investors respond to insider trading enforcement; see Bhattacharya (2014) for a review. Specifically, we identify Raj's arrest as the launch of the unprecedented enforcement campaign that radically changed investor behavior.[4] Our results are consistent with the cross-country evidence that price efficiency improves (Fernandes and Ferreira (2009)) and illegal insider trading is deterred (Bris (2005)) once a country initiates an enforcement of insider trading laws.

Finally, a growing literature studies stock "anomalies." For example, McLean and Pontiff (2016) argue that anomaly profitability declines post-publication as investors learn about and trade on those signals. The put-call ratio anomaly provides several insights. First, the put-call ratio was the strongest anomaly in the sample of S&P 500 stocks. Second, its profitability was not affected by CBOE and ISE making the open-close data available to investors in 2006 and 2007, respectively. Arbitrageurs did not jump on this signal for years even though Pan and Poteshman (2006) results had been widely known. Finally, our results indicate that the put-call ratio anomaly was mainly driven by insider trading, which stopped after Raj's arrest. Thus, we identify a specific mechanism behind this anomaly and contribute to the debate on whether anomalies are genuine mispricing, compensation for risk, or the result of data mining.

The paper is organized as follows. Section 2 describes the data. Section 3 presents the main results about return predictability before and after Raj's arrest. Section 4 briefly concludes.

[4] Raj's arrest can be useful for other applications. The introduction of the SEC Whistleblower Program is often used to lessen the selection bias in prosecuted insider cases (e.g., Kacperczyk, and Pagnotta (2019)); however, this program was launched in July 2010, nine months after Raj's arrest, when most investors were already on high alert.

2. Data and main variables

We combine several datasets. Most importantly, the open-close data from CBOE and ISE let us extract the information content of option trades. Pan and Poteshman (2006) pioneered the use of (CBOE) open-close data that identify trade direction, size, investor type, and distinguish between trades that open and close positions. Relying on these rich data, they document informed trading in the equity options by showing that the put-call ratio, that we define below, predicts stock returns. We follow their methodology and obtain similar open-close data from CBOE and ISE, the two largest option exchanges at the time. CBOE and ISE accounted for 33% and 29% of total option volume in 2006. The open-close data only account for the trades executed at a given exchange. Therefore, we study CBOE and ISE put-call ratios separately, to validate the results over two semi-independent signals. The sample period covers 12 years; it starts in May 2005, due to the availability of ISE data, and ends in May 2017. We are not aware of any other paper that studies these two datasets jointly.

The open-close data follow the same format at both exchanges. Exchanges split its daily option volume for each option contract into trades of public customers and firms. “Customer” can be any public account, ranging from retail investors to largest hedge funds. “Firm” is an OCC clearing member firm proprietary account (e.g., Morgan Stanley). Customer trades are further split by volume into small (1-100), medium (101-199), and large (200+) trades. “Small” + “customer” category dominates the rest by trading activity. As both customer and firm categories can trade on insider information, we combine trade volume by both categories and all trades sizes.[5] For each option contract, trader type, and trade size bucket, the data are further split into four categories: volume from buy orders that opens new positions (open-buy volume), volume from sell orders that opens new positions (open-sell volume), volume from buy orders that closes existing positions (close-buy volume), and volume from sell orders that closes existing positions (close-sell volume). These categories show investor’s intent and cannot be inferred from regular intraday option data.

Pan and Poteshman (2006) introduce the put-call ratio. For a given stock and date, they compute the put-call ratio as the open-buy put volume (across all puts) divided by the open-buy call volume (across all calls). We modify the original put-call ratio slightly by adding small volume

[5] In later years, both CBOE and ISE further split investor types. Since 10/2009, ISE broke firm trades into Broker/Dealer and Proprietary and added Professional Customers as a subcategory of customer trades. Similarly, since 01/2011, CBOE added Broker-Dealer, Pro-customer, and Market Maker categories. To compute the put-call ratio, we aggregate all non-market-maker categories.

ε = 5 contracts to both put and call volumes, which avoids the division-by-zero problem and shrinks the ratio to 0.5 if option volume is tiny. Since our analysis focuses mainly on top and bottom decile portfolios, the shrinkage adjustment ensures that only stock-days with sufficient option volume appear in these portfolios. Shrinkage is a standard statistical technique and often performs better than the unshrunk statistics. Overall, we define the open-buy put-call ratio as

$$PC_{i,t} = \frac{(OBP_{i,t} + \varepsilon)}{(OBP_{i,t} + \varepsilon) + (OBC_{i,t} + \varepsilon)}, \tag{1}$$

where OBC (OBP) is the open-buy call (open-buy put) volume for stock *i* on day *t*. The ratio is between zero and one. If an investor buys a put to open a new position, this purchase increases the put-call ratio and signals lower future stock returns. Similarly, buying a call is a positive return signal and decreases the ratio. Thus, if option trades are informed, the ratio will negatively predict stock returns. To earn positive returns, the long-short strategy buys a low put-call ratio portfolio and sells a high put-call ratio portfolio. For some tests, we compute a similar ratio based on close-buy trades to serve as a control group; option buys that open new position are much more informed than buys that close old positions, which we confirm.

We limit our sample to stocks in S&P 500 index identified using the index files from CRSP. S&P 500 stocks provide us with a consistent sample to compare stock return predictability over time. We also require that CBOE and ISE option volumes are positive for a given stock and day. The final sample includes 1,123,573 stock-days and 3,018 days between May 2005 and May 2017. The number of stocks varies from 278 to 434 per day with the average of 372.3.

[Table 1 is here]

Panel A of Table 1 reports summary statistics. Open-buy and close-buy put-call ratios are 0.42 to 0.45 on average. The average ratios are slightly below 0.5 because calls are traded more actively than puts. Median capitalization is 15 billion dollars as we study mega-cap stocks (S&P 500 constituents). The average weekly return remains positive, 0.22%, despite the financial crisis.

Panel B of Table 1 reports correlations between the put-call ratios. As expected, CBOE and ISE ratios are positively correlated, but the correlation is only 0.36. Thus, the two signals provide a lot of independent information, hence we study the CBOE and ISE ratios separately. As expected, ratios from the same exchange are more correlated than ratios from different exchanges; and close-buy and open-buy ratios are less correlated than ratios of the same buy type. Relatedly, Muravyev (2016) shows that order imbalances computed from public OPRA data (analog of TAQ, which contain option trades and NBBO quotes) are only weakly correlated with order imbalances computed from the open-close data.

We supplement the open-close data with several standard datasets. Stock returns are from CRSP. Daily returns are adjusted for delisting and aggregated to the required horizon (e.g., weekly). We focus on predicting weekly returns, which correspond to days $t+2$ to $t+6$ relative to the put-call ratio signal from day t. We skip a day between the signal and returns to avoid non-tradable microstructure effects, such as the bid-ask bounce. The Fama-French and momentum factors are from Kenneth French's data library. Firm fundamentals are from Compustat. Unscheduled news events are from RavenPack and include 56,809 news through December 2015. On average, there are about 21.9 news per day in our sample of optionable S&P 500 stocks.

3. Return predictability before and after the arrest

In this section, we study how the put-call ratio predicts stock returns pre- and post-arrest.

3.1 Predictability before the arrest

We first explain the methodology and then present the return predictability results. We focus on the portfolio analysis because insiders likely have private information about only few stocks at a given time. Each trading day, we sort stocks into decile portfolios based on the put-call ratio (for CBOE or ISE) defined in Equation (1). We then compute equally weighted portfolio returns over next week. Portfolio returns are converted into alphas with the four-factor Fama-French model that includes the momentum factor. Put (call) purchases are a negative (positive) signal, thus, the strategy buys (sells) stocks with low (high) put-call open-buy ratio to earn positive returns. Specifically, it sells stocks in the top decile and buys stocks in the bottom decile. Each day, we replace one-fifth of the long-short portfolio and hold the newly added stocks for one week (five trading days); Jegadeesh and Titman (2001) introduce a similar rotation approach for the classic momentum strategy.

The put-call ratios from CBOE and ISE predict returns for S&P 500 stocks extremely well in the pre-arrest period (between May 2005 and October 2009). Table 2 shows the performance for the long-short strategy for the put-call ratios from CBOE and ISE in Panels A and B. This strategy earns alphas of 23.8 basis points (pbs) and 23.5 pbs per week for CBOE and ISE signals, respectively, or 12.0% per year.[6] The alphas are highly statistically significant with *t*-statistics of 3.81 and 3.77, respectively. The Sharpe ratios are 1.76 and 1.67, much higher than a 0.04 Sharpe for the strategy that buys and holds S&P 500 index during this period. Figure 2 shows cumulative returns for the long-short strategy and indicate that the predictability remains remarkably stable even during the 2008 financial crisis. In fact, the returns are positive in every calendar year.

[Table 2 and Figure 1 are here]

The return predictability remains strong beyond the first week. For ISE, the 23.5 bps alpha next week decreases to 15.5 bps in week two, to 12.7 bps in weeks three to four, and to 10.5 bps in weeks five to eight. Even for the later period, the alpha remains statistically significant with *t*-statistics of 2.3. We find similar results for the put-call ratio from CBOE. To supplement Table 2, Figure 2 shows the pre-arrest alphas for different horizons and their confidence intervals. These results are consistent with option investors having information not only about return direction but also about return timing.

[Figure 2 is here]

Fama-MacBeth regressions confirm the portfolio results. Unlike the long-short strategy that focuses on stocks in extreme deciles, Fama-MacBeth regressions weighs all stocks equally and controls for standard return predictors. Log of market capitalization controls for size. CAPM beta is computed from daily returns over the prior year. Amihud illiquidity is computed as an average over a month of the daily ratio of absolute return divided by trading volume. Idiosyncratic volatility is standard deviation of daily residuals from the three factor Fama-French model over the prior month. Stock reversal is computed as stock return over the prior month. We also include two lags of daily stock returns to control for daily reversal. Momentum is the prior six-month return excluding the prior month, so that it does not interfere with the reversal.

[Table 4 is here]

Table 4 reports Fama-MacBeth regression results and shows that both CBOE and ISE ratios robustly predict returns with the *t*-statistics of -2.69 and -4.54. The negative sign means that, as

[6] We can try to compare our pre-arrest results with Pan and Poteshman (2006), who also find that the put-call ratio strongly predicts returns between 1990 and 2001. They rely mainly on univariate Fama-MacBeth regressions as few stocks had active options during their sample. If we try to convert their estimates to make them comparable to long-short portfolios that we construct, they find a weekly alpha of about 0.5%. This alpha is higher than 0.24% that we find for S&P 500 stocks perhaps because the stock and option markets were less integrated during 1990-2001.

expected, high put-call ratio (high put buying) negatively predicts returns. A two-standard deviation increase in ISE ratio corresponds to a 12 bps lower returns next week (6.3% annualized). The economic magnitudes are smaller than for portfolio sorts because most informed trading is concentrated in top/bottom portfolios, which why most of the paper focuses on the portfolio sort analysis. In untabulated results, we also confirm that the put-call ratio predicts returns beyond next week in these regressions. Finally, none of the standard predictors that we control for in these regressions are consistently significant in our sample of S&P 500 stocks.

Figure 1 shows how the cumulative return trajectories from trading on CBOE and ISE ratios strongly co-move. Thus, option informed investors usually do not cluster at a particular option exchange. Indeed, options on all S&P 500 stocks are traded on every major option exchange, and brokers must send market orders to whichever exchange quotes the best price unless specifically instructed otherwise. In contrast to open-buy trades, the ratios based on close-buy trades do not predict returns (the dashed lines in the figure). While both open-buy and close-buy ratios rely on buy trades, the intentions differ: opening trades are often leveraged bets on the stock, while closing trades are typically motivated by profit taking and other liquidity reasons.

What can explain this remarkable return predictability? The risk-based explanations struggle to explain it. The long-short strategy returns are unaffected by risk-adjustment; and it is hard to justify why some S&P 500 stocks earn 12% per year more than other broadly similar stocks. In fact, the put-call ratio is the biggest stock anomaly for the sample of S&P 500 stocks. Trading and shorting costs also cannot explain the predictability. S&P 500 stocks are always easy to short because of the ample supply from S&P 500 index funds. Furthermore, in untabulated results, we show that alpha comes primarily from the long side that requires buying a stock. Similarly, trading costs are low for S&P 500 stocks; institutional investors, who rely on execution algorithms, estimate the costs of trading S&P 500 stocks at about 6 bps. (Frazzini, Israel, and Moskowitz (2018)).

Pan and Poteshman (2006) interpret their results as “strong and unambiguous evidence that there is informed trading in the option market,” and “the predictability appears to be driven by valuable nonpublic information which traders bring to the option market.” Building on their work, we identify the source of “valuable nonpublic information.” Investors can either extract nonpublic signals from public data or obtain nonpublic information directly from corporate insiders. While the former is legal, the latter is typically illegal. Distinguishing between these two channels is hard because investors hide the source of their information edge to preserve alpha. Luckily, a major shock to insider trading enforcement occurred during our sample period. Investors who trade on public information will not respond to the insider enforcement campaign, while investors who trade on nonpublic information will cut their trading. We test this hypothesis in the next section.

3.2 Predictability after the arrest

We repeat the analysis of the last section for the post-arrest period and compare the results to the pre-arrest period. The put-call ratio was the strongest return predictor for S&P 500 stocks pre-arrest. But this predictability suddenly disappeared after Raj Rajaratnam's arrest on October 16, 2009. Table 2 show that the long-short alpha for put-call ratio from ISE drops from 23.5 pbs per week pre-arrest (t-statistics of 3.8) to -1.3 bps post-arrest (t-statistics of -0.6). Similarly, alphas for CBOE ratio and for other return horizons also drop to near zero. Figure 2 highlights the discontinuity in weekly alphas pre- and post-arrest. Pre-arrest alphas are statistically significant up to two months while none of post-arrest alphas are significant and range from -4.4 bps to 1.3 bps. Similarly, for Fama-MacBeth regressions in Table 4, the coefficient for the put-call ratio from ISE (CBOE) drops from -0.20 to 0.01 (from -0.13 to 0.03) post-arrest and is insignificant. Suddenly, option trades are no longer informative about future stock returns.

The long-short strategy stopped generating abnormal returns shortly after Raj's arrest. To highlight the discontinuity in predictability, we study a short window around the arrest – two years before and after the arrest – and report the results in Table 3. The predictability drops from 33.6 and 28.2 bps for CBOE and ISE pre-arrest to -6.0 and -2.9 bps post-arrest, and the difference is statistically significant despite the short subsample. In contrast, the put-call ratio based on close-buy volume, which is mostly uninformed, does not predict returns pre- and post-arrest. In this difference-in-difference analysis, we compare predictability in a short window pre- and post-arrest and use non-information motivated option buys as a control group.

[Table 3 is here]

These results are consistent with the insider trading hypothesis. The return predictability was strong because option investors traded on insider information. The predictability disappeared post-arrest because option investors refrained from trading on insider information scared by the spike in the prosecution intentsity.

Trading volume. After establishing our main result that the return predictability disappeared post-arrest, we further test the insider trading hypothesis. If informed trading constituted a large fraction of open-buy option volume and if those investors withdrew from the market, then option volume would have dropped. We test and confirm this hypothesis in two ways. We first consider the total open-buy option volume aggregated across all S&P 500 stocks. Figure 3 shows that the volume peaked shortly before Raj's arrest for both ISE and CBOE. Specifically, the aggregate open-buy volume for ISE peaked at 2,200 contracts shortly before the arrest and then declined to about 1,000 next year as investors arguably realized the full extent of the enforcement campaign. Similarly, the open-buy volume for CBOE peaked at 1,700 contracts pre-arrest and then gradually declined to about 1,000 contracts in the next two years.

[Figure 3 is here]

To address the concern that option volume is skewed towards few large tech stocks, we also estimate panel regressions that weigh stocks equally. Specifically, we regress a log of open-buy volume (we add one to volume to avoid the log of zero) on stock fixed effects, the time trend, and the interaction between the time trend and the post-arrest indicator. The interaction coefficient tells us how the time trend changes after the arrest. The coefficient for the time trend reflects growth rate for volume pre-arrest, and the sum of the coefficients for time trend and the interaction term reflect volume growth rate post-arrest.

Table 5 shows that the open-buy option volume was increasing by about 15% per year for CBOE and was flat for ISE before Raj's arrest. This trend changed radically (and statistically significantly) after the arrest – the volume started to decrease by 16% and 27% per year for CBOE and ISE. Across both exchanges, volume was *increasing* by 4.5% per year pre-arrest and was *decreasing* by 21% post-arrest. These results are consistent with the hypothesis that informed investors stopped buying options. Did option insiders stop trading options, or did they switch from options to the underlying stock market? The evidence is more consistent with the quit-options hypothesis. The last column in Table 5 reports, that the stock dollar volume was increasing by 5.1% per year, but this growth slowed down to 1.8% post-arrest.

[Table 5 is here]

Predictability and option leverage. Informed investors are attracted to options by their high leverage. Thus, we expect the return predictability to originate primarily from volume in out-of-the-money (OTM) options that have particularly high leverage rather than from in-the-money (ITM) options. To confirm this hypothesis, we split option contracts into two groups, OTM and ITM, based on whether the stock price is above or below the strike price. A put (call) is OTM if the stock price is above (below) the strike price. About 65% of option volume is classified as OTM, and the remaining 35% as ITM according to this definition. We compute the put-call ratios following Equation (1) separately for OTM and ITM options and then compare how the ratios predict returns two years before and after Raj's arrest using the difference-in-difference framework in Table 3.

[Table 6 is here]

Table 6 shows that the predictability originates solely from trading in OTM options. The long-short strategy based on the OTM ratio earns 0.36% and 0.32% per week before the arrest, and then the predictability completely disappears after the arrest. In contrast, the ITM ratio is not a significant predictor and if anything has the "wrong" sign. The results are very similar for CBOE and ISE. These findings suggest that informed investors are indeed attracted to OTM options and their high leverage and rarely trade ITM options.

Predictability around news. In most of the prosecuted insider cases, insiders traded shortly before important stock-specific news such as earnings and M&A announcements. The insider trading hypothesis implies that the put-call ratio should predict returns on news days particularly well. In contrast, the predictability should be weaker during periods without news. The intuition is simple, regular investors do not know about the unscheduled news in advance, but insiders may know the timing of some news.

We test this hypothesis using a comprehensive sample of unscheduled news. Specifically, we sort stocks into quintiles on the put-call ratio and label stocks with upcoming news as "news stocks." We set the news indicator to one if news occurs in the first day of weekly return to avoid double-counting. We sort news and no-news stocks jointly, but then compute long-short returns for news and no-news stocks in the top/bottom quintile separately. The average number of stocks with news is 21.9 per day with about four news stocks in each quintile on average.

[Table 7 and Figure 4 are here]

Table 7 reports long-short portfolio returns around news. Trading on the put-call ratio signal before news produces three times higher return than trading on the ratio prior to weeks without news – 40.4 pbs per week versus 13.6 bps for CBOE, and 49.5 bps versus 17.5 bps for ISE. However, post-arrest, the predictability on news weeks dropped more than four-fold to 9.0 and 7.2 bps for CBOE and ISE and became statistically insignificant with *t*-statistics of 0.89 and 0.77. Figure 4 plots cumulative returns from the long-short strategy (similar to Figure 1) and highlights that the news-based strategy stopped working almost exactly at Raj's arrest.

Overall, the predictability is concentrated on news weeks before Raj's arrest, and then it disappeared right after the arrest. This result further supports the hypothesis that insider trading rather than regular informed trading is responsible for the return predictability. Indeed, regular informed investors do not know the timing of unscheduled news and thus cannot time their trades before news. In contrast, insiders typically have a good idea about when insider information will be released to the public. Thus, insider trading likely explains why the put-call ratio predicts returns primarily around unscheduled news.

3.3 Other results

Market reaction to the arrest. Finally, we document that Raj's arrest shocked investors and affected the aggregate stock market. Figure 5 shows that S&P 500 E-mini futures dropped in response to the arrest. It plots the cumulative returns for the front-month futures contract from 6:00 pm on 10/15/2009 (pre-arrest day) to 4:00 pm on 10/16/2009 (arrest day). The returns are computed relative to 6:20 am, the approximate time of the arrest.[7] The market was flat through the night but dropped by 0.6% between the arrest time and 7:00 am. The market continued to drop and reached a cumulative return of -1.2% by 10:00 am, shortly after the live press conference where the prosecutors announced the insider trading charges against Raj and his friends. Overall, S&P 500 index dropped significantly shortly after Raj's arrest, which indicates that investors were totally surprised by this event.

[Figure 5 is here]

Public versus private signal. Did arbitrageurs exploit the put-call ratio anomaly? While Pan and Poteshman (2006) results were well-known, the open-close data were not available for sale when they circulated their study. Thus, arbitrageurs could not construct and trade on the put-

[7] "At 6:00 am the following morning [October 16, 2009], the FBI cordoned off a portion of East Fifty-third Street, and a team of agents descended on Rajaratnam's Sutton Place duplex. A few minutes later, Kang came out with Rajaratnam in handcuffs." Kolhatkar (2018)

call ratio. Fortunately, CBOE and ISE started to sell the open-close data shortly after Pan and Poteshman published their study. The exchanges also backfilled the data for the pre-sale period.

Thus, we can study how the put-call ratio's profitability changed as investors could observe and trade on the ratio. Moreover, CBOE started to sell the data in July 2006, while ISE did so more than a year later in November 2007.[8] Thus, the CBOE ratio was public while the ISE ratio was private for more than a year, which makes for a particularly nice comparison. We break the period between the start of open-close ISE data and the start of the active phase of the financial crisis (August 2008) into three subperiods. Before July 2006, the put-call ratio was private for both exchanges. Between July 2006 and November 2007, investors could buy CBOE data but not ISE data. Finally, after November 2007, investors could observe both ratios.

The put-call ratio anomaly provides a rare opportunity to identify how arbitrageurs' trading affects anomaly profitability. For this anomaly, we know exactly when the data and thus the signal became available to arbitrageurs. We build on McLean and Pontiff (2016), who argue that anomalies become less profitable post-publication as investors learn about and trade on them. However, some arbitragers discover anomalies before academics. Thus, the analysis of publication dates cannot precisely identify how much anomalies attenuate due to arbitrager trading.

How quickly did arbitragers start trading on the put-call ratio? Strikingly, Table 8 shows that the put-call ratio's profitability was *not* affected by the availability of the open-close data. If anything, the long-short return increased slightly by 9.6 bps per week after CBOE started to sell the data. Similarly, the long-short returns for ISE ratio remained unchanged once ISE started to sell its data. However, the strongest results come from the comparison of CBOE and ISE ratios when one was public, and the other was private. Remarkably, CBOE and ISE ratios also earn the same return (22.2 versus 22.6 bps) when CBOE ratio was public while ISE ratio was private. These results indicate that even if some arbitrageurs traded on the put-call ratio, their trading did not affect its profitability.

[Table 8 here]

[8] According to the New York Times (link), CBOE started to sell the open-close data to the public in July 2006. ISE started to sell its open-close data in November 2007 (link) with data backfilled to May 2005. "The ISE Open/Close Trade Profile offering will allow investors to program extensive put/call data into their quantitative models and to monitor market activity at a highly granular level," said Jeff Soule, Head of Market Data at ISE. "We are pleased to introduce yet another market data offering that enables investment professionals to trade smarter."

Surprisingly, investors did not rush to exploit the put-call ratio despite its high profitability. Results of Pan and Poteshman (2006) were known among practitioners (e.g., they were featured in the New York Times), and the data subscriptions were reasonably priced (600 dollars per month). In fact, the predictability remained consistently high up until Raj's arrest in October 2009, more than *three years* after CBOE data became public. The predictability disappeared not because arbitrageurs suddenly started to aggressively exploit the put-call ratio but because the ratio lost its informational content as insiders stopped trading option on non-public information. Overall, we provide an important example of how and why an anomaly disappears for the anomaly literature.

Comparison with other stock anomalies. The put-call ratio strategy was by far the most consistent and strongest stock anomaly in the sample of S&P 500 stocks. S&P 500 is a difficult sample for stock anomalies because large stocks are typically efficiently priced. Stock anomalies are concentrated in small stocks and became much weaker in recent years.

We compare the put-call ratio to a comprehensive set of stock anomalies among S&P500 stocks during the pre-arrest period. This sample facilitates the comparison with the put-call ratio results above. Chen and Zimmermann (2021) replicated most of the known stock anomalies and generously shared the data on anomaly predictors at the stock-by-month level. We start with all predictors that they provide and only drop anomalies for which we have fewer than five stocks in the top and bottom decile portfolios on average. This filter eliminates mostly "discrete" anomalies, such as whether a stock did an IPO recently. Our final sample includes 154 anomalies. We sort stocks into decile portfolios and compute equally weighted returns over the next month. We are not aware of any other study that explores stock anomalies in the S&P 500 sample.

We find several notable results. First, the 154 stock anomalies that we study generate no alpha on average in our sample. The top decile portfolio outperforms the bottom decile by only 6 bps per month, which is not statistically different from zero.

Second, profitability varies greatly across anomalies, but top-minus-bottom returns are statistically different from zero for only two out of 154 anomalies. The sales growth over inventory growth by Abarbanell and Bushee (1998) earns abnormal returns of -0.70% per month with *t*-statistics of -1.99. The negative minus sign means that the predictability has as an opposite sign than in Abarbanell and Bushee (1998). The return seasonality for years 11 to 15 by Heston and Sadka (2008) earns abnormal returns of 0.91% per month with *t*-statistics of 2.59. Heston and

Sadka also suggest nine other modifications of their signal that did not perform nearly as well in our sample as the "years 11 to 15" version.

Finally, we would expect two anomalies out of 154 to be significant just by chance (false positives). If so, the profitability for these outlier anomalies would "converge to the mean," which is zero, out-of-sample. Indeed, the long-short returns for the two signals, the seasonality for years 11 to 15 and the sales growth over inventory growth signals, drop to zero and -0.10%, respectively, in the second part of our sample from November 2009 to May 2017. Overall, these results highlight that the put-call ratio's profitability is not only large in absolute terms but also relative to other stock anomalies evaluated on the same sample.

3.4 Discussion

In this section, we discuss the implications of our results. First, the predictability was large pre-arrest but suddenly disappeared post-arrest. Second, the predictability was concentrated in out-of-the-money options and before stock-specific news pre-arrest. Third, option volume that opens new positions peaked right before the arrest and declined post-arrest. Finally, S&P 500 index futures dropped by -0.6% within an hour after the arrest.

We first discuss the insider trading hypothesis and its implications and then move to other explanations. The explanation that is most consistent with our results is that informed trading in the options market was primarily driven by insider information. First, the alpha is huge pre-arrest. What information can consistently produce a 12.0% p.a. alpha within S&P500 stocks? Furthermore, this estimate is a lower bound on the alpha that informed investors obtain because sometimes the put-call ratio can be high due to uninformed trading, which produces no alpha. Pre-arrest, prosecutors focused on few cases against relatively minor investors; and thus, major investors felt relatively safe trading on insider information. Raj's arrest and subsequent actions by prosecutors clearly indicated that no one was safe post-arrest. This shift in enforcement scared investors, so that most of them discontinued trading on potentially insider information. Volume results confirm that fewer new option positions were opened. As a result, the put-call ratio stopped predicting returns. Although investors could keep trading on legal private information, such trading did not translate into meaningful predictability post-arrest. Thus, most of the informed trading was due to trading on illegal insider information.

Other explanations that we consider struggle to explain the results. First, following Pan and Poteshman (2006) we conduct numerous tests that reject the risk-based explanations. The predictability is large, not sensitive to the risk-adjustment, and stable through the pre-arrest period. Standard risk factors behave normally with regular returns around October 2009. Second, transaction costs are low for S&P 500 stocks and, thus, cannot explain abnormal returns. In any case, the costs do not speak to the original driver of the predictability. Third, maybe the format of the open-close data changed rather than the underlying informed trading. Such changes must be filled and approved by the SEC; we find only one small change from ISE (more investor subcategories for option volume) and no changes from CBOE in 2009. Also, we find very similar results for two independent datasets from CBOE and ISE.

We study by far the biggest shock to insider trading enforcement in the U.S. It was so large and consequential that many investors radically changed their behavior and stopped trading on insider information in the options market. Insider trading is very lucrative but is difficult to scale up or down on demand. Thus, insiders unlikely to react to small shocks in the environment, and once scared off, they may not revert to their prior behavior for a while. Such extreme shocks are rare, and we are fortunate to observe one during our sample. We wish we had comparable data that would let us study the major enforcement campaign in mid-1980s.

The important limitation of our study is that our sample period only covers one unprecedented insider trading campaign. Thus, we cannot completely rule out some of the alternative explanations. What if some other major event occurred around the same time and made option investors abruptly switch from trading on private information. But what could it be? In June 2009, the NBER officially declared the end of the Great Recession. The stock market mostly recovered after the crisis and the last quarter of 2009 was uneventful. Other studies of uniquely important events such as the financial crisis or the COVID pandemic face similar challenges. Hundreds of papers study those important events, while ours is the first to study the effect of Raj's arrest on insider trading.

Our results connect two broad literatures. Numerous papers study informed trading in the options market. We show that the main source of option investors' information edge was insider trading. The insider trading literature debates on how prevalent insider trading is. We show that insider trading was dominant in the options market, not just around certain events but for the entire market.

4. Conclusion

In this paper, we identify a major shock to illegal insider trading. The arrest of Raj Rajaratnam, a billionaire superstar hedge fund manager, launched the biggest enforcement campaign against insider trading in history and shocked the investor community. We focus on its effect on the options market and leave for future research to study its effect on other markets and outcome variables.

We find that option trades strongly predicted returns for S&P 500 stocks before the arrest. The put-call ratio generated a 0.24% weekly alpha, which is large compared to other return predictors within the universe of S&P 500 stocks. However, this impressive predictability abruptly and permanently disappeared shortly after the arrest. Moreover, option volume results indicate that investors opened fewer new option positions post-arrest. The results hold independently for option volume executed at ISE and CBOE and survive various robustness tests.

Our results are most consistent with the hypothesis that the return predictability induced by the put-call ratio was driven primarily by option trading on potentially illegal insider information. After Raj's arrest, option investors who traded on inside information realized the increased risks and quit trading options. While investors could still trade on legal private information, the lack of return predictability post-arrest indicates that trading on such information was not widespread in options. Remarkably, all the informed trading in options, a major financial market, appears to be fueled by insider information. Thus, insider trading is much more prevalent than previously thought or is implied by the number of the prosecuted cases. This paper's results improve our understanding of informed trading and insider trading in general.

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Figure 1

The figure shows cumulative returns for four strategies that trade S&P 500 stocks based on their option volume. Each strategy buys the bottom decile and sells the top decile of stocks sorted based on the put-call ratio signal (the put-call ratio predicts returns negatively). The strategies skip a day between the signal and portfolio formation. Blue (green) lines correspond to option volume executed at CBOE (ISE). Solid (dashed) lines denote option volume that opens new (closes old) positions. The grey area denotes the period from October 16, 2009 (Raj's arrest) to November 19, 2010 (WSJ article that reveals the attack on SAC Capital), when investors gradually realized the campaign against insider trading was launched.

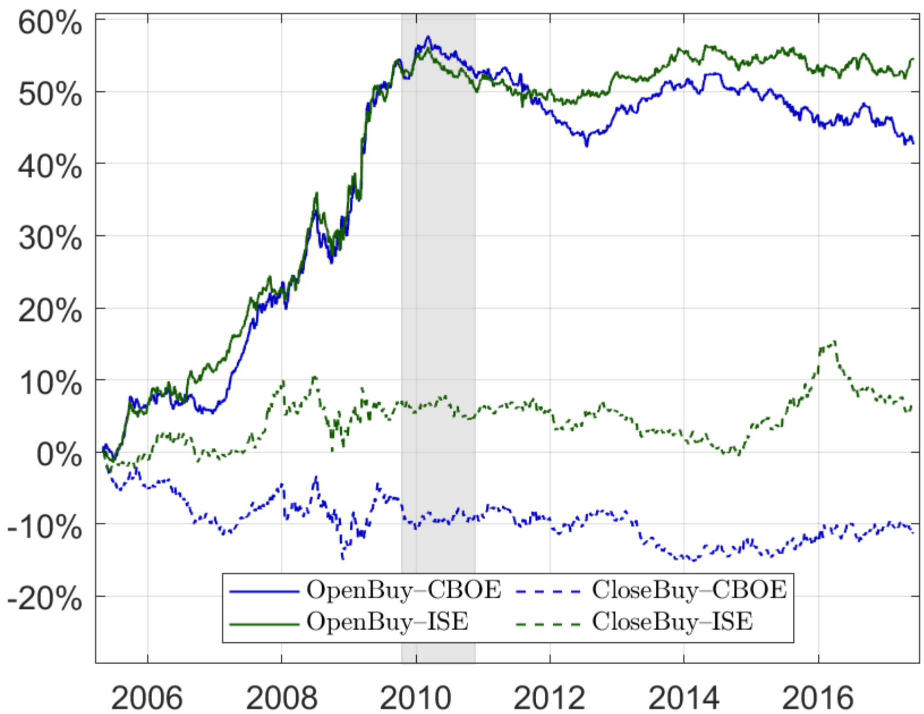

Figure 2
The figure compares alphas of the long-short strategy before and after Raj's arrest on October 16, 2009. The long-short strategy buys (sells) stocks with low (high) put-call open-buy ratio (OB). Alphas are computed with respect to the four-factor Fama-French model. Blue (green) bars denote alphas for the put-call ratio from CBOE (ISE). Alphas are in basis points per week. We report alphas for four non-overlapping horizons: next week (1w), week two (2w), weeks three and four (1m), and weeks five through eight (2m). We skip a day between the signal and portfolio formation. The error bars denote the 2.5% to 97.5% confidence intervals.

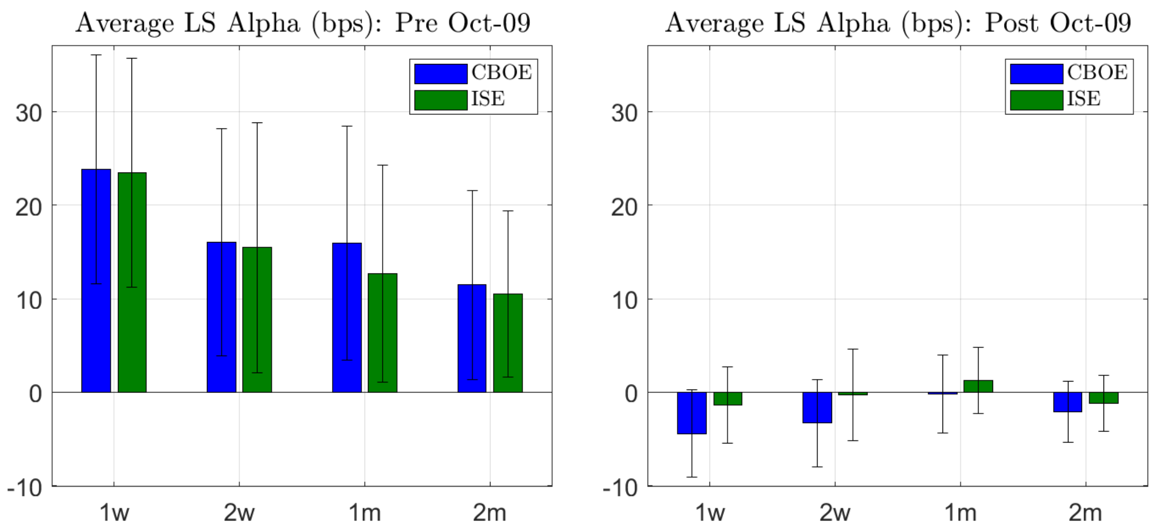

Figure 3
The figure plots the open-buy option volume at CBOE (blue line) and ISE (green line). Each day we sum contract volume across options on S&P 500 stocks that pass the filters described in Section 2. We plot 3-month moving averages of CBOE and ISE open-buy volume. The grey area denotes the period from October 16, 2009, to November 19, 2010, when investors gradually realized the campaign against insider trading was launched.

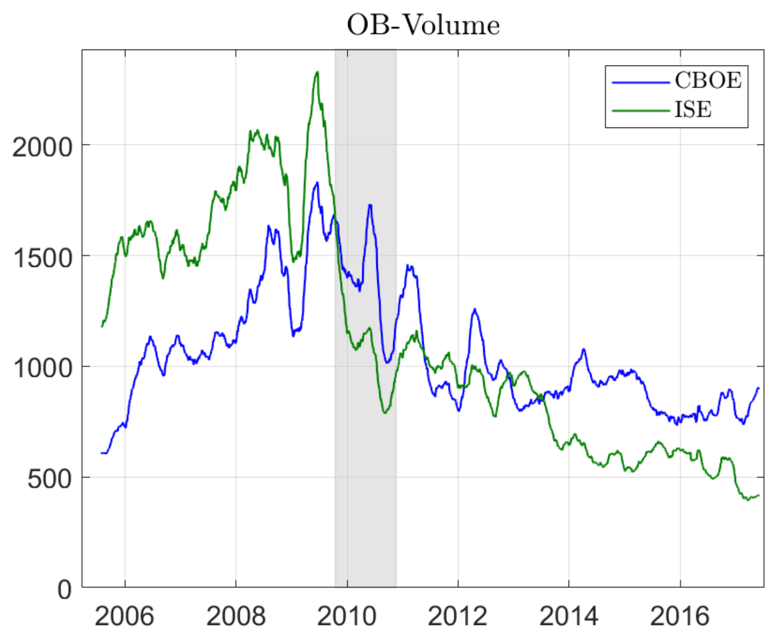

Figure 4
The figure studies the predictability by the put-call ratio around news. Each day, the stocks are sorted based on the put-call ratio for the open-buy volume from either CBOE or ISE. Similar to Figure 2, we sort stocks into quantiles based on their put-call ratio on a given day. We then form "news" and "no-news" portfolios from the top/bottom quantile for stocks with and without subsequent news, respectively. For example, "News" strategy buys the news stocks from the bottom quintile and sell the news stocks from the top quintile, while "No News" strategy does the same for the no-news stocks from the extreme quintiles. On rare days, the top or bottom quintiles might have zero news stocks, in which case the return for that day is set to zero. The grey area denotes the period from October 16, 2009 (Raj's arrest) to November 19, 2010.

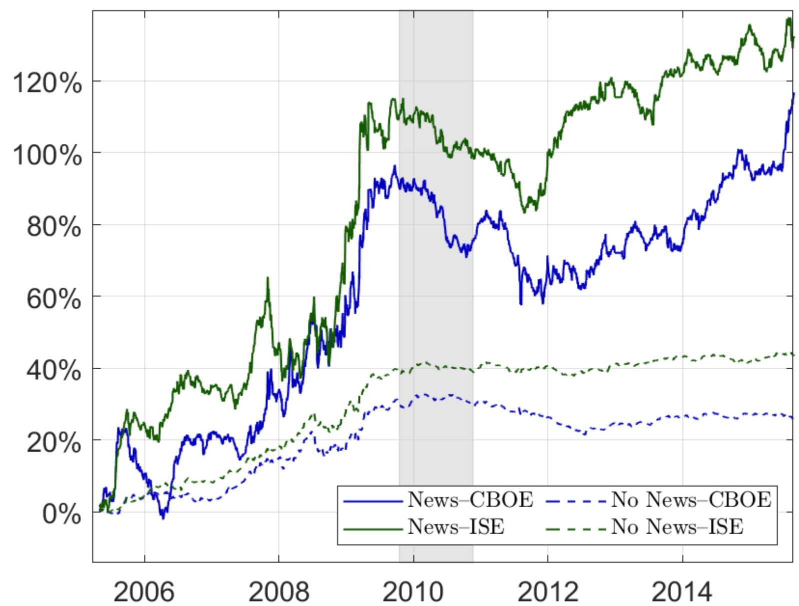

Figure 5
This figure shows the cumulative returns of S&P 500 E-mini future on 10/16/2009, the day that Raj Rajaratnam was arrested. Raj was arrested in his Manhattan apartment around 6:20 am, which is marked with pink vertical line. Cumulative returns are reset at zero at this time to help quantify market decline after the arrest.

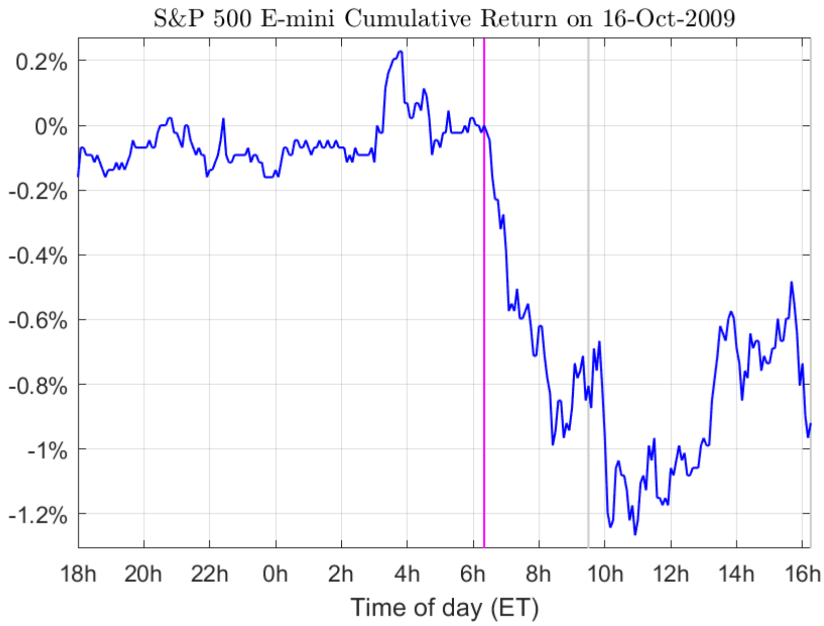

Table 1
Panel A. Summary statistics
This panel reports summary statistics: average, standard deviation, minimum, several percentiles, and maximum. The statistics are computed over a pooled day-by-stock panel. The first two letters OB (CB) stand for open-buy (close-buy). The last letter C (I) stands for CBOE (ISE). E.g., OBC is the put-call ratio based on open-buy option volume at CBOE. For a given date and stock, the put-call ratio is computed as the open-buy put volume divided by the open-buy call volume (see Equation 1). We limit the sample to S&P 500 stocks. The final sample includes 1,123,573 stock-days and 3,018 days. The number of stocks per day varies between 278 and 434 with the average of 372.3.

Variable	Mean	Std. Dev.	Min	5%	50%	95%	Max
OBC	0.42	0.27	0.00	0.04	0.42	0.91	1.00
OBI	0.45	0.27	0.00	0.03	0.46	0.93	1.00
CBC	0.44	0.25	0.00	0.05	0.44	0.89	1.00
CBI	0.44	0.25	0.00	0.05	0.46	0.90	1.00
MCap ($ Bln)	31.68	51.63	0.15	3.06	14.78	128.27	813.88
Ret1w (%)	0.22	5.17	-98.52	-7.14	0.26	7.29	295.12
Ret1m (%)	0.93	10.15	-99.29	-14.16	1.10	15.02	339.14

Panel B. Correlations
This panel reports correlations for the put-call ratios computed from open-buy and open-sell option volume executed at CBOE and ISE.

	OBC	OBI	CBC	CBI
OBC	1.00			
OBI	0.36	1.00		
CBC	0.20	0.09	1.00	
CBI	0.10	0.19	0.25	1.00

Table 2
The put-call ratio profitability before and after Raj's arrest
The table compares alphas of the long-short strategy before (Panel A) and after (Panel B) October 16, 2009, the day Raj Rajaratnam was arrested. The strategy buys (sells) stocks with low (high) put-call open-buy ratio. Alphas are computed with respect to the four-factor Fama-French model. Alphas are in basis points per week (e.g., 23.95 is 0.2395%). We report alphas for four non-overlapping horizons: next week (1w), week two (2w), weeks three and four (3-4w), and weeks five through eight (2m). We skip a day between the signal and portfolio formation.

Panel A. The put-call ratio for the open-buy volume from **CBOE**

	Pre Oct-2009				Post Oct-2009			
OBC	1w	2w	3-4w	2m	1w	2w	3-4w	2m
Return, bps	23.95	15.84	15.90	11.92	-2.80	-1.38	2.05	-0.62
Alpha, bps	23.82	16.02	15.97	11.46	-4.35	-3.34	-0.23	-2.05
t-statistics	3.81	2.60	2.50	2.23	-1.82	-1.40	-0.11	-1.24
Sharpe Ratio	1.76	1.17	1.10	0.98	-0.42	-0.20	0.33	-0.14

Panel B. The put-call ratio for the open-buy volume from **ISE**

	Pre Oct-2009				Post Oct-2009			
OBI	1w	2w	3-4w	2m	1w	2w	3-4w	2m
Return, bps	23.62	15.42	12.84	10.89	0.49	0.72	2.34	0.06
Alpha, bps	23.45	15.48	12.68	10.52	-1.25	-0.33	1.25	-1.15
t-statistics	3.77	2.27	2.14	2.33	-0.60	-0.13	0.69	-0.76
Sharpe Ratio	1.67	1.04	0.96	1.03	0.09	0.10	0.49	0.02

Table 3
The put-call ratio profitability shortly before and after Raj's arrest
The table compares alphas for the long-short strategy based on put-call ratios in a short window around Raj's arrest – two years before and after. We consider four put-call ratios based on open-buy volume for CBOE and ISE (OBC and OBI) and close-buy volume for CBOE and ISE (CBC and CBI). The latter two signals serve for comparison as closing trades are known to be much less informed than opening trades. The last column reports the difference between "After" and "Before". Alphas are computed with respect to the four-factor Fama-French model. Alphas are in basis points per week (e.g., 33.55 is 0.3355%). *t*-statistics are based on Newey-West standard errors with 21 lags and reported in squared brackets.

	Before	After	A.-B.
OBC	33.55	-5.95	-39.51
	[2.94]	[-1.11]	[-3.17]
OBI	28.20	-2.90	-31.10
	[2.17]	[-0.63]	[-2.26]
CBC	-1.47	-1.04	0.43
	[-0.15]	[-0.23]	[0.04]
CBI	2.05	0.03	-2.02
	[0.22]	[0.01]	[-0.20]

Table 4

Fama-MacBeth regressions for the put-call ratio before and after Raj's arrest

We consider two put-call ratios based on open-buy volume for CBOE and ISE (OBC and OBI). Controls include log of market capitalization, CAPM beta, Amihud illiquidity, idiosyncratic volatility, previous month return (reversal), return in the last six months excluding the previous month (momentum), and two lags of daily stock returns. "Before" and "After" samples are relative to 16-Oct-2009 and include 1119 and 1899 trading days, respectively. *t*-statistics are based on Newey-West standard errors with 21 lags and reported in squared brackets. Adjusted R^2 for the first column is 14.95%.

	Before	After	Diff.	Before	After	Diff.	Before	After	Diff.
OBC	-0.13	0.03	0.17				-0.07	0.04	0.11
	[-2.69]	[1.54]	[3.10]				[-1.55]	[1.78]	[2.18]
OBI				-0.20	0.01	0.21	-0.18	-0.01	0.17
				[-4.54]	[0.30]	[4.30]	[-4.83]	[-0.37]	[4.19]
Controls	+	+		+	+		+	+	
R^2, %	14.95	11.79		14.90	11.79		14.98	11.81	
N, days	1,119	1,899		1,119	1,899		1,119	1,899	

Table 5
Option volume around Raj's arrest
This table studies how open-buy option volume changes around Raj's arrest. We estimate a panel regression of log open-buy volume on the time trend (years since the start of the sample, "Trend"), its interaction with the post-arrest indicator ("After"), and stock fixed effects:

$$\log(1 + OB\ Volume)_{i,t} = c_{i,t} + \alpha_1 * Trend + \alpha_1 * Trend * After + \epsilon_{i,t},$$

"OB Volume" is the total open-buy volume (puts plus calls) for a given stock and day. We estimate three regressions for option volume executed on CBOE, ISE, and for the combined volume at the two exchanges. The volume was increasing before the arrest but reversed the trend after the arrest. The last column estimates and reports a similar regression for the underlying (dollar) stock volume. *t*-statistics are double-clustered and reported in squared brackets. Adjusted R^2 for the first column is 3.5%.

	log (1+OB Volume)			log (1+ $ Stock Volume)
	CBOE	ISE	All	
Trend	0.154***	-0.031*	0.045***	0.051***
	[8.94]	[-1.81]	[2.88]	[6.48]
Trend*After	-0.320***	-0.242***	-0.258***	-0.033***
	[-15.14]	[-11.13]	[-13.24]	[-3.29]
Stock FE	+	+	+	+
R^2	0.035	0.107	0.078	0.025
# Obs.	1,123,573	1,123,573	1,123,573	1,123,569

Table 6
The put-call ratio profitability for OTM versus ITM options
We split all options into out-of-the-money and in-the-money based on the whether the stock price is above or below the strike price. The table compares alphas for the long-short strategy based on put-call ratios computed from OTM and ITM options two-years pre- and post-arrest (similar to Table 3). We consider four open-buy put-call ratios for CBOE and ISE computed for OTM or ITM options. E.g., OBC-OTM is the ratio computed from CBOE OTM puts and calls. The last column reports the difference between "After" and "Before". Alphas are computed with respect to the four-factor Fama-French model and are in basis points per week (e.g., 35.97 means 35.97%). *t*-statistics are based on Newey-West standard errors with 21 lags and are reported in squared brackets.

	Before	After	A.-B.
OBC-OTM	35.97	-0.98	-36.95
	[2.45]	[-0.19]	[-2.38]
OBI-OTM	32.32	0.75	-31.57
	[2.52]	[0.15]	[-2.31]
OBC-ITM	-22.24	-2.13	20.11
	[-1.12]	[-0.32]	[0.96]
OBI-ITM	-21.44	-6.17	15.28
	[-1.12]	[-0.90]	[0.75]

Table 7
Return predictability before news

The table compares weekly returns for the long-short strategy based on put-call ratios with and without subsequent news. Returns are compared separately for CBOE and ISE signals, before and after Raj's arrest. "Before" and "After" samples are relative to 16-Oct-2009 and include 1119 and 1473 trading days, respectively. The last column reports the difference between "After" and "Before". Returns are in basis points per week. *t*-statistics are based on Newey-West standard errors with 21 lags and reported in squared brackets.

	CBOE			ISE		
	Before	After	A.-B.	Before	After	A.-B.
News	40.37	8.96	-31.41	49.49	7.27	-42.22
	[2.19]	[0.89]	[-1.49]	[2.45]	[0.77]	[-1.89]
No News	13.61	-1.34	-14.95	17.50	1.51	-15.99
	[2.77]	[-0.66]	[-2.83]	[4.11]	[0.79]	[-3.43]
News – No News	26.76	10.30	-16.46	31.99	5.76	-26.22
	[1.60]	[1.02]	[-0.84]	[1.73]	[0.60]	[-1.26]

Table 8

The put-call ratio profitability before and after the put-call ratio became public

The put-call ratio cannot be computed without the open-close data. CBOE and ISE started to sell the open-close data in July 2006 and November 2007, respectively. How did the predictability change once investors could compute and trade on the ratio? The table reports long-short weekly returns for the open-buy ratios from CBOE and ISE (OBC and OBI) and three non-overlapping periods. The "no data for sale" period is between May 2, 2005 (the start of ISE data) and July 19, 2006 (CBOE starts to sell the data). The "CBOE only" period is between July 20, 2006, and November 13, 2007 (ISE starts to sell the data). The "CBOE and ISE" period is between November 14, 2007, and August 31, 2008 (the start of the active phase of the financial crisis). Dark (light) grey color denotes the period when given data is (not) available to investors. The last row reports the difference between before and after given the data became available to investors. The last column reports the difference between ISE and CBOE. Returns are in basis points per week (e.g., 10.99 means 0.1099%). *t*-statistics are based on Newey-West standard errors with 21 lags and reported in squared brackets.

	Num. Days	OBC	OBI	OBI - OBC
No data for sale	307	10.99	11.82	0.83
		[1.24]	[1.42]	[0.14]
CBOE only	333	22.22	22.58	0.36
		[3.01]	[3.02]	[0.05]
CBOE and ISE	200	17.84	22.26	4.43
		[1.02]	[1.41]	[0.50]
After-Before		9.58	4.84	
		[0.80]	[0.29]	