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# Detecting abnormal trading activities in option markets

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We develop an econometric method to detect "abnormal trades" in option markets, i.e., trades which are not driven by liquidity motives. Abnormal trades are characterized by unusually large increments in open interest, trading volume, and option returns, and are not used for option hedging purposes. We use a multiple hypothesis testing technique to control for false discoveries in abnormal trades. We apply the method to 9.6 million of daily option prices.



## 1. Introduction

An important distinction of option trades is between liquidity and non-liquidity trades. The former is solely driven by liquidity shocks to option traders. The latter can be driven by various motives, including private information and hedging needs. Disentangling these option trades can potentially improve our understanding of the functioning of option markets.

This paper develops an econometric approach to detect certain non-liquidity option trades that we call *abnormal trades*. We define abnormal trades as unusual trades in option contracts which generate large gains, are not used for option hedging purposes, and are made a few days before the occurrence of a specific event.

We develop two statistical methods to detect abnormal trades. The first method uses only ex-ante information and aims to detect abnormal trades as soon as they take place. We look for option trades characterized by unusually large increments in open interest, i.e., number of outstanding contracts, which are close to daily trading volumes. In those cases the originator of such transactions is not interested in intraday speculations but has reasons for keeping her position for a longer period. As it turns out in our empirical study, the higher the increment in open interest and volume the higher the future return of the corresponding option. We refine the first method using a nonparametric test to check whether those option trades are hedged with the underlying asset or used for option hedging purposes. The second method uses also ex-post information and encompasses the first method by adding an additional criterion. An option trade is identified as abnormal when the increment in open interest and volume is unusual, not hedged (as in the first method), and generates large option gains.

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Our approach to detect option abnormal trading has two distinctive features: it controls for false discoveries in abnormal trades and accounts for option hedging. Addressing these issues is a challenging task. In any statistical method, the probability that any liquidity trade will appear to be abnormal simply by chance is not zero. This misclassification is induced by the Type I error in hypothesis testing, as the test of abnormal trade is repeated each day. However, this misclassification error can be formally quantified using multiple hypothesis testing techniques. Intuitively, liquidity trades should have zero return on average, while abnormal trades should have statistically large returns. Under the null hypothesis that all trades are liquidity trades, the proportion of lucky liquidity trades depends on the size of the test and can be calculated using option returns. When the difference between the actual fraction of large returns (due to abnormal and lucky trades) and the expected fraction of large returns due to lucky liquidity trades is statistically large, the test rejects the null hypothesis that all trades are liquidity trades.

We develop a nonparametric test to assess whether option hedging takes place or not. For example, when studying long positions in call options, the idea is to decompose the underlying stock seller-initiated trading volume in the hedging and non-hedging components. This decomposition is achieved using the theoretical amount of stock trading which would have been generated if no abnormal trading would have occurred. Then the test rejects the null hypothesis of absence of hedging when the hedging component is statistically large.

An obvious question at this stage is who originates abnormal trades. Although information on traders' identity is not available, it is conceivable that mainly informed traders are behind abnormal trades in call options. This conjecture would be consistent with the large returns generated by call option abnormal trades. For abnormal trades in put options the situation is different. Informed traders and/or corporate insiders hedging their human capital are most probably behind those trades.[1] Without knowing trader identities, it is not possible to disentangle whether put option abnormal trades are due to informed traders or corporate insiders hedging their human capital. We describe this situation as saying that we are testing a *joint hypothesis*.

We apply the two statistical methods to 9.6 million of daily option prices of 31 selected companies mainly from airline, banking and insurance sectors. Several millions of intraday stock price and volume data are also analyzed to assess whether an option trade is hedged or not. The sample period spans 14 years, from January 1996 to September 2009 (part of our sample ends in April 2006), and our analysis is at the level of individual option, rather than on the cross-section of stock returns.[2]

Our empirical findings can be summarized as follows. First, abnormal trades tend to cluster prior to certain events such as merger and acquisition (M&A) announcements, quarterly financial or earning related statements, the terrorist attacks of September 11th, and first announcements of financial disruptions of banking and insurance companies during the Subprime financial crisis 2007–2009. Second, prior to a particular event which will impact a particular company, abnormal trades can involve more than one option but rarely the cheapest option, i.e., deep out-of-the-money and with shortest maturity. Third, the majority of abnormal trades take place in put rather than call options. Fourth, estimated option gains of abnormal trades easily exceed several millions for a single event. Finally, the underlying stock price does not display any particular behavior on the day of the detected abnormal trade. Only some days later, for example when a negative company news is released, the stock price drops generating large gains in long put positions.

The paper is organized as follows. Section 2 reviews the related literature. Section 3 presents our method to detect abnormal trades. Section 4 describes the dataset. Section 5 summarizes the empirical results. Section 6 quantifies false discoveries in abnormal trades. Section 7 discusses various robustness checks. Section 8 concludes.

## 2. Related literature

Although we are testing a *joint hypothesis* for put options, abnormal trades can be related to informed trades which have been the subject of an extensive literature; see, e.g., Hasbrouck (1991), Easley and O'Hara (1992), Easley et al. (1998), Poteshman (2006), and Boulatov et al. (2013). As discussed in Grossman (1977), Diamond and Verrechia (1987), and others, option markets offer significant advantages to informed traders. Options provide potential downside protection, an alternative way of short selling when shorting stocks is expensive or forbidden, additional leverage which might not be possible in stock or bond markets (Biais and Hillion, 1994), and possibly more discreetness for trading on private signals. Indeed, Cao et al. (2005) show that call–volume imbalances prior to unscheduled takeover announcements are strongly related to stock returns on the announcement day. Pan and Poteshman (2006) report clear evidence that option trading volumes predict future price changes. Bali and Hovakimian (2009) show that the difference between realized and implied volatilities of individual stocks predicts the cross-sectional variation of expected returns. Cremers and Weibaum (2010) find that deviations from put–call parity contain information about future stock returns. Yan (2011) documents a negative relation between the slope of implied volatility smile and stock return. In these studies (and others), the analysis is systematically conducted at an aggregate level, e.g., extracting information from *all* current option prices, while we conduct the analysis at *individual* option contracts.

Stephan and Whaley (1990), Chan et al. (1993), Manaster and Rendleman (1982), and Lee and Yi (2001), among others, discuss why informed traders may consider options as superior trading vehicles. Our results show that option markets can offer significant

[1] Human capital can be defined as the sum of the present value of the future cash income, shares, stock options, etc., and it represents the most significant risk faced by corporate insiders especially senior managers. To the extent that it is legal, a long put option is probably the only liquid instrument that can be used by corporate insiders to hedge the risk attached to their human capital.

[2] As mentioned above, we rely on statistical methods to detect abnormal trades. Therefore, those trades will be abnormal only with a certain probability. For brevity, we refer to those trades simply as abnormal trades. Moreover, detected abnormal trades might or might not be legal. From a legal viewpoint this study does not constitute proof per se of illegal activities. Legal proof would require trader identities and their motivations, information which is not contained in our dataset.

profits to informed traders, lending empirical support to these studies. Chen et al. (2001) show that asset crashes can be predicted using shares trading volume. We complement this work by showing that certain increments in open interest and trading volume have predictive power for future movements in the underlying stock. Blume et al. (1994) and Vijh (1990) provide related studies on trading volume and information-related trading.

## 3. Detecting option abnormal trades

We propose two methods to detect option abnormal trades. The first method relies on a broad definition of an option abnormal trade, based on open interest and volume, and makes use only of ex-ante information. The second method is based on a more stringent definition of abnormal trades and uses ex-post information as well.

We now describe the second method with the first method being a special case. We define an option abnormal trade as follows: $C_1$) an unusual trade in an option contract, $C_2$) which is made a few days before the occurrence of a specific event and generates large gains in the following days, and $C_3$) the position is not hedged in the stock market and not used for option hedging purposes. These three characteristics, $C_i$, $i = 1, 2, 3$, lead to the following method to detect abnormal trading activities in option markets: first on each day the option contract with largest increment in open interest (i.e., number of outstanding contracts) and volume is identified, then the rate of return and dollar gain generated by this transaction are calculated, and finally it is studied whether option hedging occurs. Option trades which are delta hedged or used for option hedging purposes are not regarded as abnormal trades. The first method relies only on characteristics $C_1$ and $C_3$, and their practical implementation. Importantly, both methods require only commonly available data and thus can be easily used to detect abnormal trades in various option markets.

We now explain how to detect abnormal trades in call options. The application to put options can easily be deduced. In the empirical section, we apply both methods to a large dataset of call and put options.

### 3.1. First criterion: increment in open interest relative to volume

For every call option $k$ available at day $t$ we compute the difference $\Delta OI_t^k := OI_t^k - OI_{t-1}^k$, where $OI_t^k$ is its open interest at day $t$, and $:=$ means defined as. When the option does not exist at time $t - 1$, its open interest is set to zero. Since we are interested in unusual transactions, only the option with the largest increment in open interest is considered

$$X_t := \max_{k \in K_t} \Delta OI_t^k \tag{1}$$

where $K_t$ is the set of all call options available at day $t$. The motivation for using open interest is the following. Large trading volumes can emerge under various scenarios for example when the same call option is traded several times during the day or large sell orders are executed. In contrast large increments in open interest are usually originated by large buy orders. These increments also imply that other long investors are unwilling to close their positions forcing the dealer or market maker to issue new call options. Consequently, we use large increment in open interest as a proxy for large buy orders.

We focus on transactions for which the corresponding volume almost coincides with the increment in open interest. Let $V_t$ denote the daily trading volume corresponding to the call option selected in Eq. (1). The positive difference $Z_t := (V_t - X_t)$ provides a measure of how often the newly issued options are exchanged: the smaller the $Z_t$, the less the new options are traded during the day on which they are created. In that case the originator of such transactions is not interested in intraday speculations but has reasons for keeping her position for a longer period possibly waiting for the realization of future events.

This first criterion already allows us to identify single transactions as potential candidates for abnormal trades. Let $q_t$ denote the time-$t$ ex-ante joint historical probability of observing an unusual large increment in open interest close to the trading volume

$$q_t := \mathbb{P}[X \geq X_t, Z \leq Z_t] = \frac{1}{N} \sum_{i=1}^{N} 1_{\{X_i \geq X_t, Z_i \leq Z_t\}} \tag{2}$$

where $\mathbb{P}$ denotes the empirical probability, $N$ the length of the estimation window, e.g., $N = 500$ trading days, and $1_{\{A\}} = 1$ when event $A$ occurs, and zero otherwise. By construction, low values of $q_t$ suggest that these transactions were unusual. For example when $q_t = 1 / N$, it means that what occurred on day $t$ has no precedents in the previous two years.

### 3.2. Second criterion: relative return and realized gain

The second criterion takes into consideration ex-post option returns and realized gains. For each day $t$ the option trade with the lowest ex-ante probability $q_t$ is considered. Let $r_t^{\max}$ denote the maximum option return generated in the following two trading weeks

$$r_t^{\max} := \max_{j=1,\ldots,10} \frac{P_{t+j} - P_t}{P_t} \tag{3}$$

where $P_t$ denotes the mid-quote price of the selected call option at day $t$. When $r_t^{\max}$ is unusually high, an unusual event occurs during the following two trading weeks.

For the computation of realized gains, we consider decrements in open interest, $\Delta OI_t^k$, which occur when exercising or selling to the market maker the call option.[3] Then we set the American call option value to its exercise value, which is true in most cases. Given our definition of abnormal trade, it is quite likely that on the event day the rise in the stock price is large enough to reach the exercise region. If options are sold rather than exercised, our calculation of realized gains may underestimate the actual gains. Hence reported gains should be interpreted as conservative estimates. For brevity, we refer to decrement in open interest as option exercise. Also, we omit the superscript $k$ and whenever we refer to a specific option we mean the one which was selected because of its largest increment in open interest close to trading volume, i.e., lowest ex-ante probability $q_t$.

Let $G_t$ denote the corresponding cumulative gains achieved through the exercise of options

$$G_t := \sum_{\tilde{t}=t+1^{\tau_t}} \left((S_{\tilde{t}-K})^+ - P_t\right) \ (-\Delta OI_{\tilde{t}}) 1_{\{\Delta OI_{\tilde{t}} < 0\}} \tag{4}$$

where $\tau_t$ is such that $t < \tau_t \leq T$, with $T$ being the maturity of the selected option. If the call options were optimally exercised (i.e., as soon as the underlying asset $S_{\tilde{t}}$ touches the exercise region), the payoff $(S_{\tilde{t}-K})^+$ corresponds to the price of the option at time $\tilde{t}$.

The cumulative gains $G_t$ could be easily calculated for every $\tau_t \leq T$. This has however the disadvantage that $G_t$ could include gains which are realized through the exercise of options which were issued before time $t$.[4] To avoid this inconsistency, the time $\tau_t$ is defined as follows

$$\tau_t^* := \arg\max_{l \in \{t+1,\ldots,T\}} \left( \sum_{\tilde{t}=t+1}^{l} (-\Delta OI_{\tilde{t}}) 1_{\{\Delta OI_{\tilde{t}} < 0\}} \leq X_t \right) \tau_t := \min(\tau_t^*, 30)$$

giving the option trader no more than 30 days to collect her gains. In general the sum of negative decrements in open interest till time $\tau_t$ will be smaller than the observed increment in open interest $X_t$. In that case, we will add to $G_t$ the gains realized through the fraction of the next decrement in open interest. Hence the sum of all negative decrements in open interest will be equal to the increment $X_t$.

Calculating $G_t$ for each day $t$ and each option in our dataset provides information on whether or not option trades with a low ex-ante probability $q_t$ generate large gains through exercise. Using the maximal return $r_t^{\max}$ in Eq. (3), we can calculate the time-$t$ ex-post joint historical probability $p_t$ of the event $\{X_t, Z_t, r_t^{\max}\}$

$$p_t := \mathbb{P}\left[X \geq X_t, Z \leq Z_t, r^{\max} \geq r_t^{\max}\right] = \frac{1}{N} \sum_{i=1}^{N} 1_{\{X_i \geq X_t, Z_i \leq Z_t, r_i^{\max} \geq r_t^{\max}\}}. \tag{5}$$

The higher the $(1 - p_t)$ the larger the option return and the more unusual the increment in open interest close to trading volume.

### 3.3. Third criterion: hedging option position

Option trades for which the first two criteria show abnormal behavior cannot be immediately classified as abnormal trades. It could be the case that such transactions were hedged by traders using the underlying asset. Without knowing the exact composition of each trader's portfolio, it is not possible to assess directly whether each option trade was hedged or not.

We attempt to assess indirectly whether unusual trades in call options are actually delta hedged using the underlying asset. The idea is to compare the *theoretical* total amount of shares sold for non-hedging purposes and the *actual* total volume of seller-initiated transactions in the underlying stock. If the latter is significantly larger than the former, then it is likely that some of the seller-initiated trades occur for hedging purposes. In the opposite case we conclude that the new option positions are not hedged.

One difficulty is that the volume due to hedging is typically a small component of the total seller-initiated volume. Usually, when hedging occurs, newly issued options are hedged on the same day which is our working assumption. Hedging analyses at the level of single option are not possible using our OptionMetrics dataset. We therefore check whether all the newly issued options are hedged on a specific day $t$. Given our definition of abnormal trades, such trades certainly account for a large fraction of the newly issued options.

For each day $t$, the total trading volume of the underlying stock is divided into seller- and buyer-initiated using intraday volumes and transaction prices according to the Lee and Ready (1991) algorithm.[5] Then the seller-initiated volume of underlying stock, $V_t^{\text{sell}}$, is

[3] On a given day, opening new positions (which increases open interest) and closing existing positions (which decreases open interest) can off-set each other. Hence the observed decrement in open interest is a lower bound for actual exercised or sold options.

[4] Consider for example an option which exhibits an unusually high increment in open interest at time $t$, say $OI_{t-1} = 1000$ and $OI_t = 3000$ resulting in $X_t := OI_t - OI_{t-1} = 2000$. Suppose that in the days following this transaction the level of open interest decreases and after $h$ days reaches the level $OI_{t+h} = 500$. One should only consider the gains realized through exercise till time $\tau_t \leq t + h$, where $\tau_t$ is such that the sum of negative decrements in open interest during $[t + 1, \tau_t]$ equals $X_t = 2000$.

[5] The algorithm states that a trade with a transaction price above (below) the prevailing quote midpoint is classified as a buyer- (seller-) initiated trade. A trade at the quote midpoint is classified as seller-initiated if the midpoint moved down from the previous trade (down-tick), and buyer-initiated if the midpoint moved up (up-tick). If there was no movement from the previous price, the previous rule is successively applied to several lags to determine whether a trade was buyer- or seller-initiated.

divided into trading volume due to hedging and to non-hedging purposes, $V_t^{\text{sell,hedge}}$ and $V_t^{\text{sell,non-hedge}}$, respectively. Let $\Delta_t^{C,k}$ be the delta of call option $k$ and $K_t^C$ be the set of call options (newly issued or already existing) on day $t$. Similarly for $\Delta_t^{P,k}$ and $K_t^P$. Let

$$\alpha_t := \sum_{k \in K_t^C} |OI_t^{C,k} - OI_{t-1}^{C,k}| \, |\Delta_t^{C,k}|, \gamma_t := \sum_{k \in K_t^P} |OI_t^{P,k} - OI_{t-1}^{P,k}| \Delta_t^{P,k}, \beta_t := \sum_{k \in K_t^C} |\Delta_t^{C,k} - \Delta_{t-1}^{C,k}| OI_{t-1}^{C,k}, \delta_t := \sum_{k \in K_t^P} |\Delta_t^{P,k} - \Delta_{t-1}^{P,k}| OI_{t-1}^{P,k}.$$

The $\alpha_t$ and $\gamma_t$ represent the theoretical number of shares to sell for hedging the new call options issued at day $t$, whereas $\beta_t$ and $\delta_t$ are the theoretical number of shares to sell to rebalance the portfolio of existing options at day $t$. Absolute changes in open interests and deltas account for the fact that each option contract has a long and short side that follow opposite trading strategies if hedging occurs. The theoretical seller-initiated volume of stock at day $t$ for hedging purposes is $V_t^{\text{sell,hedge - theory}} := \alpha_t + \beta_t + \gamma_t + \delta_t$.

When the first two criteria of our method do not signal any abnormal trade, we approximate $V_t^{\text{sell,hedge}}$ by $V_t^{\text{sell,hedge - theory}}$. Then the amount of stock sold for non-hedging purposes is calculated as $V_t^{\text{sell,non - hedge}} = V_t^{\text{sell}} - V_t^{\text{sell,hedge - theory}}$.

When abnormal trades take place on day $i$, $V_i^{\text{sell,non - hedge}}$ cannot be computed as in the last equation because $V_i^{\text{sell,hedge - theory}}$ would be distorted by the unhedged option abnormal trades. We circumvent this issue by forecasting the volume $V_i^{\text{sell,non - hedge}}$ on day $i$ using historical data on $V_t^{\text{sell,non - hedge}}$. The conditional distribution of $V_i^{\text{sell,non - hedge}}$ is estimated using the adjusted Nadaraya–Watson estimator and the bootstrap method proposed by Hall et al. (1999)

$$\widetilde{F}(y|\mathrm{x}) = \frac{\sum_{t=1}^{T} 1_{\{Y_t \le y\}} w_t(\mathrm{x}) K_{\mathbf{H}}(\mathbf{X}_t - \mathrm{x})}{\sum_{t=1}^{T} w_t(\mathrm{x}) K_{\mathbf{H}}(\mathbf{X}_t - \mathrm{x})} \tag{6}$$

with $Y_t := V_t^{\text{sell,non - hedge}}$, $\mathbf{X}_t := (|r_t|, V_{t-1}^{\text{sell,non - hedge}})$, $K_{\mathbf{H}}(\cdot)$ being a multivariate kernel with bandwidth matrix $\mathbf{H}$, $w_t(\mathrm{x})$ the weighting function, and $r_t$ the stock return at day $t$; we refer the reader to Fan and Yao (2003) for the implementation of Eq. (6).

We can now formally test the null hypothesis, $H_0$, that hedging does not take place at day $i$. Whenever the observed $V_i^{\text{sell}}$ is large enough, say above the 95% quantile of the predicted distribution of $V_i^{\text{sell,non - hedge}}$, it is likely that a fraction of $V_i^{\text{sell}}$ is due to hedging purposes. Hence we reject $H_0$ at day $i$ when $V_i^{\text{sell}} > q_{0.95}^{V_i^{\text{sell,non-hedge}}}$, where $q_\alpha^{V_i^{\text{sell,non-hedge}}} = \widetilde{F}^{-1}(\alpha|\mathbf{X}_i)$ is the $\alpha$-quantile of the predicted distribution of $V_i^{\text{sell,non - hedge}}$ estimated using Eq. (6). The separate appendix shows that the power of the test depends on the conditioning variables $\mathbf{X}_i$ but can be as high as 20% when $V_i^{\text{sell}}$ is 20% larger than $V_i^{\text{sell,non - hedge}}$.

We remark that the null hypothesis $H_0$ of no hedging (when abnormal trades occur) concerns only long positions in newly issued call options. Short positions in the same call options do not affect our hedging detection method. It is so because the total volume of the underlying stock is divided into buyer- and seller-initiated and only the latter matters when hedging long call options.

### *3.4. Detecting abnormal trades combining the three criteria*

Let $k_t$ denote the selected abnormal trade at day $t$ in call option $k$. The two methods to detect option abnormal trades can be described using the following four sets of events: $\Omega_1 := \{k_t \text{ such that } q_t \le 5\,\%\}$; $\Omega_2 := \{k_t$ such that "$H_0$: non-hedging" is not rejected at day $t\}$; $\Omega_3 := \{k_t \text{ such that } r_t^{\max} \ge q_{0.90}^{r_t^{\max}}\}$; and $\Omega_4 := \{k_t \text{ such that } G_t \ge q_{0.98}^{G_t}\}$. The first method detects an abnormal trade when it belongs to the first two sets, i.e., $k_t \in \Omega_1 \cap \Omega_2$. According to the second method an option trade is abnormal when it belongs to all four sets, i.e., $k_t \in \Omega_1 \cap \Omega_2 \cap \Omega_3 \cap \Omega_4$.

## 4. Data

To keep the empirical analysis manageable, we focus on three main sectors, i.e., banking, insurance, and airline, and within each sector we consider some of the main companies. In addition, we also consider a number of randomly selected companies from other sectors, such as Coca Cola and Philip Morris, to broaden our empirical analysis. We organize our dataset in two parts. The first part includes only put options, while the second part put and call options.

The first part of our dataset includes 14 companies from airline, banking and various other sectors. The list of companies includes: American Airlines (AMR), United Airlines (UAL), Delta Air Lines (DAL), Boeing (BA) and KLM for the airline sector; Bank of America (BAC), Citigroup (C), J.P. Morgan (JPM), Merrill Lynch (MER) and Morgan Stanley (MWD) for the banking sector; and AT&T (ATT), Coca Cola (KO), Hewlett Packard (HP), and Philip Morris (MO) for the remaining sectors. Option data are from the Chicago Board Options Exchange (CBOE) as provided by OptionMetrics. The dataset includes the daily cross-section of available put options for each company from January 1996 to April 2006 and amounts to about 2.1 million options. Option data for DAL and KLM were available for somewhat shorter periods. Stock prices are downloaded from OptionMetrics as well to avoid non-synchronicity issues and are adjusted for stock splits and spin-offs using information from the CRSP database. Intraday transaction prices and volumes for each underlying stock price are from NYSE's Trade and Quote (TAQ) database. This dataset consists of several millions of records for each stock and is necessary to classify trading volumes in buyer- and seller-initiated transactions in order to complete the analysis related to the hedging criterion. Discrepancies among datasets have been carefully taken into account when merging databases.[6] Additionally, we analyze put options on 3 European companies, Swiss Re, Munich Re and EADS, using daily data from the EUREX provided by Deutsche Bank.

The second part of our dataset includes 19 companies from the banking and insurance sectors. Put and call options data are from January 1996 to September 2009, covering the recent financial crisis, and amounts to about 7.5 million options. The list of American companies includes: American International Group (AIG), Bank of America Corporation (BAC), Bear Stearns Corporation (BSC), Citigroup (C), Fannie Mae (FNM), Freddie Mac (FRE), Goldman Sachs (GS), J.P. Morgan (JPM), Lehman Brothers (LEH), Merrill Lynch (MER), Morgan Stanley (MS), Wachovia Bank (WB) and Wells Fargo Company (WFC). Most of these companies belong to the list of banks which were bailed out and, in which, the American Treasury Department invested approximately $200 billion through its Capital Purchase Program in an effort to bolster capital and support new lending. Options and stock data are from the same databases as before, namely CBOE, TAQ, and CRSP. Furthermore we analyze 6 European banks: UBS, Credit Suisse Group (CS) and Deutsche Bank (DBK) whose options are traded on EUREX, and Societé Générale (GL), HSBC (HSB) and BNP Paribas (BN) with options listed on Euronext. Option data as well as intraday transaction prices and volumes for the underlying stock are obtained from EUREX provided by Deutsche Bank, and from EURONEXT provided by NYSE Euronext database. All analyzed options are in American style.

## 5. Empirical results

The two proposed methods to detect option abnormal trades are applied to the companies listed in the previous section. We recall that when testing abnormal trades in put options, we are testing the *joint hypothesis* discussed in the introduction.

The first method, which relies only on ex-ante information, aims at detecting abnormal trades as soon as they take place. On average, less than 0.1% of the total analyzed trades belongs to the set $\Omega_1 \cap \Omega_2$ defined in Section 3.4. As an example for AMR our first method detects 141 abnormal trades, the total number of analyzed options being more than 137,000. This suggests that already the ex-ante method can be quite effective in signaling abnormal trades.

The second method, which relies also on ex-post information, selects a significantly smaller number of abnormal trades. For example, only 5 abnormal trades are detected for AMR. Importantly, the empirical patterns of abnormal trades based on the two methods are roughly the same. For example, both methods suggest that most abnormal trades for AMR occur before an acquisition announcement in May 2000 and the 9/11 terrorist attacks.

Due to space constraints we only discuss abnormal trades selected by the ex-post method. The separate appendix reports a detailed analysis of various abnormal trades.

Analyzing the first part of our dataset, 37 transactions on the CBOE have been identified as belonging to the set $\Omega_1 \cap \Omega_2 \cap \Omega_3 \cap \Omega_4$ defined in Section 3.4. Nearly all the detected abnormal trades can be associated to one of the following three event categories: merger and acquisition (M&A) announcements, six transactions; quarterly financial/earnings related statements, 14 transactions; and the terrorist attacks of September 11th, 13 transactions. Four transactions could not be identified. Tables 1 and 2 summarize abnormal trades for the airline sector. Corresponding tables for the banking sector and the last group of companies are reported in the separate appendix.

The second part of our dataset focuses on the banking and insurance sectors and consists of call and put options. Detailed empirical results are collected in the separate appendix. Although the sample period spans almost 15 years, from January 1996 to September 2009, the vast majority of detected abnormal trades occur during the Subprime crisis 2007–2009. Most abnormal trades involve put options which speaks to the *joint hypothesis* discussed in the introduction. We also detect abnormal trades in call options for every bank and insurance company analyzed. Call option abnormal trades are mainly related to positive quarterly announcements and news about certain companies raising new capital during the financial crisis 2007–2009.

To provide some insights on option abnormal trading, below we discuss in detail the case of an acquisition announcement in the U.S. airline sector in May 2000. Additional cases are discussed in the separate appendix.

The ex-post method detects two put option abnormal trades on May 10th and 11th, 2000. They involved AMR and UAL. On May 10th and 11th, the number of options issued with strike $35 and maturity in June 2000 with underlying AMR is very large: 3374 on May 10th and 5720 the day after (at 99.7% and 99.9% quantile of their two-year empirical distributions, respectively). These transactions correspond to those which exhibit the strongest increments in open interest during a span of five years; see Fig. 1 (upper left graph) and Fig. 2.

On May 10th, the underlying stock had a value of $35.50 and the selected put was traded at $2.25. For UAL 2505 put option contracts (at 98.7% quantile of its two-year empirical distribution) with strike $65 and the same maturity as those of AMR were issued on May 11th at the price of $5.25 when the underlying had a value of $61.50. The market conditions under which such transactions took place are stable. For example the average return of the stock the week before is, in both cases, positive and less than 0.5%.

The days of the drop in the underlying stock price are May 24th and May 25th, 2000, with the first day corresponding to the public announcement of United Airline's regarding a $4.3 billion acquisition of US Airways. As reported in the May 25th, 2000 edition of the New York Times, "shares of UAL and those of its main rivals crashed."[7] The stock price of AMR dropped to $27.13 (−23.59% of value losses when compared to the stock price on May 11th) increasing the value of the put options to $7.88 (resulting in a return of 250% in

[6] For example data for J.P. Morgan from OptionMetrics and TAQ do not match. Whereas the stock volume reported in OptionMetrics for the years 1996–2000 is given by the sum of the volume of Chase Manhattan Corporation and J.P. Morgan & Co. (Chase Manhattan Corporation acquired J.P. Morgan & Co. in 2000); TAQ only reports the volume of J.P. Morgan & Co. Same issue was found for Bank of America Corporation and NationsBank Corporation, whose merger took place in 1998 under the new name of Bank of America Corporation.

[7] The New York Times article reports that AMR was considered the company most threatened by the merger, explaining therefore the 17% drop in its share price in the days after the public announcement. According to James Goodwin, chairman and chief executive of UAL, two major hurdles would challenge UAL: "the first is to get US Airways shareholders to approve this transaction. [The second] is the regulatory work, which revolves around the Department of Transportation, the Department of Justice and the European Union." The skepticism on Wall Street was immediately reflected on UAL share price which declined $7.19 to $53.19 on the announcement day.

**Table 1**
Abnormal trades in the airline sector. The table shows the day on which the transaction took place, Date; identification number of the put option, *Id*; moneyness, i.e., stock price divided by strike price, $S / K$; time-to-maturity, $\tau$; level of open interest the day before the abnormal trade, $OI_{t-1}$; increment in open interest from day $t-1$ to day $t$, $\Delta OI_t$; its quantile with respect to its empirical distribution computed over the last two years, $q_t^{\Delta OI}$; total increment in open interest, i.e., when considering all the available options at day $t$ and not only the ones which had the highest increment, $\Delta OI_t^{tot}$; corresponding volume, $Vol_t$; maximum return realized by the selected option during the two-week period following the transaction day, $r_t^{\max}$; number of days between transaction day $t$ and when this maximum return occurs, $\tau_2$; gains realized through the exercise of the option issued at time $t$ as in (4), $G_t$; minimum between the number of days (starting from the transaction day) needed for the exercise of $\Delta OI_t$ and 30 days, $\tau_3$; percentage of $\Delta OI_t$ exercised within the first 30 days after the transaction, *%ex.*; ex-ante probability in Eq. (2), $q_t$; $p$-value of the hypothesis that delta hedging does not take place at time $t$, $p$-value; and ex-post probability of abnormal trading in Eq. (5), $1-p_t$. * means that the hypothesis of non-hedging can be rejected at a 5% level.

| Summary of airline sector Jan 1996–Apr 2006 | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | *Id* | $S / K$ | $\tau$ | $OI_{t-1}$ | $\Delta OI_t$ | $q_t^{\Delta OI}$ | $\Delta OI_t^{tot}$ | $Vol_t$ | $r_t^{\max}$ | $\tau_2$ | $G_t$ | $\tau_3$ | *%ex.* | $q_t$ | $p$-Value | $1-p_t$ |
| *American Airlines (AMR) Jan 1996–Apr 2006* | | | | | | | | | | | | | | | | |
| 10 May 00 | 10821216 | 1.01 | 38 | 20 | 3374 | 99.7% | 3378 | 3290 | 106% | 9 | 906,763 | 11 | 100% | 0.002 | 0.286 | 0.998 |
| 11 May 00 | 10821216 | 1.02 | 37 | 3394 | 5720 | 99.9% | 5442 | 5320 | 98% | 10 | 1,647,844 | 11 | 100% | 0.002 | 0.349 | 0.998 |
| 31 Aug 01 | 20399554 | 0.91 | 22 | 96 | 473 | 95.7% | 571 | 500 | 455% | 7 | 662,200 | 11 | 100% | 0.016 | 0.645 | 0.984 |
| 10 Sep 01 | 20428354 | 0.99 | 40 | 258 | 1312 | 98.5% | 1701 | 1535 | 453% | 2 | 1,179,171 | 26 | 100% | 0.012 | 0.096 | 0.998 |
| 24 Aug 05 | 27240699 | 0.97 | 24 | 1338 | 4378 | 93.5% | 8395 | 5319 | 163% | 8 | 575,105 | 17 | 100% | 0.048 | 0.123 | 0.952 |
| *United Airlines (UAL) Jan 1996–Jan 2003* | | | | | | | | | | | | | | | | |
| 11 May 00 | 11332850 | 0.95 | 37 | 35 | 2505 | 98.7% | 2534 | 2505 | 132% | 10 | 1,156,313 | 26 | 100% | 0.002 | 0.373 | 0.998 |
| 6 Sep 01 | 20444473 | 1.06 | 44 | 21 | 1494 | 96.3% | 1189 | 2000 | 1322% | 7 | 1,980,387 | 28 | 100% | 0.030 | 0.165 | 0.998 |
| *Delta Air Lines (DAL) Jan 1996–May 2005* | | | | | | | | | | | | | | | | |
| *1 Oct 98 | 10904865 | 1.01 | 16 | 140 | 974 | 97.7% | 483 | 924 | 261% | 6 | 537,594 | 12 | 100% | 0.016 | 0.000 | 0.996 |
| 29 Aug 01 | 20402792 | 0.98 | 24 | 1061 | 202 | 89.7% | 224 | 215 | 1033% | 9 | 328,200 | 13 | 100% | 0.044 | 0.528 | 0.998 |
| 19 Sep 02 | 20718332 | 0.99 | 30 | 275 | 1728 | 98.7% | 550 | 1867 | 132% | 7 | 331,676 | 22 | 100% | 0.004 | 0.190 | 0.998 |
| 9 Jan 03 | 21350972 | 1.10 | 44 | 274 | 3933 | 99.7% | 4347 | 4512 | 112% | 9 | 1,054,217 | 30 | 100% | 0.002 | 0.065 | 0.998 |
| *Boeing (BA) Jan 1996–Apr 2006* | | | | | | | | | | | | | | | | |
| 24 Nov 98 | 10948064 | 0.99 | 53 | 3758 | 1047 | 93.5% | 1285 | 1535 | 467% | 7 | 883,413 | 24 | 100% | 0.040 | 0.481 | 0.996 |
| 29 Aug 01 | 20400312 | 0.92 | 24 | 1019 | 2828 | 96.7% | 3523 | 3805 | 382% | 10 | 1,972,534 | 8 | 100% | 0.028 | 0.252 | 0.998 |
| 5 Sep 01 | 20429078 | 1.01 | 45 | 472 | 1499 | 92.1% | 2538 | 1861 | 890% | 8 | 1,805,929 | 22 | 100% | 0.048 | 0.085 | 0.998 |
| 6 Sep 01 | 11839316 | 0.75 | 135 | 13228 | 7105 | 99.3% | 13817 | 7108 | 118% | 7 | 2,704,701 | 3 | 100% | 0.006 | 0.150 | 0.998 |
| *7 Sep 01 | 20400311 | 0.90 | 15 | 7995 | 4179 | 98.5% | 4887 | 5675 | 306% | 6 | 5,775,710 | 7 | 100% | 0.016 | 0.000 | 0.998 |
| *17 Sep 01 | 20400309 | 0.90 | 5 | 116 | 5026 | 98.9% | 2704 | 5412 | 124% | 4 | 2,663,780 | 5 | 100% | 0.010 | 0.000 | 0.998 |
| *KLM Jan 1996–Nov 2001* | | | | | | | | | | | | | | | | |
| 5 Sep 01 | 20296159 | 0.91 | 17 | 3 | 100 | 99.3% | 34 | 100 | 467% | 9 | 53,976 | 9 | 100% | 0.006 | 0.368 | 0.998 |

two trading weeks). The same impact can be found for UAL: the stock price after the public announcement dropped to $52.50 (−14.63% when compared to the value on May 11th) raising the put's value to $12.63 (corresponding to a return of 140% in two trading weeks). In the case of AMR, the decline in the underlying stock can be seen in Fig. 2, where the option return largely increased.

On the day of the public announcement 4735 put options of AMR were exercised; see Fig. 2. After this large decrement in open interest, 1494 and 1376 additional put options were exercised in the following two days respectively (reflected in additional drops in open interests in Fig. 2). The unusual increments in open interest observed on May 10th and May 11th are therefore offset by the exercise of options when the underlying crashed. The corresponding gains $G_t$ from this strategy are more than $1.6 million within two trading weeks. These are graphically shown in the lower graph in Fig. 1, from which we can see how fast these gains were realized. In the case of UAL similar conclusions can be reached; see Tables 1 and 2. Based on these trades, a total gain of almost $3 million was realized within a few trading weeks using options with underlying AMR and UAL. The non-hedging hypothesis cannot be rejected suggesting that such trades are unhedged option positions. Comparable abnormal trades have been found for American Airlines, United Airlines and Boeing (and to a lesser extent for Delta Air Lines and KLM) before the terrorist attacks of 9/11, and are discussed in the separate appendix.

## 6. Controlling false discoveries in abnormal trades

Any statistical method can generate false discoveries in abnormal trades, i.e., the probability that an option trade can satisfy various criteria simply by chance is not zero. Controlling for false discovery is then an important task, which allows abnormal trades with high gains to be truly separated from liquidity trades that luckily achieved also high gains. To separate the two groups of trades we use a multiple hypothesis testing technique. Barras et al. (2010) adopted a similar approach to discriminate between skilled and lucky mutual fund managers based on fund performance.

For the sake of presentation, we phrase the discussion in terms of informed versus uninformed traders. We say that abnormal trades with high gains are generated by informed traders (and lucky uninformed traders). In practice, traders with private information and/or who are hedging their human capital are probably originating put option abnormal trades, which is the *joint hypothesis* discussed in the introduction. In the presentation of the multiple hypothesis test we omit such a distinction.

Suppose we observe option returns generated by $M$ traders characterized by different degrees of information, ranging from highly accurate private information to no information (or possibly even misleading information). Let $\pi_0$ denote the fraction of uninformed

**Table 2**
Abnormal trades in the airline sector: Description of events. The table shows the day on which the transaction took place, Date; average return of the stock during the last two trading weeks, Return; minimum return of the stock during the two-week period following the transaction day, Min; day when the stock drops, Drop; and why the stock drops, Event's description. * means that the hypothesis of non-hedging can be rejected at a 5% level.

| Summary of airline sector Jan 1996–Apr 2006 | | | | |
|---|---|---|---|---|
| Date | Return | Min | Drop | Event's description |
| *American Airlines (AMR) Jan 1996–Apr 2006* | | | | |
| 10 May 00 | 0.4% | −17.6% | 24/25 May 00 | UAL's acquisition of US Airways |
| 11 May 00 | 0.0% | −17.6% | 24/25 May 00 | UAL's acquisition of US Airways |
| 31 Aug 01 | −0.4% | −39.4% | 17 Sep 01 | 9/11 terrorist attacks |
| 10 Sep 01 | −1.4% | −39.4% | 17 Sep 01 | 9/11 terrorist attacks |
| 24 Aug 05 | 0.4% | −5.3% | 30 Aug 05 | Hurricane Katrina |
| *United Airlines (UAL) Jan 1996–Jan 2003* | | | | |
| 11 May 00 | 0.3% | −12% | 24 May 00 | UAL's acquisition of US Airways |
| 6 Sep 01 | −1.0% | −43.2% | 17 Sep 01 | 9/11 terrorist attacks |
| *Delta Air Lines (DAL) Jan 1996–May 2005* | | | | |
| *1 Oct 98 | −1.7% | −11.4% | 07/08 Oct 98 | Not identified |
| 29 Aug 01 | 0.0% | −44.6% | 17 Sep 01 | 9/11 terrorist attacks |
| 19 Sep 02 | −5.2% | −24.4% | 27 Sep 02 | Expected quarter loss |
| 9 Jan 03 | 2.1% | −15.7% | 21/22 Jan 03 | Restrictions on alliance |
| *Boeing (BA) Jan 1996–Apr 2006* | | | | |
| 24 Nov 98 | −0.2% | −22.0% | 02/03 Dec 98 | Production scale back |
| 29 Aug 01 | −0.4% | −25.0% | 17/18 Sep 01 | 9/11 terrorist attacks |
| 5 Sep 01 | −0.8% | −25.0% | 17/18 Sep 01 | 9/11 terrorist attacks |
| 6 Sep 01 | −0.9% | −25.0% | 17/18 Sep 01 | 9/11 terrorist attacks |
| *7 Sep 01 | −1.9% | −25.0% | 17/18 Sep 01 | 9/11 terrorist attacks |
| *17 Sep 01 | −5.6% | −25.0% | 17/18 Sep 01 | 9/11 terrorist attacks |
| *KLM Jan 1996–Nov 2001* | | | | |
| 5 Sep 01 | −1.9% | −31.6% | 17/18 Sep 01 | 9/11 terrorist attacks |

traders and $\delta_m$, $m = 1, \ldots, M$, the expected return generated by trader $m$. Under the null hypothesis all option traders are uninformed. Formally, this multiple hypothesis reads $H_{0,m} : \delta_m = 0, m = 1, \ldots, M$. Each hypothesis is tested at significance level $\gamma$, e.g., $\gamma = 10\,\%$, using a two-side $t$-statistic, i.e., $H_{0,m}$ is rejected when the corresponding $t$-statistic is either below the 5th or above the 95th percentiles of its distribution under $H_{0,m}$. When the null hypothesis is true, all $p$-values based on $t$-statistics are uniformly distributed between 0 and 1. When the null hypothesis is not true, large option returns and corresponding low $p$-values are generated by both informed and lucky traders. Under such alternative hypothesis, $E[S_\gamma^+]$ is the expected fraction of $p$-values below $\gamma/2$ corresponding to positive and significant $t$-statistics. The key step is to adjust $E[S_\gamma^+]$ for the presence of lucky traders. The expected fraction of truly informed traders is $E[T_\gamma^+] = E[S_\gamma^+] - \pi_0\,\gamma/2$.[8] The last step is the estimation of $\pi_0$. Intuitively, large $p$-values correspond to estimated $\delta_m$ not statistically away from zero and hence generated by uninformed traders. The fraction of $p$-values above a certain threshold $\lambda$ is extrapolated over the interval [0,1]. Multiplying this fraction of $p$-values by $1/(1-\lambda)$ provides an estimate of $\pi_0$. This estimation approach has been developed by Storey (2002); see, e.g., Romano et al. (2008) for a review. We choose $\lambda$ using the data-driven approach in Barras et al. (2010). The observed fraction of positive and significant $t$-statistics provides an unbiased estimate of $E[S_\gamma^+]$.

Obviously, we do not observe option returns achieved by traders with various degrees of private information. Consistently with our detection method, we use the historical probability $q_t$ of observing unusual increments in open interest and volume, as well as high gains, as a proxy for private information. The working assumption is that the smaller such probability is, the higher the degree of private information of the option trader.

For every underlying asset, for every day $t$, and for every option trade $k = 1, \ldots, K_t$ in our sample, we compute the historical probability $q_t^k$ as in Eq. (2) of observing an increment $\Delta OI_t^k$ in open interest and distance $Z_t^k := (V_t^k - \Delta OI_t^k)$ between trading volume and increment in open interest, and corresponding maximal return as in Eq. (5). By definition, the probability $q_t^k$ lies in the interval [0,1]. We sort in ascending order all $q_t^k$ and divide such unit interval into $M = 1000$ subintervals $I_1, \ldots, I_M$ such that in every subinterval the same number of $q_t^k$ is available. Then we group all option trades $q_t^k$ and corresponding returns $r_t^k$ according to which subinterval $I_m$ they belong. This procedure allows us to construct $M$ hypothetical option traders, each one of them characterized by a different degree of private information and option returns. In subintervals $I_m$, $m = 1, \ldots, M$, the lower the value of $m$, the more informed the trader is, and therefore, the more likely it is that she will generate large positive return $r_t^k$. Within each subinterval $I_m$, we regress unadjusted annualized option returns $r_t^k$ on a subinterval-specific constant $\delta_m$, estimating the expected return of trader $m$.[9]

[8] Note that under the null hypothesis all traders are uninformed, i.e., $\pi_0 = 1$, and by definition half the size of the test $\gamma/2 = E[S_\gamma^+]$. Therefore the expected fraction of truly informed traders is $E[T_\gamma^+] = 0$.

[9] In the regression, we do not adjust option returns for market return or any other variable because the focus is on the ability of the option trader to generate large returns, including those returns based on predicting future market or other variable movements. In order to make least squares estimation more robust we exclude negative returns below the 5% empirical quantile. The impact of winsorizing on the false discovery rate is virtually negligible.

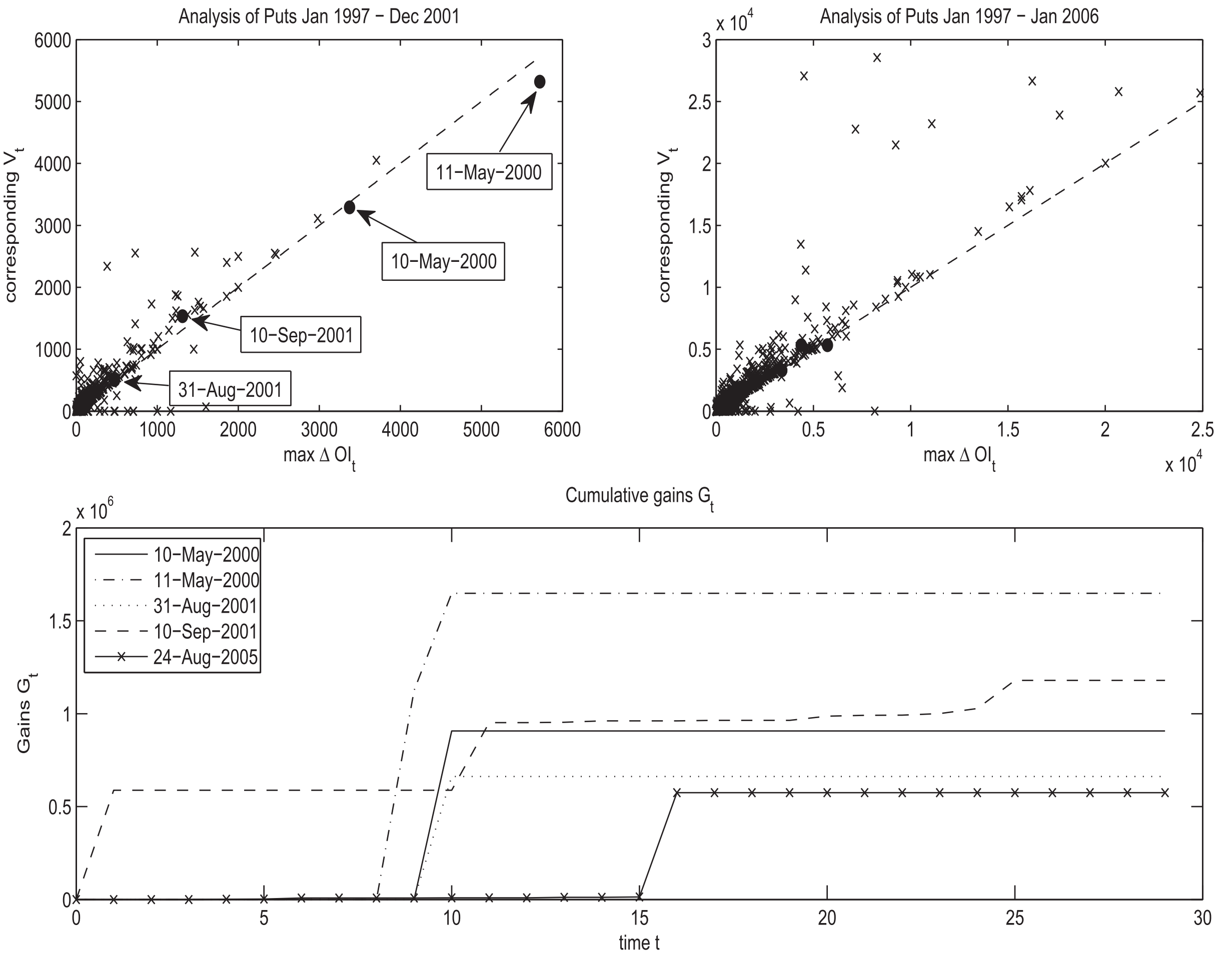


**Fig. 1.** Detecting abnormal trades: American Airlines' example. Upper graphs show on the x-axis maximal daily increment in open interest across all put options with underlying American Airlines (AMR), and on the y-axis the corresponding trading volume. Upper-left graph covers the period January 1997–December 2001, and upper-right graphs the period January 1997–January 2006. Lower graph shows cumulative gains $G_t$ in USD as in Eq. (4) for detected option abnormal trade on AMR. Gains correspond to those realized by daily exercising/selling the options.

As an example Fig. 3 shows estimated $\delta_m$ for American Airlines. The lower the value of $m$, the higher the estimated $\delta_m$, and the relation is nearly monotonic. Moreover, for small $m$, the estimated $\delta_m$ are positive and significant, whereas for increasing $m$, $\delta_m$ becomes statistically indistinguishable from zero.

We briefly discuss now the estimates of false discovery rates for American Airlines and Citigroup. For AMR, the total number of analyzed option trades amounts at 137,000, implying that each regression coefficient $\delta_m$ has been computed by relaying on 137 option returns $r_t^k$. The expected fraction of truly abnormal trades has been estimated to be $E[T^+] = 9.8\,\%$ (with standard error 1.15%, optimal $\lambda = 0.65$, and $\gamma = 0.11$), corresponding to 98 trades. As the ex-ante procedure detects 141 abnormal trades for AMR, the test result suggests that some of these trades may be actually liquidity uninformed trades. In contrast, the ex-post procedure is more conservative and detects only 5 abnormal trades, which implies that these trades are most likely abnormal trades. For the case of Citigroup, option trades amount at 246,000 and the estimated fraction of truly abnormal trades $E[T^+] = 10.6\,\%$ (with standard error 1.09%, optimal $\lambda = 0.612$, and $\gamma = 0.07$), corresponding to 106 trades. The ex-post method detects only 2 abnormal trades. Thus also in this case the detection procedure is conservative and detected trades are most likely abnormal. For the remaining companies we found similar results. Because of space constraints, figures and tables are not reported but available upon request from the authors.

Finally, to assess the ability of the FDR test at controlling for false discoveries, we run the following experiment.[10] We identify the major natural disasters, such as floods, hurricanes, volcanic eruptions, oil spills, and earthquakes from 2000 to 2011. As the exact timing of the event is in principle unpredictable, this should rule out any abnormal trade that generates large returns upon the occurrence of the natural disaster. Then, we consider all the option trades over the two weeks prior to the relevant event in the companies that were affected ex-post by the event. Given the setup, no option trade should be classified as abnormal.

[10] We thank an anonymous referee for suggesting this experiment.

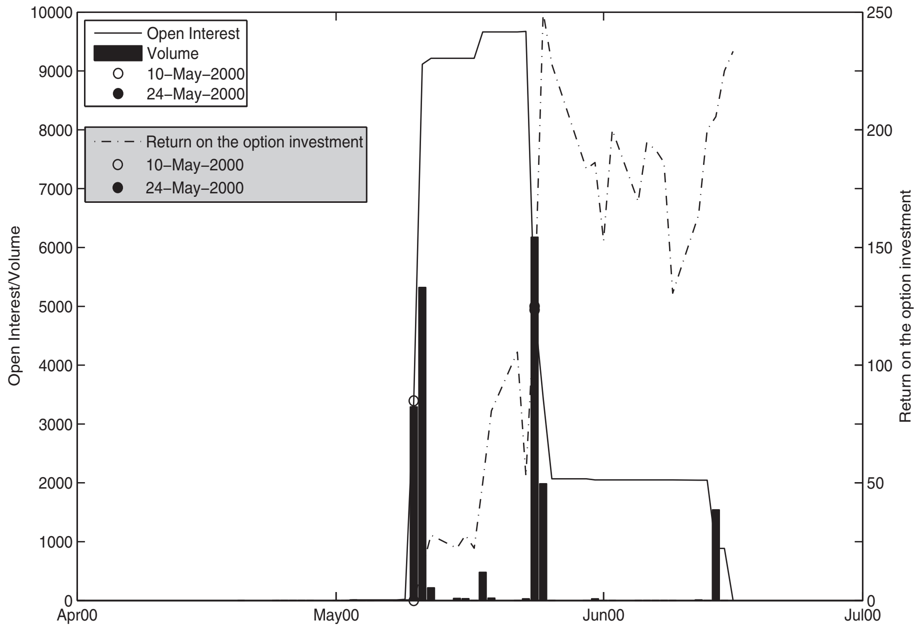


**Fig. 2.** Selected abnormal trade: American Airlines' example. Selected put option for abnormal trading with underlying stock American Airlines (AMR) before the United Airlines (UAL) announcement of $4.3 billion acquisition of US Airways in May 2000. The solid line shows the daily dynamic of open interest, the bars show the corresponding trading volume (left y-axis) and the dash–dot line the option return (right y-axis). The empty circle is the day of the transaction, the filled circle is the day of the announcement (partially covered by the highest bar). This put option had a strike of $35 and matured at the end of June 2000.

Table 3 provides the list of natural disasters and affected companies, as well as the rationale for including these companies. For example we consider British Petroleum before the oil spill in the U.S. Gulf Coast in 2010. The list of companies is constrained by option data availability, i.e., open interest and volume for individual options. Computing $q_t$ as in Eq. (2) and considering $q_t < 5\,\%$, a very small number of suspicious option trades is detected over the two weeks prior to a natural disaster. When applying the FDR test all such trades are attributed to luck, confirming the validity of our procedure. Detailed test results are available from the authors upon request.

## 7. Robustness checks

The input parameters in our detection procedure are: the length $N$ of the estimation window, chosen to be $N = 500$ trading days, used for the computation of the ex-ante probability $q_t$, the conditional distribution of $V_t^{\text{sell,non - hedge}}$, and the quantiles $q_\alpha^{r_t^{\max}}$ and $q_{\alpha'}^{G_t}$; the time period after the transaction day used for the computation of $r_t^{\max}$, chosen to be 10 trading days; the time horizon $\tau_t$ used for the calculation of the gains $G_t$, chosen to be 30 trading days; the quantile levels $\alpha$ and $\alpha'$ in $q_\alpha^{r_t^{\max}}$ and $q_{\alpha'}^{G_t}$ used for the computation of the sets $\Omega_3$ and $\Omega_4$, chosen to be $\alpha = 90\,\%$ and $\alpha' = 98\,\%$; and the probability level used to select trades belonging to the set $\Omega_1$, chosen to be 5%. In what follows we set the input parameters to different values and we repeat all previous analysis for all companies. To save space we report only some of the results and for a few companies giving a sense of the robustness of our results. Additional results are available from the authors upon request.

When varying the length of the estimation window $N$ between 200 and 1000 (all other parameters being unchanged), the number of selected transactions does not change significantly. For example in the case of AMR, we selected 5 abnormal trades when considering the last two trading years ($N = 500$ days); for $N \in [200,\ 1000]$ the number of detected abnormal trades ranges between 4 and 6; for UAL, we detected 2 abnormal trades when considering the last two trading years ($N = 500$ days); this number remains unchanged with respect to the original choice for $N > 450$ and decreases by one when $N \in [200,\ 450]$. In the case of BAC and AT&T, the deviation from the original number of selected trades is less than 2. With respect to the choice of the time period used for the computation of $r_t^{\max}$ and $\tau_t$, our results are also robust. We let the length of the first period vary in the range [1,30] days and the second one in [1,40] days. In the case of AMR, the number of transactions ranges from 2 to 8, being therefore centered around the original number and with a small deviation from it. For UAL, the corresponding range is from 1 to 4, for BAC from 2 to 8 and for AT&T from 1 to 6. The number of detected trades is obviously a decreasing function of $\alpha$ and $\alpha'$ (all other parameters being unchanged). In the case of AMR, when $\{\alpha, \alpha'\} \in [0.85,\ 0.95] \times [0.96,\ 1]$, the number of transactions selected does not exceed 15. For UAL, the number of selected trades varies between 1 and 10, for BAC between 5 and 25, and for AT&T between 1 and 18. Finally, with respect to the probability level used to determine the set $\Omega_1$, our findings are very robust as well. When increasing the level from 1% to 10%, the number of trades selected for AMR varies between 1 and 6; for UAL it ranges between 2 to 4, and for BAC and AT&T from 1 to 7. We simultaneously changed several parameters and found that the number of detected transactions does not change significantly and in almost all cases in

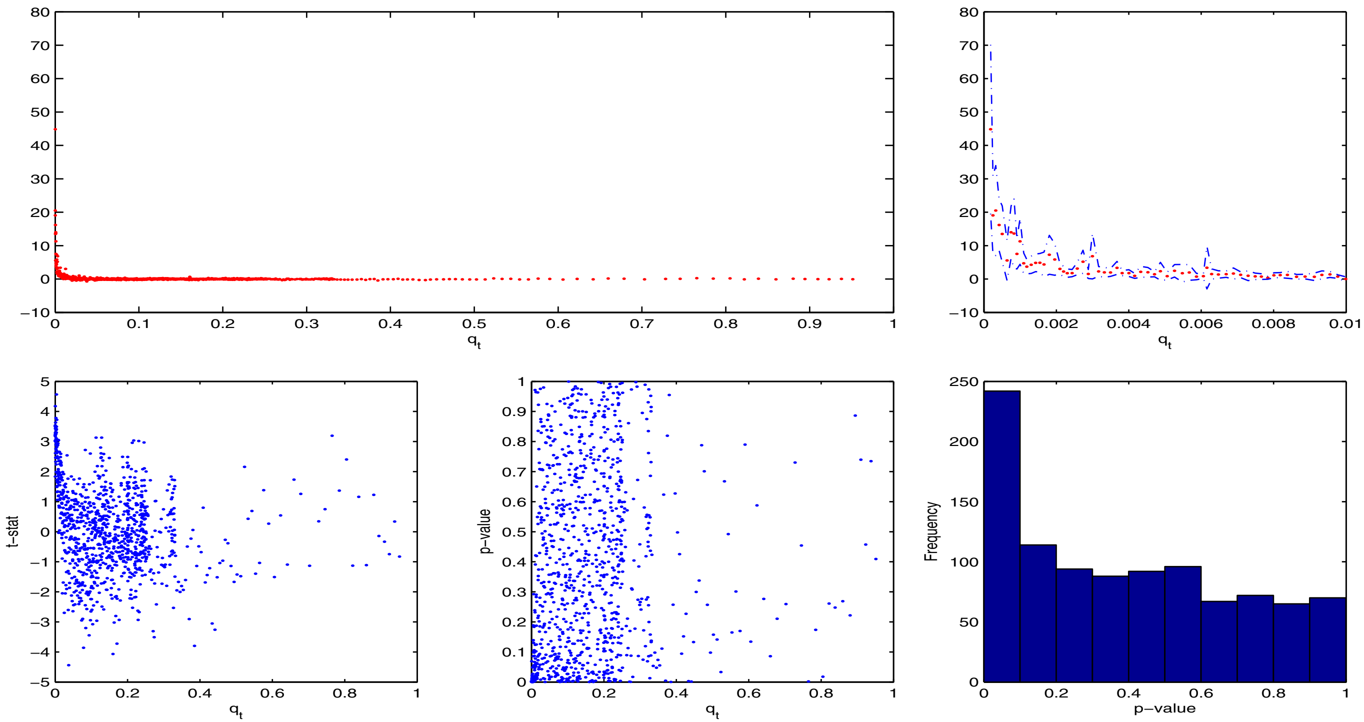


**Fig. 3.** False discovery rate: American Airlines' example. The upper-left graph shows on the x-axis the probability $q_t$ (the right-end point in each subinterval $I_m$), and on the y-axis the corresponding average option returns $\delta_m$ associated to the $m$th option trader. The upper-right graph shows the same quantities when $0 \le q_t \le 0.01$. Dashed–dotted lines represent 95% confidence intervals for $\delta_m$. The lower graphs, from left to right, show $t$-statistics of option returns associated to the $M$ option traders for the null hypothesis $H_0 : \delta_m = 0, m = 1, \ldots, M$, $p$-values, and frequency histogram of $p$-values, respectively.

**Table 3**
List of natural disasters and involved companies. The table lists some of the natural disasters that occurred between 2000 and 2011, the date of the event, and some of the companies that were affected ex-post by the event. The rationale for including the companies is the following. Central Europe floods: Advanced Micro Devices was operating a main chip fabrication plant in Dresden which was eventually only marginally affected by the floods. Hurricane Katrina: ExxonMobil was operating a major refinery near the U.S. Gulf Coast. Eruptions of Eyjafjallajökull: the International Air Transport Association imposed an air travel ban and transportation companies like FedEX were negatively affected. Deepwater Horizon oil spill: British Petroleum was responsible for the oil spill and operated the oil prospect. Japan earthquake: the earthquake has led to a fall in the oil price, which has added pressure on British Petroleum's share price.

| Natural disasters and false discoveries of informed trades | | |
|---|---|---|
| Event | Date | Company |
| Central Europe floods | 11 Aug 02 | Advanced Micro Devices |
| Hurricane Katrina | 29 Aug 05 | ExxonMobil |
| Eruptions of Eyjafjallajökull (Iceland) | 14 Apr 10 | FedEX |
| Deepwater Horizon oil spill | 20 Apr 10 | British Petroleum |
| Japan earthquake | 11 Mar 11 | British Petroleum |

steps of one. We recall that approximately 9.6 million of options are analyzed. Based on these results, we conclude that our findings are robust.

## 8. Conclusion

We develop two statistical methods to detect option abnormal trades, i.e., unusual trades in option contracts that generate large gains, are not used for option hedging purposes, and are made a few days before the occurrence of a specific event. The first method uses only ex-ante information and aims at detecting abnormal trades as soon as they take place. The second method relies on a more stringent definition of abnormal trades and also uses ex-post option returns. We control for false discoveries in abnormal trades using a multiple hypothesis testing technique.

We apply the two methods to 9.6 million of daily option prices. Our empirical findings can be summarized as follows. Detected option abnormal trades tend to cluster prior to major corporate events, such as acquisitions or financial disruption announcements, involve often liquid options, generate easily large gains exceeding millions, and are not contemporaneously reflected in the underlying stock price.

Our findings have policy, pricing, and market efficiency implications. If some of the detected abnormal trades are indeed illegal, it can be optimal for regulators to expend relatively more monitoring efforts on option markets. Pricing models should account for all relevant current information. However, nearly all option prices (and underlying assets) involved in abnormal trades do not show any specific reaction to large increments in open interest and volume. The strong movements in detected options are simply due to subsequent large movements in stock prices originated by specific firm news. Finally, certain increments in open interest and volume appear to predict large price movements and simple option trading strategies can generate large returns. Further research is necessary to assess whether those returns question market efficiency or rather reflect compensation for risk factors.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.jempfin.2015.03.008.

## References

Bali, Turan, Hovakimian, Armen, 2009. Volatility spreads and expected stock returns. Manag. Sci. 55, 1797–1812.
Barras, Laurent, Scaillet, Olivier, Wermers, Russ, 2010. False discoveries in mutual fund performance: measuring luck in estimated alphas. J. Financ. 65, 179–216.
Biais, Bruno, Hillion, Pierre, 1994. Insider and liquidity trading in stock and options markets. Rev. Financ. Stud. 7, 743–780.
Blume, Lawrence, Easley, David, O'Hara, Maureen, 1994. Market statistics and technical analysis: the role of volume. J. Financ. 49, 153–181.
Boulatov, Alex, Hendershott, Terrence, Livdan, Dmitry, 2013. Informed trading and portfolio returns. Rev. Econ. Stud. 80, 35–72.
Cao, Charles, Chen, Zhiwu, Griffin, John, 2005. Informational content of option volume prior to takeovers. J. Bus. 78, 1073–1109.
Chan, Kalok, Chung, Peter, Johnson, Herb, 1993. Why option prices lag stock prices: a trading-based explanation. J. Financ. 48, 1957–1967.
Chen, Joseph, Hong, Harrison, Stein, Jeremy, 2001. Forecasting crashes: trading volume, past returns, and conditional skewness in stock prices. J. Financ. Econ. 61, 345–381.
Cremers, Martijn, Weibaum, David, 2010. Deviations from put–call parity and stock return predictability. J. Financ. Quant. Anal. 45, 335–367.
Diamond, Douglas, Verrechia, Robert, 1987. Constraints on short-selling and asset price adjustment to private information. J. Financ. Econ. 18, 277–311.
Easley, David, O'Hara, Maureen, 1992. Time and the process of security price adjustment. J. Financ. 47, 577–605.
Easley, David, O'Hara, Maureen, Srinivas, P., 1998. Option volume and stock prices: evidence on where informed traders trade. J. Financ. 53, 431–465.
Fan, Jianqing, Yao, Qiwei, 2003. Nonlinear Time Series: Nonparametric and Parametric Methods. Springer-Verlag, New York.

Grossman, Sanford, 1977. The existence of futures markets, noisy rational expectations and information externalities. Rev. Econ. Stud. 44, 431–449.
Hall, Peter, Wolff, Rodney, Yao, Qiwei, 1999. Methods for estimating a conditional distribution function. J. Am. Stat. Assoc. 94, 154–163.
Hasbrouck, J., 1991. Measuring the information content of stock trades. J. Financ. 46, 179–207.
Lee, Charles, Ready, Mark, 1991. Inferring trade direction from intraday data. J. Financ. 46, 733–746.
Lee, Janson, Yi, Cheong, 2001. Trade size and information-motivated trading in the options and stock markets. J. Financ. Quant. Anal. 36, 485–501.
Manaster, Steven, Rendleman, Richard, 1982. Option prices as predictors of equilibrium stock prices. J. Financ. 37, 1043–1057.
Pan, Jun, Poteshman, Allen, 2006. The information in option volume for future stock prices. Rev. Financ. Stud. 19, 871–908.
Poteshman, Allen, 2006. Unusual option market activity and the terrorist attacks of September 11, 2001. J. Bus. 79, 1703–1726.
Romano, Joseph, Shaikh, Azeem, Wolf, Michael, 2008. Formalized data snooping on generalized error rates. Econ. Theory 24, 404–447.
Stephan, Jeans, Whaley, Robert, 1990. Intraday price change and trading volume relations in the stock and stock option markets. J. Financ. 45, 191–220.
Storey, John, 2002. A direct approach to false discovery rates. J. R. Stat. Soc. 64, 479–498.
Vijh, Anand, 1990. Liquidity of the CBOE equity options. J. Financ. 45, 1157–1179.
Yan, Sh.u., 2011. Jump risk, stock returns, and slope of implied volatility smile. J. Financ. Econ. 99, 216–233.

# Detecting Abnormal Trading Activities in Option Markets: Supplemental Appendix*

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# Detecting Abnormal Trading Activities in Option Markets: Supplemental Appendix

**Abstract**

This supplemental appendix extends the empirical results in the main paper. Abnormal trading activities on call and put options are analyzed for 19 companies in the banking and insurance sectors from January 1996 to September 2009. Our empirical findings suggest that certain events such as the takeovers of AIG and Fannie Mae/Freddie Mac, the collapse of Bear Stearns Corporation and public announcements of large losses/writedowns are preceded by abnormal trading activities in call and put options. The realized gains amount to several hundreds of millions of dollars. Several cases are discussed in detail.

**Keywords:** Options Trades, Open Interest, False Discovery Rate, Massive dataset, Financial Crisis

**JEL Classification:** G12, G13, G14, G17, G34, C61, C65

# Contents

# 1 Introduction

As a result of the Subprime financial and economic crisis, the United States Department of the Treasury announced its voluntary Capital Purchase Program. The program was designed to encourage U.S. financial institutions to increase their capital. The Treasury was willing to purchase up to $250 billion in senior preferred shares in qualifying U.S. controlled banks and savings associations. Each financial institution was able to obtain a maximum of $25 billion Tier 1 capital paying an interest rate as high as 5% during the first five years and 9% thereafter. The financial institution willing to participate in the program had to adopt the Treasury Department standards for executive compensation and corporate governance for the period during which the Treasury holds equity issued under the program. An unprecedented volume of the Capital Purchase Program and huge losses/writedowns have seen over 2009–2011. Stocks of many companies have been subject to astonishing ups and downs as well as huge amounts of equity value erased over a remarkably short period of time. Informed traders or corporate insiders could have exploited private information concerning default risk and bailout programs before its public release in order to take advantage of those large stock movements.

In this appendix we analyze abnormal trading activities in put and call options from January 1996 to September 2009, covering the recent financial crisis. Three different options markets are considered: the Chicago Board Options Exchange (CBOE), with companies American International Group (AIG), Bank of America Corporation (BAC), Bear Stearns Corporation (BSC), Citigroup (C), Fannie Mae (FNM), Freddie Mac (FRE), Goldman Sachs (GS), J.P. Morgan (JPM), Lehman Brothers (LEH), Merrill Lynch (MER), Morgan Stanley (MS), Wachovia Bank (WB) and Wells Fargo Company (WFC); Eurex (Zurich and Frankfurt), with UBS, Credit Suisse Group (CS) and Deutsche Bank (DBK); and Euronext (Paris and London), with Societé Générale (GL), HSBC (HSB) and BNP Paribas (BN). Many of the American companies belong to the list of banks which were bailed out receiving approximately $200 billion through the Capital Purchase Program in an effort to bolster capital and support new lending. The remaining companies have been severely affected by the financial crisis. Daily returns during the crisis are characterized not only by unusually negative values, but large rises as well. Quarterly results, writedowns, bank run and sold off of stocks easily lead to daily returns of more than ±20%. Due to the large positive and negative stock movements, we apply the procedure introduced in the main paper for detecting abnormal trading activities in put and call options.

As discussed in the introduction of the main paper, informed traders and/or corporate insiders hedging their human capital are most probably behind abnormal trades in put options. Without knowing trader identities, it is not possible to disentangle whether put option abnormal trades are due to informed traders or corporate insiders hedging their human capital. We describe this situation as saying that we are testing a *joint hypothesis*.

## 2 Data

For completeness, we describe our dataset in this appendix as well. We analyze several American and European companies from the banking and insurance sectors. For American companies, options data are from the Chicago Board Options Exchange (CBOE) as provided by OptionMetrics. Stock prices are downloaded from OptionMetrics as well to avoid non-synchronicity issues, and are adjusted for stock splits and spin-offs using information from the CRSP database. Intraday transaction prices and volumes for each underlying stock price are from the NYSE's Trade and Quote (TAQ) database. This database consists of several millions of records for each stock and is used in the classification of volumes in buyer and seller-initiated trades in order to complete the analysis related to the hedging criterion. For European companies, options data as well as intraday transaction prices and volumes for the underlying stock are obtained from EUREX provided by Deutsche Bank, and from EURONEXT provided by NYSE Euronext. All datasets include the daily cross section of available put and call options for each company and intraday data for the underlying assets from January 1996 to September 2009. We eliminate obvious data errors such as open interest reported at zero for all existing options by excluding those days from our analysis. The list of American and European companies analyzed is given in the Introduction. All options are American style.

## 3 Empirical Results

We apply the procedure in introduced in the main paper to the above-mentioned American and European companies. We use the same notation as in the main paper. We report most of the results in tabular form. Tables 1–13 present an overview of the put and call abnormal trades belonging to the intersection of $\Omega_1 \cap \Omega_2 \cap \Omega_3 \cap \Omega_4$ for the 13 American companies analyzed, Tables 14–16 for the European companies with options listed on EUREX, and Tables 17–19 for the European companies with options listed on EURONEXT. These tables report only the selected transactions during 2007–2009. The total number of detected options for the whole sample period 1996–2009 is given in brackets after the option specification (put or call).

In the following subsections, we separately analyze our empirical findings for the three markets; CBOE, EUREX, and EURONEXT. We discuss some specific cases. Additional tables and figures are available from the authors upon request. Although our sample period covers almost 14 trading years, the percentage of transactions that fall into the Subprime financial crisis (2007–2009) is remarkably high. There may be several reasons for this: first, the high volatility during the crisis induced large and sudden movements in stock prices generating gain opportunities for informed market participants; second, due to the dramatic and rapid collapse of the financial system, the number of corporate and governmental decisions made has sharply increased, giving rise to numerous potential information leakages and abnormal trading activities; third, trades made before scheduled announcements could be based on speculative bets, the latter being facilitated by several rumors already present in the market. With respect to realized gains, the numbers are generally higher than the ones detected during 1996–2006 and reported in the main paper. By virtue of leverage, large drops/rises in the underlying stock lead relatively quickly to net profits of more than 1 million through option trading. With respect to the option type, we find that the number of detected put trades is usually larger than the number of detected call trades.

## 3.1 Trading Activities on the CBOE

### 3.1.1 J.P. Morgan's Takeover of Bear Stearns Corporation in March 2008

The financial crisis began spreading more widely in August 2007 with the collapse of two Bear Stearns hedge funds which had heavily invested in Subprime-related securities. On December 20th, 2007 Bear Stearns posted fourth quarter losses of $854 million after mortgage related writedowns of $1.9 billion. It was the first quarterly loss in its 85-year history.

In Spring 2008, Bear Stearns was the subject of a multitude of market rumors regarding its liquidity. Early in the week of March 10th, 2008 rumors swirled around Wall Street that European firms had suspended fixed income trading with Bear Stearns. U.S. traders began to stop trading with Bear, hedge funds pulled money from prime brokerage accounts, money market funds reduced their investment in short-term Bear issued debt. The company then suffered a cash crunch.

On Thursday, March 13th, Bear shares fell more than 7% to $57. Bear called J.P. Morgan, its clearing bank, to warn that it might not have enough cash to meet its obligations on Friday and needed emergency help. It also called the Securities and Exchange Commission and the Federal Reserve Bank of New York. In an evening conference call among the New York Fed, the Securities and Exchange Commission, the Fed Board of Governors and the U.S. Treasury, the SEC said Bear Stearns might file for bankruptcy the next morning.

On Friday, March 14th, the New York Fed, the Fed Board of Governors and the Treasury held a conference call to discuss the options. They decided to issue an overnight non-recourse loan to J.P. Morgan so that the bank could then loan money to Bear Stearns. The loan was intended to get Bear Stearns through to the weekend while the companies and government officials explored Bear Stearns' options and ways to contain potential damage. Bear shares fell 46% to $30.85. Credit rating agencies downgraded Bear Stearns debt and customers continued to pull funds to the point where Bear Stearns officials feared the bank would be insolvent by the time Asian markets opened on Sunday evening.

On Sunday evening, March 16th, J.P. Morgan announced that it would acquire Bear for about $2 a share and that the Fed would provide J.P. Morgan with a $30 billion loan backed by Bear assets. J.P. Morgan guaranteed billions of dollars in Bear trading obligations. The deal was announced just before Asian markets opened. On Monday, March 17th, Bear shares started the day with a drop of nearly 90% to $2.86.

For the period 1999–2009, our procedure detected 16 transactions in put options and 11 in calls. 9 trades in puts and 2 in calls fall into the time period 2007–2009. We now focus on a series of trades in put options which took place in the days leading up to the collapse of Bear Stearns. We detected 6 large trades in put options from March 4th till March 14th, most of them involving deep out-of-the money options. Since the dynamics of such trades are similar, we do not report all details for every transaction, but concentrate on a few examples.

On March 10th, Bear Stearns stock traded at $62.30. On that day, 11,757 contracts of put options with strike $30 and maturity end of March were created at CBOE. Due to the deep out-the-money moneyness, these options were traded at the cheap price of $0.625. Such an increment of open interest corresponds to the 99.70% quantile of its historical distribution. The same options exhibited another unusually high increment the following day when its open interest increased by an additional 22,809 contracts. The price of the option even decreased to $0.25 as the stock price increased slightly.

On March 17th, when the market reopened after the intense negotiations marathon between Bear Stearns, J.P. Morgan and the Fed, the stock dropped nearly 85% to $2.86, increasing the value of these put option to $27.14. The day of the announcement corresponds to the exercise of 8,150 option contracts. On March 18th, an additional 9,310 put options were exercised, leading to net gains of more than $50 million.

On March 12th, the put option with strike $40 and maturity April, exhibited a large increment in open interest: on that day, the stock traded at $61.58, making the option deep out-of-the money and tradable at $1.86. On the day of the announcement, its value increased to $37.14, resulting in a net profit of more than 1,700% in three trading days. The sequential exercise of these options over the following weeks generated net gains of more than $6 million. Additional details can be found in the separate appendix.

### 3.1.2 The Case of American International Group

We start with a concise summary of key events involving AIG, and discuss thereafter our empirical findings. In October 2007, when the stock was at $68.59, AIG entered a turbulent period. The company reported that its swaps portfolio lost $352 million. A month later, that figure was revised to $1.1 billion. Between early October and mid-November 2007, AIG's stock price fell 25%. In February 2008, AIG announced estimated losses of $11.5 billion, and that it had posted $5.3 billion in collateral, pushing down the stock to under $50. In summer 2008, it was reported that the Justice Department was investigating AIG for possible criminal fraud. The UK's Serious Fraud Office would later announce its own probe. At the beginning of September 2008, when the stock was at $21.96, AIG executives learned that the ratings agencies planned to downgrade the company's rating again. That would trigger more collateral calls, which AIG knew it could not begin to cover. Desperate negotiations to keep the company afloat—including a possible $75 billion bridge loan from Goldman Sachs and J.P. Morgan, both major counterparties on the credit default swaps—ensued. Tim Geithner, Head of the Federal Reserve Bank of New York, was called in. It became clear that AIG's level of exposure to its credit default swap losses was higher than anyone had yet understood. On September 16th, 2008 the Federal Reserve Board announced that it would take a nearly 80% equity stake in AIG—effectively taking over the firm—and provide an $85 billion loan. On that day, AIG stock was at $3.75.

Applying our detection procedure, we selected a total of 17 transactions in put options and 17 in call options for the whole sample period, with 7 and 2, respectively, falling into the financial crisis, January 2007–September 2009. We now discuss some cases in detail. Information regarding the remaining transactions can be found in the reported tables.

The first transaction in put options took place on October 5th, 2007. The underlying stock was at \$69.39. The average return of the underlying stock during the last two trading weeks, $M_t$, was slightly positive, 0.18%. The requested put options are at-the-money with a value of \$1.9 and a maturity of November 2007. The increment in open interest is 7,594 contracts, corresponding to 95.7% of its historical distribution. This transaction precedes the first AIG reported losses concerning its business activities in CDS. In the following weeks, the underlying stock fell sharply, increasing the option's value to levels above \$7. Many of these options were sequentially exercised which led to net gains of approximately \$7 million. An interesting sequence of transactions took place in the days leading up to the takeover of AIG on September 16th, 2008. On September 10th, 11th and 12th, large increments in put options were observed on the CBOE. The maturities of these options were October and November 2008. The market was bearish during the preceding trading weeks and a large demand for protective put options seemed to be a plausible consequence. On September 10th the stock traded at \$17.50 and 23,137 new put options with strike \$18 were requested. These options were at-the-money with a price of \$3.40. The following day, the stock traded at \$17.55 and 14,494 new put options with strike \$8 were bought on the CBOE. These options were deep out-of-the-money and therefore quite cheap (\$0.69). Furthermore, on September 12th, 14,249 new out-of-the-money put options with strike \$10 were bought on the CBOE. Their price was \$1.465. The first two options matured in November 2008, whereas the latter matured at the end of September. Three trading days later, on September 16th and just one day after the collapse of Lehman Brothers, the Federal Reserve announced that it would take over AIG. The stock price dropped to \$3.75, pushing those put options deep in-the-money and increasing their value to more than \$14 in the first case, \$5 in the second and third case. On the same day, 12,931 options of the first type, 13,924 of the second and 1,974 of the third were exercised, leading to a net profit of more than \$13 million, \$6 million and \$1 million, respectively. On September 17th and 18th, when the underlying stock decreased further in value to \$2, a large number of these options were exercised, leading to large profits. The total realized gains through exercise, $G_t$, amounted to \$24, \$4.5 and \$7.9 million, respectively. Figures 1 and 2 report the dynamics of these transactions.

We now discuss a detected transaction in call options which took place on July 30th, 2009. The stock traded at \$13.13 with bearish market condition, with $M_t$ being at $-2.21\%$. 2,806 out-of-the-money (strike \$15) call options were requested on July 30th with a price of \$0.95. A few days later, on August 7th, a profit quarterly announcement increased the stock value to \$27.14, raising the value of the call options to \$12.38. This represents a net profit of more than 1,200% in less than two trading weeks. On August 28th the stock reached the level of $50.23, increasing the option's value to $35. Between July 30th and maturity, i.e., September 2009, exercising the call options led to net gains of more than $5.5 million. The remaining out-of-the-money call option detected on August 18th, shows similar behavior and the total net gains amounted to $5.3 million. Additional information can be found in Table 1 and Figure 3.

#### 3.1.3 The Case of Fannie Mae and Freddie Mac

For the case of Fannie Mae, our procedure detected 17 transactions in put options, 10 of which took place in the years 2007–2009, and 13 in call options, 4 of which during the financial crisis. In the case of Freddie Mac, these include 12 for puts and 15 for calls, respectively. 5 trades in puts and 6 in calls occur after 2007.

On July 13th, 2008, after a weekend of negotiations, the Treasury and the Federal Reserve announced emergency measures to backstop Fannie Mae and Freddie Mac. The two companies would get access to credit lines, including direct access to Fed money if necessary, and a provision for the Treasury to take an equity stake in the companies if required. The Securities and Exchange Commission announced measures aimed at stemming the spread of false rumors. Two days later, Fannie Mae and Freddie Mac shareholders still found no overt assurance regarding the fate of common stock in any government bailout. Freddie Mac shares plunged 26% and Fannie Mae plummeted 27%. In the following days, Freddie Mac completed its second successful debt sale of the week, and confidence regarding the fate of the rescue effort moving through Congress rose. Fannie Mae shares rose more than 18% and Freddie Mac added nearly 22%. On July 23rd, the House of Representatives approved a housing market support package including a mandate for the U.S. Treasury to provide equity or debt to Fannie Mae and Freddie Mac. The White House dropped opposition to other measures in the broad housing bill and pledged to sign it into law. Fannie Mae shares rose almost 12% to $15, their highest close since July 9th. Freddie closed up more than 11% at $10.80, its highest close since July 8th. On August 8th, Fannie Mae posted a second quarter loss of $2.3 billion before preferred dividend payments, or $2.54 a share. It was the fourth straight quarterly loss, bringing its cumulative loss over 12 months to $9.44 billion before preferred dividends. Fannie cut its dividend and said it would raise loss reserves. Based on an article published on August 17th in Barron's magazine, the Treasury Department was increasingly likely to recapitalize Fannie Mae and Freddie Mac in the coming months using taxpayer's money. The following day, share prices for mortgage finance companies dropped, with Fannie Mae's price plunging 22% to a 16-year low of \$6.15 and Freddie Mac's down 25% to \$4.39. The New York Times and Washington Post reported late on Friday, September 5th, that in what could be the largest financial bailout in the nation's history, the U.S. government planned to put government sponsored mortgage finance companies Fannie Mae and Freddie Mac under federal control. The closing share price on that Friday was \$7.04 for Fannie Mae and \$5.1 for Freddie Mac. On Sunday, September 7th, 2008 the Federal Government announced its takeover of Fannie Mae and Freddie Mac, effectively nationalizing them. At that point Fannie Mae and Freddie Mac owned or guaranteed about half of the U.S.'s \$12 trillion mortgage market. This led to panic as almost every home mortgage lender and Wall Street bank relied on them to facilitate the mortgage market; investors worldwide owned \$5.2 trillion of debt securities backed by them. On Monday, September 8th, when the market reopened, the stock price of Fannie Mae crashed by almost 90% to under \$1, and Freddie Mac stock fell to \$0.88, decreasing its value by more than 80%.

Our procedure detected a series of abnormal trades in put options starting on August 11th, the month leading up to the takeover of Fannie Mae and Freddie Mac. 6 large increments in put options were found for the underlying Fannie Mae and one for Freddie Mac. In all cases, the acquired put options were deep out-of-the-money, making them available at a cheap price. On September 7th, when both underlying stocks lost more than 80% of their value, these options went deep in-the-money and, through a sequential exercise in the following days, several millions in net gains were collected. We now discuss a few of these transactions in detail. Additional information for the remaining ones can be found in Tables 5 and 6 and Figures 4 and 5.

For Fannie Mae, on August 11th, 2008 the put option with strike \$6 and maturity September saw an impressive increment in open interest of 10,164 contracts. The underlying stock traded at \$8.40, the market condition $M_t$ was slightly negative ($-0.21\%$) and the put price was \$0.675. Before this strong increment, the level of open interest was almost zero. In the following weeks, the open interest of these options continuously increased, reaching a maximum number of 31,824 contracts on September 4th, where another strong increment of 5,774 contracts was detected by our procedure as an abnormal trade. On that day, the price of the underlying stock was \$6.42 and the price of the put option \$0.75. On Monday, September 8th, the day after the announcement that the Fed would take over Fannie Mae and Freddie Mac, the value of the put options increased by more than 600%, reaching a value of \$5.3 per option contract. On the same day, 7,162 contracts were exercised, leading to net gains of more than \$3 million. Furthermore, another large number of options (11,730 contracts) were exercised a few days later. The net gains from this exercised amount were more than \$5 million. Another put option abnormal trade with underlying stock Fannie Mae was detected on August 28th; see Figure 4. The increment in open interest totaled 15,178 contracts, the strike price was \$7 and the option had a time-to-maturity of 114 days. The underlying stock traded at \$7.95 and the put option had a value of \$2.6. Until September 9th, the level of open interest remained constant. The day after, 14,701 contracts were exercised when the option's price was \$6.2. The net gains amounted to more than \$5 million. In the case of Freddie Mac, our methodology detected only one transaction in put options on September 3rd, 2008. Its strike was \$3 with a time-to-maturity of 136 days. The underlying asset traded at \$5.38 and the put had a value of \$0.9. The strong increment in open interest observed on September 3rd (2,260 contracts) was offset by the exercise of 2,430 options on September 10th, when the option had a value of \$2.35. The net gains from this transaction amounted to approximately \$300,000. With respect to the detected transaction in call options, both companies were subject to large trade in calls in March 2008. Our procedure detected 3 abnormal trades for Fannie Mae on March 5th, 7th and 11th, and three for Freddie Mac on March 10th, 11th and 18th. All these options were almost at-the-money and matured at the end of March. The market condition variable was between $-1\%$ and $-2\%$, indicating that these call options had been bought during a bearish period. We do not provide the details of these transactions but are available upon request. The dynamics behind these trades are the same as those described in the previous examples: the observed increments in open interest are all above their 94% historical quantiles and occurred during the days leading up to March 20th, 2008 when U.S. regulators eased capital requirements for the two firms in order to provide up to \$200 billion in immediate liquidity for stressed mortgage markets. On that day, shares of Fannie Mae and Freddie Mac jumped by approximately 26%. In both cases, a considerable number of call options were exercised in the subsequent days leading to net gains of several millions. Additional details can be found in Tables 5 and 6.

#### 3.1.4 Additional Comments on the CBOE Options Trades

For the remaining companies with options traded on the CBOE, we do not report detailed results but refer to the corresponding tables. We collect a list of option abnormal trades. The dynamics of these trades are the same as in the previous extensively discussed examples.

For Bank of America, on November 14th, 2008 and January 14th, 2009 two abnormal trades in put options were detected. Both trades were followed by a stock crash of more than 20% due to the announcements of 35,000 and 1,000 job cuts, respectively. The resulting gains through exercise amounted to \$5.4 million and \$3.3 million, respectively. Quarterly profits announced on July 22nd, 2008 (with a stock value increase of 22.4%), were preceded by a series of transactions in call options resulting in total net gains of more than \$8 million. For Citigroup, our method detected a transaction on Friday, November 21st, 2008 in a deep out-of-the-money call option with short time-to-maturity. The increment in open interest amounted to 61,927 option contracts, i.e. the 99.7% quantile of its historical distribution. On the following Monday, the government's plan to help Citigroup by buying \$20 billion of preferred stock was announced. The stock value increased in the following days by more than 50% and a large number of call options were exercised, leading to net gains of more than \$7 million. The amount of financial losses reported on January 16th, 2009 induced a drop in the underlying stock of more than 23%, and were preceded by 3 transactions in out-of-the-money put options traded on the CBOE on January 7th, 8th and 12th. The total realized gains after the stock crashed amounted to more than \$9 million. The profit drop of 76% announced by J.P. Morgan on January 15th, 2009 was preceded by three large trades in put options on December 31st, January 2nd and 6th. Realized gains totaled more than \$17 million. The strong rise in stock value between March 9th and March 18th (from \$15.9 to \$27.11) was preceded by unusually high increments in out-of-the-money call options between March 5th and 9th. Realized gains from options exercise totaled more than \$16 million. For Morgan Stanley, we found 2 large transactions in deep out-of-the-money call options on October 9th and 10th, 2008. These precede the announcement on Monday, October 13 that a Japanese bank intended to buy 1/5 of Morgan Stanley. The stock value nearly doubled that day, resulting in net gains of more than \$12 million through the exercise of those call options. A series of abnormal trades in put options with underlying stock in Wachovia Bank was detected during the month of September 2008, the period leading up to the announcement on September 29th that the bank would be taken over due to its uncertain situation. On that day, the stock plummeted by more than 81%, pushing these put options deep in-the-money. The subsequent exercise of these options led to realized gains of more than \$23 million. For Wells Fargo, the underlying stock had been sharply loosing value during the first two months of 2009: the stock was traded around \$30 in January 2009, and on February 27th, it was worth \$12.1. We detected abnormal trades on January 6th, 7th, 8th and 28th. The subsequent exercise of these put options led to substantial gains.

## 3.2 Trading Activities on EUREX—Frankfurt and Zurich

Option contracts with underlying German and Swiss companies are traded on EUREX, one of the world's largest derivatives exchanges and the leading clearing house in Europe established in 1998 after the merger between Deutsche Terminbörse (DTB, the German derivatives exchange) and SOFFEX (Swiss Options and Financial Futures). In this section we use the EUREX database provided by Deutsche Bank to analyze option transactions with underlying UBS, Credit Suisse Group (CS) and Deutsche Bank (DBK). Our empirical findings are summarized in Tables 14, 15 and 16. In the case of UBS, our procedure detected 16 transactions in put options, 13 of which fell into the period 2007–2009. The proportion of call options is smaller, with 3 out of 13 transactions taking place during the financial crisis. For CS, we detected 16 trades in puts and 13 trades in calls for the entire sample period. The proportion falling into the period after 2007 is around one third. For DBK, we identified a total of 16 transactions in put and 3 in call options. More than half of these put trades took place in the last two years of our sample, whereas only one call abnormal trade was found for the years 2007–2009.

We now discuss a specific event related to Credit Suisse. On October 13th, 2008 Israeli holding company Koor Industries (KOR.TA) invested CHF 1.2 billion in Credit Suisse in exchange for a 3% stake in the bank. On that day, CS jumped by more than 27%. Furthermore, on October 16th, 2008 Credit Suisse raised approximately CHF 10 billion, about 12% of its outstanding equity, from private investors. The Qatar Investment Company increased its stake in Credit Suisse to 8.9%, while Saudi conglomerate Olayan increased its stake to 3.6%. Our procedure detected an abnormal trade on September 18th in deep out-of-the-money call options with maturity December 2008. The increment in open interest amounted to 10,010 contracts, being at the 93% quantile of its historical distribution. Due to the remarkable rise in stock value observed a few weeks later, these options went in-the-money and saw gains through exercise of approximately CHF 1.5 million.

## 3.3 Trading Activities on EURONEXT—London and Paris

Options with underlying French and British companies are traded on EURONEXT in Paris and London. In this subsection we report our empirical findings for Societé Générale (GL), BNP Paribas (BN) and HSBC (HSB). We discuss some specific cases. Information regarding the remaining transactions can be found in Tables 17–19.

### 3.3.1 The Case of Societé Générale

On January 24th, 2008 the bank announced that a single futures trader at Societé Générale had fraudulently lost the bank €4.9 billion, the largest such loss in history. Jérome Kerviel, a relatively junior futures trader, allegedly orchestrated a series of bogus transactions that spiraled out of control amid turbulent markets in 2007 and early 2008. Executives said the trader acted alone and that he may not have benefited directly from the fraudulent deals. The bank announced it would be immediately seeking €5.5 billion Euros in financing. On Tuesday, January 22nd, 2008 the French stock market regulator said that it had begun a formal investigation into Société Générale. It was not clear whether the inquiry was related to the revelation that Robert Day, a member of Société Générale's Board, had sold shares in the bank worth €45 million on January 18th, the day Société Générale explained that management had first been alerted to Mr. Kerviel's unauthorized trading, and two days before the bank's audit committee was informed of a planned €2.05 billion writedown linked to the bank's exposure to the U.S. Subprime lending market. Société Générale and a spokesman for Mr. Day said in separate statements that the share sales by Mr. Day and his family's trusts occurred in several transactions from December 2007 to January 18th, 2008 during a predetermined window when directors were allowed to exercise options. Both statements said all required disclosures had been made, and "no inside information was used in any way" with respect to these sales. Our detection procedure detected two abnormal trades in put options on January 9th and 16th, 2008. Both options were out-of-the-money with short maturity. Their exercise led to gains of more than €1.7 million. In addition, the February 12th, 2008 announcement that Société Générale planned to raise $8 billion in capital was preceded by two abnormal trades in deep-out-of the money call options. After the substantial stock rise, the exercise of these options led to a total gain of more than €9 million. Other abnormal trades in put as well as call options can be found in Table 17.

### 3.3.2 Additional Comments on EURONEXT Options Trades

For BNP Paribas and HSBC we do not report detailed results but refer to the corresponding tables for additional information (Tables 18 and 19). For BNP Paribas, we detected a series of abnormal trades which took place between January 14th and 18th, 2008. The involved put options were deep out-of-the-money with short maturity. On January 30th, the announcement that quarterly profit would slump over 40% had a strong impact on the underlying asset. The exercise of these put options led to a net profit of more than €2 million.

### 3.4 Controlling False Discoveries in Option Abnormal Trades

We apply the procedure described in the main paper to control for false discoveries in abnormal trades. We briefly discuss the results Lehman Brothers. For the remaining companies, similar results have been found. Details are available upon request from the authors. The total number of analyzed options trades amounts at 218,000, implying that the regression coefficients $\delta_m$ for the subintervals $I_m$ have been computed by relaying on 218 returns $r_t^k$. The estimated proportion of truly abnormal trades is $E[T^+] = 6.9\%$ (with standard error 0.9%, optimal $\lambda = 0.6$, and $\gamma = 0.05$), corresponding to 69 abnormal trades. As our method detected 7 option abnormal trades, it appears to be conservative. Figure 7 shows estimated $\delta_m$, $t$-statistics, and p-values for computing the false discovery rate for Lehman Brothers.

## 4 Additional Cases

Tables 24 and 25 describe put option abnormal trades for the various sectors analyzed in the main paper.

### 4.1 Delayed Delivery Announcement of EADS Superjumbo A380 in May 2006

At the time of the writing of this paper, European Aeronautic Defence and Space (EADS), a large European aerospace corporation and the parent of plane maker Airbus, is under investigation for illegal insider trading activities. On July 2nd, 2006, co-CEO Noël Forgeard and Airbus CEO Gustav Humbert resigned following the controversy caused by the June 14th, 2006 announcement that deliveries of the superjumbo jet A380 would be delayed by a further 6 months. Mr. Forgeard was one of a number of executives who sold his stake in EADS a few months before the public announcement. In June shares of EADS exhibited a 26% fall (the closing price of EADS shares on June 13th was €25.42 and on June 14th €18.73) wiping more than €5 billion from the company's market value. He and 21 other executives are currently under investigation as to whether they knew about the delays in the Airbus A380 project and sold their stock on the basis of this private information, constituting therefore illegal insider trading. In the financial press, the profits resulting from this strategy are estimated to total approximately €20 million.[1]

[1]The New York Times edition of June 18th, 2008: "Executive Questioned in EADS Insider Trading Case".

For the period 2003–2009 our procedure detects 4 put option contracts on EUREX related to abnormal trades, all of which took place between April 6th and May 22nd, 2006.[2] These options contracts had the following maturities May, June, July, and December 2006. For example, the options maturing in July 2006 exhibited large increments in open interest on May 16th (1,135 contracts), on May 19th (4,061 contracts), and on May 22nd (1,250 contracts). These increments correspond to very high quantiles of their respective two-year empirical distributions. For example, the main increase in open interest (May 19th) corresponds to 99.8% quantile. The 4 options contracts had strikes of €31, €31, €26 and €30 and the underlying traded at €32.4, €27.5, €27.5 and €32.1 respectively on the transaction days. The average returns generated from these trades are large. For example, the selected option contract with maturity June was bought mainly three times April 5h, April 6h, and May 18th at the following prices €0.96, €1.17 and €3.46 when the stock price was respectively at €32.77, €32.37 and €27.50. These contracts were mainly exercised on June 16th at option prices €11.10 and stock price of €19.80. The total gain corresponds to €2.2 million and the average return is 370% within two months. Similar patterns are observed for the other 3 options contracts. Based on all 4 detected options, a total gain of €8.7 million had been realized within 60 trading days after the announcement.

Options contracts with underlying EADS are traded at the EURONEXT in Paris as well. Using a database provided by EURONEXT NYSE, our second method detects 3 options contracts related to abnormal trades which took place between April and May 2006. The total gains of these transactions amount to approximately €18.7 million. Details are available upon request.

## 4.2 Quarterly Loss of UBS in October 2007

Our detection procedure identified 3 trades in put options which took place in October 2007, maturing in October, December and June 2008. 2 of the 3 acquired options were out-of-the money. These trades preceded the October 30th announcement that UBS, Europe's largest bank by assets, reported its first quarterly loss in almost five years. Declines in the U.S. Subprime mortgage market led to $4.4 billion in losses and writedowns on fixed-income securities. Third quarter net loss was CHF 830 million ($712 million). In the following weeks, UBS stock started an impressive decline, and through the exercise of these puts options net gains of more than CHF 24 million were

[2]On May 12th, 2006, a meeting of the company board took place in Amsterdam in order to discuss possible solutions to the management crisis triggered by the future announcement which was planned for the following month. According to the New York Times edition of June 29th, 2006, 13 people were present, including Noël Forgeard and Gustav Humbert. The delay in A380 deliveries was likely to cost EADS €2 billion over the following four years.

collected. On February 14th, 2008 UBS saw its shares fall to a four-year low after it produced the worst quarterly loss in the bank's history and revealed new details of its full exposure to the Subprime crisis. Its stock fell more than 8% in Zurich and New York as executives failed to rule out further writedowns—which already totaled $18.1 billion—or give a date for a return to profitability. The fall accelerated after U.S. Federal Reserve Chairman, Ben Bernanke, said investment banks would have further writedowns. UBS confirmed that it lost CHF 12.5 billion in the final quarter of 2007, with full-year losses of CHF 4.4 billion—the first in the decade since it merged with the Swiss Bank Corporation—and had written off $13.7 billion in the final quarter of the preceding year. Our method detected 3 transactions in put options on January 30th, and February 11th and 12th, 2008. All options had short-term maturities and generated high returns after the stock crash on February 14. Estimated gains amounted to nearly CHF 7 million. With respect to call options, we identified 3 trades falling into the period 2007–2009, whose gains amounted to more than CHF 10 million.

### 4.3 Terrorist Attacks of September 11th: Options Traded in CBOE

The terrorist attacks have generated many articles, in which political, strategic and economic aspects have been considered. The financial dimension has also been discussed by the press. In particular, the question of whether the terrorist attacks of September 11th had been preceded by abnormal trading volumes, generated widespread news reports just after 9/11. As far as official regulators and control committees have been concerned, they dismiss charges against possible informed traders. The American 9/11 Commission has stated that "exhaustive investigations by the Security and Exchange Commission, FBI and other agencies have uncovered no evidence that anyone with advance knowledge of the attacks profited through securities transactions."[3]

From an academic point of view, this topic did not generate much research interest. The article of Poteshman (2006) is a notable exception. Focused mainly on the airline sector, Poteshman computes the distributions of option market volume statistics both unconditionally and when conditioning on the overall level of option activity, the return and trading volume on the underlying stocks and the return on the overall market. He finds that "when the options market activity in the days leading up to the terrorist attacks is compared to the benchmark distributions, volume ratio statistics are seen to be at typical levels. As an indicator of long put volume, however, the volume ratio statistics appear to be unusually high which is consistent with informed investors hav-

[3]The 9/11 Commission Report, Page 172, available on http://www.9-11commission.gov/report/911Report.pdf.

ing traded in the options market in advance of the attack." In the following the abnormal option trades detected by our ex-post method are discussed in detail. We expect that corporate insiders of the involved companies were unaware of the pending terrorist attacks, and therefore the *joint hypothesis* does not apply in this case.

In total 13 transactions satisfy our criteria of abnormal trade and involve five airlines companies (AMR, UAL, BA and to a lesser extent DAL and KLM) and four banks (BAC, C, JPM and MER). Concerning the airline sector, AMR and UAL are the two companies whose planes were hijacked and crashed by the terrorists. Abnormal option trade for KLM may be surprising, but would support the suspicion of "insider trading in KLM shares before September 11th attacks", as reported in a Dutch government investigation (Associated Press Worldstream). The terrorist attacks had indirect implications for BA and DAL, like a potential decrease in the number of passengers. Based on our methodology, AMR, UAL, and BA were more likely object of abnormal trade than DAL and KLM. With respect to the banking sector, Merrill Lynch, Bank of America, and J.P. Morgan were located in World Trade Center or nearby, and the Travelers Insurance Unit of Citigroup was expected to pay $500 million in claims.

In the case of American Airlines we will now report the details of the transaction which took place on September 10th. Additional tables are available from the authors upon request. The upper graphs in Figure 8 show the plot of option volume, $V_t$, versus its increment in open interest, $X_t$. The abnormal trades are highlighted with the circles. The left graph covers the period from January 1997 to December 2001, to better visualize the option market condition up to December 2001. The right graph covers the period January 1997–January 2006. The selected transactions are isolated from the bulk of the data, suggesting that they are statistically unusual.

For September 2001 Figure 9 shows the dynamic of three variables: open interest, volume and the option return. As claimed in several newspaper articles, the volume and open interest of puts had been unusually high in the days leading up to September 11th. On September 10th 1,535 put contracts were traded and from September 7th to September 10th the open interest increased of 1,312 contracts (at 99.5% quantile of its two-year empirical distribution). The trading volume was more than 60 times the average of the total daily traded volume during the three weeks before September 10th. These puts had a strike price of $30 and a maturity in October. On September 10th, the stock price was $29.7 and the put price was $2.15. On September 17th, when markets reopened after the attacks, the stock price was $18 and the put price was $12. Such an investment in put options generated an unusually high return (458% in one week). Put options were obviously exercised on September 17th, the open interest decreased of 597 contracts, generating a gain of almost \$600,000. A few days later, another considerable number of put options (475 contracts) were exercised: Table 20 reports the gains ($G_t$) of such a trade. Twenty-six days later the sum of exercised options corresponded to the increment observed on September 10th and lead to a cumulative gain of more than one million ($G_t = \$1{,}179{,}171$).

The lower graph in Figure 8 shows the cumulative gain for all transactions selected by our procedure. The trade in put options of AMR corresponds to the transaction that leads to the highest gains in the shortest time interval in the period we are considering. Trading volume after September 17th was negligible meaning that the main gain was realized through exercise and not selling the options. Similar conclusions can be reached for the other trades selected using our procedure. For example two trading days before the terrorist attacks 4,179 put options (at 98.5% quantile of its two-year empirical distribution) on Boeing were issued. The underlying stock was traded at \$45.18 and the option had a strike of \$50. On September 17th, the stock was traded at \$35.8. Six days afterwards these options were exercised leading to gains of more than \$5 million. Concerning Bank of America, a large increment of 3,380 in open interest (at 96.3% quantile of its two-year empirical distribution) took place on September 7th for an option with a strike of \$60 when the underlying asset had a value of \$58.59 (on September 17th, the underlying stock had a value of \$54.35). The exercise of those options in the following seven days resulted in net gains of almost \$2 million; for Merrill Lynch, on September 10th, 5,615 put options (at 99.1% quantile of its two-year empirical distribution) with strike \$50 were issued, the underlying stock had a value of \$46.85. On September 17th the underlying stock was traded at \$41.48. Less than six days later these options had been exercised leading to gains of around \$4.5 million. For the remaining companies similar results can be reached from the reported tables. Tables 20 and 22 show that the total gains in the airline sector amount to more than \$16 million, whereas in the banking sector \$11 million in gains have been computed. Interestingly, in nearly all cases the hypothesis of non-hedging cannot rejected.[4]

[4] In the article "Not much stock in put conspiracy: the attacks on New York City and Washington have led to a new urban legend, namely that inside traders used put options on airline stocks to line terrorist pockets" published on June 3th, 2002 by Kelly Patricia O'Meara in *Insight on the News*, other repeated spikes of volumes of put options on American Airlines and United Airlines during the year before 9/11 are highlighted and used as argument that what occurred in the days leading up to 9/11 was not as unusual as other theories claim. Both our methods do not select those option trades mainly because those spikes in volume do not correspond to large increments in open interest.

### 4.4 Terrorist Attacks of September 11th: Options Traded in EUREX

Several reinsurance companies suffered severe losses from the terrorist attacks of September 11th. Liabilities for Munich Re and Swiss Re—the world's two largest reinsurers—were estimated to be in the amount of billions of dollars a few days after the attacks. At the same time, several newspapers reported that trading in shares of these two companies were at unusual levels in the days leading up to September 11th, divulging some rumors of abnormal trading activities. A detailed analysis of transactions on the options market has however thus far been ignored. Options with underlying Swiss Re and Munich Re are mainly traded on the EUREX, one of the world's largest derivatives exchanges and the leading clearing house in Europe established in 1998 after the merger of Deutsche Terminbörse (DTB, the German derivatives exchange) and SOFFEX (Swiss Options and Financial Futures). In this section we use the EUREX database provided by Deutsche Bank to analyze transactions in put options with underlying Swiss Re and Munich Re. The database does not contain intraday data and hence the hedging dimension cannot be investigated.

In the case of Munich Re, 4 abnormal trades are detected between 1999 and 2008 which belong to the set $\Omega_1 \cap \Omega_3 \cap \Omega_4$, one of which took place on August 30th, 2001. As we are mainly interested in abnormal trades surrounding the terrorist attacks in this subsection, we only discuss the details of this transaction (the others took place on August 29th, 2002; September 2nd, 2002; and October 19th, 2007). The detected put option with underlying Munich Re matured at the end of September, 2001 and had a strike of €320 (the underlying asset was traded at €300.86 on August 30th). That option shows a large increment in open interest of 996 contracts (at 92.2% quantile of its two-year empirical distribution) on August 30th. Its price on that day was €10.22 and the ex-ante probability $q_t$ is slightly lower than 5%. On the day of the terrorist attacks, the underlying stock lost more than 15% (the closing price on September 10th was €261.88 and on September 11th €220.53) and the option price jumped to €89.56, corresponding to a return of 776% in 8 trading days. On September 12th, 1,350 put options with those characteristics were exercised. The gains $G_t$ related to the exercise of the 996 put options issued on August 30th correspond to more than €3.4 million.

In the case of Swiss Re, 6 abnormal trades are detected between 1999 and 2008 which belong to the set $\Omega_1 \cap \Omega_3 \cap \Omega_4$, one of which took place a few weeks before the terrorist attacks, on August 20th. This option expired at the end of September, 2001, had a strike of €159.70 and had a large increment in open interest of 3,302 contracts (at 99.8% quantile of its two-year empirical distribution) on August 20th. That option was traded at €0.8 and exhibits an ex-ante probability $q_t$ of 0.4%, meaning that such an event happens on average once a year. The Swiss Re closing share price was €177.56 on August 20th. On September 11th, when the stock price fell from €152.62 to €126.18, the option generated a return of 4,050% in three trading weeks, when its price jumped to €33.2. Through the exercise of these put options in the 9 days following the attacks, the total gains were more than €8 million. Together with Munich Re, a total gain of €11.4 million had been realized in less than two trading weeks by using two options with underlying Munich Re and Swiss Re. To save space the corresponding tables and figures are omitted but are available from the authors upon request.

# 5 Accuracy of the Hedging Detection Method

In this appendix we provide an assessment of the accuracy of our hedging detection method used in the main paper. Recall that the hypothesis $H_0$ of no hedging when abnormal trades occur at day $i$ is rejected whenever $V_i^{\text{buy}} > q_\alpha^{V_i^{\text{buy,non-hedge}}}$, implying that a sizable component of buyer-initiated trades in the stock is due to hedging. We measure the accuracy of the method by computing the probability of rejecting $H_0$ when the latter does not hold, namely the power of the test. Let $V_i^{\text{buy}} = (1+h_i)\ V_i^{\text{buy,non-hedge}}$, where $h_i \geq 0$. The $h_i$ represents the ratio between buyer-initiated volume due to hedging and buyer-initiated volume due to non-hedging. By construction $H_0$ is equivalent to $h_i = 0$ meaning that volume trades due to hedging is zero. The hypothesis $H_0$ should be rejected when $h_i > 0$, and the higher the rejection rate the more accurate the hedging detection method. Let $q_\alpha := q_\alpha^{V_i^{\text{buy,non-hedge}}}$, the measure of accuracy $\mathbb{A}(h_i)$ reads

$$\mathbb{A}(h_i) := \mathbb{P}\Big[V_i^{\text{buy}} > q_\alpha | h_i\Big] = \mathbb{P}\Big[V_i^{\text{buy,non-hedge}} > q_\alpha/(1+h_i) | h_i\Big]. \tag{1}$$

The hedging detection method is accurate whenever $\mathbb{A}(h_i)$ increases fast enough in $h_i$. The probability in (1) can be calculated as $(1-\tilde{F}(q_\alpha/(1+h_i)|\mathbf{X}_i))$, where $\tilde{F}$ is estimated using the adjusted Nadaraya–Watson estimator as in the main paper and $\alpha = 0.95$ as in our empirical analysis. We computed $\mathbb{A}(h_i)$ for several stocks, sample periods, estimation windows, and different values of $h_i$ and of the conditioning variables $\mathbf{X}_i = (|r_i|, V_{i-1}^{\text{buy,non-hedge}})$. Table 26 gives numerical values of $\mathbb{A}(h_i)$ for Citigroup on the randomly chosen day December 17th, 2001. Corresponding results for other stocks and days are fairly similar and available upon request from the authors. When $h_i = 0$, $\mathbb{A}(h_i)$ is very close to $0.05 = (1-\alpha)$, which is the non-eliminable size of the test. When $h_i$

increases, $\mathbb{A}(h_i)$ increases as well although certain combinations of the conditioning variables are more favorable than others to reject the hypothesis of no hedging. Overall the power of the test is fairly satisfactory. For example when $h_i = 0.20$, $\mathbb{A}(h_i)$ can be as high as 20%.

## 6 Conclusion

This supplemental appendix extends the empirical results in the main paper and analyzes call and put options trades on several financial institutions from January 1996 to September 2009, covering the Subprime financial crisis. We find that the detected option trades are not uniformly distributed over our sample period (1996–2009), but that the great majority falls into the period 2007–2009. Our empirical findings suggest that periods leading up to certain events such as the takeovers of AIG, Fannie Mae/Freddie Mac, the collapse of Bear Stearns Corporation and public announcements relating to large losses/writedowns are preceded by abnormal trading activities in options. Realized gains amount to several hundreds of millions of dollars.

## References

Poteshman, A., 2006, "Unusual Option Market Activity and the Terrorist Attacks of September 11, 2001," *Journal of Business*, 79, 1703–1726.

**Content of Tables:** day on which the transaction took place, Day; market condition at day $t$ measured by the average return of the underlying stock during the last two trading weeks, $M_t$; option strike $K$; option price, $P_t$; stock value, $S_t$; its time-to-maturity, $\tau$; increment in open interest from day $t-1$ to day $t$, $\Delta OI_t$; its quantile with respect to its empirical distribution computed over the last two years, $q_t$; corresponding volume, $V_t$; maximum for calls and minimum for puts return realized by the underlying stock during the two-week period following the transaction day, $r_t^{\mathrm{s}}$; number of days between transaction day $t$ and when this maximum return occurs, $\tau_1$; maximum return realized by the selected option during the two-week period following the transaction day, $r_t^{\mathrm{o}}$; number of days between transaction day $t$ and when this maximum return occurs, $\tau_2$; gains realized through the exercise of the new option issued at time $t$, $G_t$; short description of the event and why the stock drops, Event's description. Number in bracket after Put options or Call options denotes the number of detected option abnormal trades for our whole sample period, January 1996 – September 2009.

**American International Group (AIG)**

| Day | $M_t$ | $K$ | $P_t$ | $S_t$ | $\tau$ | $\Delta OI_t$ | $q_t$ | $V_t$ | $r_t^{\mathbf{s}}$ | $\tau_1$ | $r_t^{\mathbf{o}}$ | $\tau_2$ | $G_t$ | Event's description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Put Options (17) | | | | | | | | | | | | | | |
| 05 Oct 07 | 0.18% | 70 | 1.90 | 69.39 | 43 | 7594 | 95.70% | 9572 | −3.21% | 17 | 181.58% | 10 | 6,948,700 | CDS loss $1.1 billion |
| 26 Feb 08 | −0.64% | 50 | 1.73 | 51.42 | 25 | 18091 | 98.30% | 26703 | −6.56% | 6 | 375.36% | 10 | 6,621,600 | 10 Mar: $7.8 billion loss |
| 07 May 08 | 0.22% | 43 | 1.29 | 45.08 | 10 | 15073 | 97.70% | 23615 | −8.77% | 5 | 258.53% | 4 | 3,282,600 | 8 May: Quarterly Loss |
| 08 Aug 08 | 0.68% | 20 | 0.66 | 24.87 | 43 | 16951 | 97.30% | 33507 | −18.05% | 2 | 221.97% | 10 | 10,386,000 | 5 Aug: Quarterly Loss |
| 10 Sep 08 | −0.23% | 18 | 3.40 | 17.50 | 38 | 23137 | 98.30% | 28252 | −60.79% | 6 | 367.65% | 6 | 24,712,000 | 16 Sept: Fed lends $85 bln to AIG |
| 11 Sep 08 | −0.35% | 8 | 0.69 | 17.55 | 37 | 14494 | 95.10% | 15335 | −60.79% | 5 | 693.48% | 5 | 4,532,100 | 16 Sept: Fed lends $85 bln to AIG |
| 12 Sep 08 | −1.24% | 10 | 1.47 | 12.14 | 8 | 14249 | 94.90% | 52077 | −60.79% | 4 | 440.96% | 4 | 7,910,900 | 16 Sept: Fed lends $85 bln to AIG |
| Call Options (17) | | | | | | | | | | | | | | |
| 30 Jul 09 | −2.21% | 15 | 0.95 | 13.13 | 51 | 2806 | 64.70% | 2808 | 62.72% | 7 | 1352.40% | 8 | 5,536,000 | 7 Aug: Quarterly profit |
| 18 Aug 09 | 4.25% | 31 | 1.21 | 24.55 | 32 | 3223 | 70.70% | 2925 | 26.93% | 10 | 1539.00% | 9 | 5,268,100 | |

Table 1: Summary of abnormal trades for American International Group. For definition of entries see Page 23.

**Bank of America Corporation (BAC)**

| Day | $M_t$ | $K$ | $P_t$ | $S_t$ | $\tau$ | $\Delta OI_t$ | $q_t$ | $V_t$ | $r_t^{\mathbf{s}}$ | $\tau_1$ | $r_t^{\mathbf{o}}$ | $\tau_2$ | $G_t$ | Event's description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Put Options (16) | | | | | | | | |
| 19 Jun 08 | −0.86% | 30 | 3.35 | 28.14 | 58 | 27151 | 99.50% | 32226 | −8.09% | 20 | 126.87% | 10 | 8,872,400 | |
| 14 Nov 08 | −1.57% | 15 | 0.59 | 16.42 | 8 | 21136 | 97.30% | 34814 | −20.92% | 13 | 541.03% | 5 | 5,410,400 | 11 Dec: cut of 35,000 jobs |
| 14 Jan 09 | −1.15% | 10 | 0.39 | 10.20 | 3 | 15774 | 94.50% | 36500 | −28.97% | 6 | 628.21% | 3 | 3,325,600 | 21 Jan: cut of 1,000 jobs |
| 07 May 09 | 2.23% | 13 | 0.66 | 13.51 | 9 | 35313 | 97.30% | 102930 | −10.20% | 7 | 167.94% | 7 | 2,002,100 | 5 Mai: needs $33.9 billion |
| | | | | | | Call Options (20) | | | | | | | | |
| 22 Jan 08 | −0.36% | 40 | 0.53 | 37.39 | 25 3 | 12606 | 98.30% | 22114 | 8.50% | 4 | 900.00% | 9 | 2,383,700 | 24 Jan: 6 bln new shares |
| 08 Jul 08 | −1.70% | 30 | 0.90 | 23.54 | 193 | 10641 | 95.50% | 12181 | 22.41% | 9 | 244.44% | 10 | 1,900,100 | 22 Jul: Quarterly profit |
| 09 Jul 08 | −1.73% | 23 | 0.93 | 22.06 | 10 | 10076 | 94.30% | 14985 | 22.41% | 8 | 435.14% | 8 | 3,994,300 | 22 Jul: Quarterly profit |
| 10 Jul 08 | −1.69% | 25 | 1.81 | 22.36 | 135 | 8486 | 92.10% | 13883 | 22.41% | 7 | 417.96% | 10 | 1,549,400 | 22 Jul: Quarterly profit |
| 15 Jul 08 | −1.20% | 28 | 0.50 | 21.67 | 130 | 5044 | 80.30% | 5761 | 22.41% | 4 | 1400.00% | 7 | 1,070,500 | 22 Jul: Quarterly profit |
| 15 Sep 08 | 0.30% | 30 | 0.57 | 26.55 | 5 | 11070 | 94.70% | 39933 | 22.56% | 7 | 935.40% | 5 | 7,654,900 | 15 Sep: BAC acquires MER |
| 06 Mar 09 | −1.64% | 4 | 0.24 | 3.14 | 15 | 26877 | 97.50% | 49783 | 27.73% | 5 | 1442.60% | 9 | 3,337,100 | 10 Mar: Surprising Value |
| 11 Mar 09 | −1.35% | 7 | 0.43 | 4.93 | 38 | 31482 | 97.70% | 41024 | 27.73% | 2 | 276.74% | 9 | 7,809,700 | 10 Mar: Surprising Value |
| 23 Apr 09 | 2.12% | 11 | 0.45 | 8.82 | 23 | 85737 | 99.70% | 134900 | 19.31% | 10 | 353.93% | 10 | 9,796,900 | 8 May: Find Ready Investors |
| 28 Apr 09 | 1.38% | 11 | 0.23 | 8.15 | 18 | 58619 | 99.50% | 101270 | 19.31% | 7 | 1344.40% | 9 | 5,719,800 | 8 May: Find Ready Investors |
| 29 Apr 09 | 1.61% | 10 | 1.06 | 8.68 | 52 | 35473 | 97.10% | 44553 | 19.31% | 6 | 338.39% | 8 | 9,254,600 | 8 May: Find Ready Investors |
| 04 May 09 | 1.80% | 10 | 1.91 | 10.38 | 47 | 35626 | 97.10% | 46098 | 19.31% | 3 | 142.78% | 5 | 6,789,800 | 8 May: Find Ready Investors |
| 05 May 09 | 1.78% | 13 | 0.41 | 10.84 | 11 | 33455 | 96.50% | 91088 | 19.31% | 2 | 374.07% | 4 | 2,024,000 | 8 May: Find Ready Investors |
| 23 Jul 09 | −0.31% | 13 | 0.50 | 12.69 | 30 | 50593 | 97.90% | 82085 | 6.72% | 18 | 635.00% | 10 | 5,314,400 | |

Table 2: Summary of detected abnormal trades for Bank of America Corporation. For definition of entries see Page 23.

**Bear Stearns Corporation (BSC)**

| Day | $M_t$ | $K$ | $P_t$ | $S_t$ | $\tau$ | $\Delta OI_t$ | $q_t$ | $V_t$ | $r_t^{\mathbf{s}}$ | $\tau_1$ | $r_t^{\mathbf{o}}$ | $\tau_2$ | $G_t$ | Event's description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Put Options (16) | | | | | | | | | | | | | | |
| 05 Oct 07 | 0.64% | 115 | 1.53 | 131.58 | 43 | 1776 | 87.10% | 2231 | −3.75% | 4 | 129.51% | 7 | 2,081,900 | |
| 09 Oct 07 | 0.89% | 125 | 2.53 | 127.46 | 11 | 5692 | 99.70% | 7061 | −5.35% | 21 | 220.79% | 9 | 2,085,500 | |
| 10 Dec 07 | −0.43% | 105 | 3.80 | 105.75 | 12 | 3713 | 96.10% | 5529 | −5.92% | 20 | 301.32% | 10 | 2'312'700 | |
| 04 Mar 08 | −0.19% | 70 | 1.65 | 77.17 | 18 | 2570 | 89.70% | 3374 | −83.97% | 12 | 3854.50% | 10 | 12,086,000 | 15 Mar: bank run |
| 10 Mar 08 | −0.60% | 30 | 0.63 | 62.30 | 12 | 11757 | 99.70% | 16260 | −83.97% | 8 | 3948.00% | 6 | 28,484,000 | 15 Mar: bank run |
| 11 Mar 08 | −0.76% | 30 | 0.25 | 62.97 | 11 | 22809 | 99.90% | 57893 | −83.97% | 7 | 10020.00% | 5 | 55'246'000 | 15 Mar: bank run |
| 12 Mar 08 | −0.79% | 40 | 1.88 | 61.58 | 38 | 4156 | 96.10% | 6210 | −83.97% | 6 | 1782.70% | 4 | 6,013,800 | 15 Mar: bank run |
| 13 Mar 08 | −1.21% | 25 | 0.28 | 57.00 | 9 | 26219 | 99.90% | 39624 | −83.97% | 5 | 7281.80% | 3 | 49,898,000 | 15 Mar: bank run |
| 14 Mar 08 | −1.10% | 20 | 2.78 | 30.00 | 8 | 25246 | 99.70% | 48910 | −83.97% | 4 | 451.35% | 2 | 28,450,000 | 15 Mar: bank run |
| Call Options (11) | | | | | | | | | | | | | | |
| 07 Sep 07 | 0.09% | 110 | 3.85 | 105.37 | 15 | 4791 | 99.10% | 6245 | 7.67% | 16 | 159.74% | 8 | 1,413,400 | |
| 20 Mar 08 | −8.34% | 8 | 1.08 | 5.96 | 30 | 6485 | 98.10% | 9653 | 88.76% | 4 | 262.79% | 2 | 1,667,400 | |

Table 3: Summary of detected abnormal trades for Bear Stearns Corporation. For definition of entries see Page 23.

**Citigroup (C)**

| Day | $M_t$ | $K$ | $P_t$ | $S_t$ | $\tau$ | $\Delta OI_t$ | $q_t$ | $V_t$ | $r_t^{\mathbf{s}}$ | $\tau_1$ | $r_t^{\mathbf{o}}$ | $\tau_2$ | $G_t$ | Event's description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Put Options (14) | | | | | | | | |
| 07 Jan 09 | −0.32% | 5 | 0.36 | 7.15 | 73 | 13329 | 80.50% | 13071 | −23.22% | 8 | 588.89% | 9 | 1,476,000 | 16 Jan: Report Big Loss |
| 08 Jan 09 | −0.09% | 6 | 0.57 | 7.16 | 72 | 24515 | 93.90% | 27180 | −23.22% | 7 | 487.72% | 8 | 4,534,800 | 16 Jan: Report Big Loss |
| 12 Jan 09 | −0.73% | 5 | 0.60 | 5.60 | 40 | 25233 | 94.90% | 40328 | −23.22% | 5 | 296.64% | 6 | 3,020,000 | 16 Jan: Report Big Loss |
| | | | | | | Call Options (24) | | | | | | | | |
| 22 Jan 08 | −0.77% | 25 | 0.98 | 24.40 | 25 | 29208 | 99.30% | 59560 | 8.03% | 4 | 392.31% | 9 | 4,484,700 | |
| 21 Nov 08 | −2.41% | 5 | 0.92 | 3.77 | 29 | 61927 | 99.70% | 101750 | 57.83% | 4 | 277.72% | 5 | 7,566,600 | 23 Nov: cash infusion from U.S |
| 08 Apr 09 | 5.99% | 2 | 0.73 | 2.70 | 38 | 25031 | 91.10% | 36978 | 25.00% | 5 | 193.10% | 4 | 2,964,100 | |
| 30 Jul 09 | −0.51% | 3 | 0.24 | 3.14 | 23 | 216040 | 99.70% | 464560 | 10.41% | 1 | 310.64% | 8 | 4,327,500 | |

Table 4: Summary of detected abnormal trades for Citigroup. For definition of entries see Page 23.

**Fannie Mae (FNM)**

| Day | $M_t$ | $K$ | $P_t$ | $S_t$ | $\tau$ | $\Delta OI_t$ | $q_t$ | $V_t$ | $r_t^{\mathbf{s}}$ | $\tau_1$ | $r_t^{\mathbf{o}}$ | $\tau_2$ | $G_t$ | Event's description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Put Options (17) | | | | | | | | |
| 08 Nov 07 | −1.24% | 45 | 2.40 | 49.80 | 44 | 1993 | 91.90% | 2196 | −24.83% | 11 | 606.25% | 9 | 2,048,600 | 10 Nov: Third-Quarter Loss |
| 09 Nov 07 | −0.91% | 40 | 1.28 | 49.00 | 43 | 3878 | 96.90% | 5642 | −24.83% | 10 | 864.71% | 8 | 1,792,500 | 10 Nov: Third-Quarter Loss |
| 20 Jun 08 | −0.74% | 21 | 1.18 | 23.81 | 29 | 2519 | 81.70% | 2693 | −27.34% | 19 | 148.94% | 10 | 1,640,700 | 10 Jul: U.S. mulls future of FNM |
| 07 Jul 08 | −1.46% | 18 | 4.55 | 15.74 | 75 | 6262 | 95.50% | 10163 | −27.34% | 9 | 140.66% | 7 | 1,096,100 | 7 Jul: U.S. mulls future of FNM |
| 11 Aug 08 | −0.21% | 6 | 0.68 | 8.40 | 40 | 10164 | 99.10% | 10657 | −26.79% | 10 | 262.96% | 8 | 3,442,900 | |
| 13 Aug 08 | 0.43% | 3 | 0.45 | 7.69 | 157 | 9603 | 97.70% | 9653 | −89.63% | 20 | 150.00% | 6 | 1,177,600 | 20 Aug: fear of potential losses |
| 27 Aug 08 | −3.48% | 3 | 0.43 | 6.48 | 52 | 7752 | 95.90% | 11376 | −89.63% | 10 | 335.29% | 8 | 733,000 | 5 Sept: under federal control |
| 28 Aug 08 | −2.75% | 7 | 2.60 | 7.95 | 114 | 15178 | 99.50% | 15240 | −89.63% | 9 | 142.31% | 7 | 5,541,700 | 5 Sept: under federal control |
| 29 Aug 08 | −2.97% | 3 | 0.40 | 6.84 | 50 | 5582 | 91.90% | 6610 | −89.63% | 8 | 362.50% | 6 | 619,600 | 5 Sept: under federal control |
| 04 Sep 08 | −1.88% | 6 | 0.75 | 6.42 | 16 | 5774 | 92.10% | 7041 | −89.63% | 5 | 640.00% | 10 | 2,609,800 | 5 Sept: under federal control |
| | | | | | | Call Options (13) | | | | | | | | |
| 20 Nov 07 | −1.63% | 30 | 3.00 | 28.25 | 32 | 3622 | 96.90% | 7832 | 18.62% | 10 | 200.00% | 8 | 1,432,700 | 7 Dec: Raise Capital |
| 05 Mar 08 | −0.94% | 26 | 1.03 | 24.27 | 17 | 10333 | 99.70% | 6006 | 27.06% | 12 | 163.41% | 10 | 3,001,600 | 20 Mar: reduction cushion of capital |
| 07 Mar 08 | −1.51% | 24 | 1.13 | 22.77 | 15 | 3580 | 94.30% | 2992 | 27.06% | 10 | 811.11% | 10 | 842,200 | 20 Mar: reduction cushion of capital |
| 11 Mar 08 | −1.75% | 23 | 1.53 | 22.00 | 11 | 5192 | 97.30% | 8494 | 27.06% | 8 | 670.49% | 8 | 4,251,400 | 20 Mar: reduction cushion of capital |

Table 5: Summary of detected abnormal trades for Fannie Mae. For definition of entries see Page 23.

**Freddie Mac (FRE)**

| Day | $M_t$ | $K$ | $P_t$ | $S_t$ | $\tau$ | $\Delta OI_t$ | $q_t$ | $V_t$ | $r_t^{\mathbf{s}}$ | $\tau_1$ | $r_t^{\mathbf{o}}$ | $\tau_2$ | $G_t$ | Event's description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Put Options (12) | | | | | | | | |
| 20 Jun 08 | −0.66% | 24 | 3.15 | 21.82 | 29 | 2937 | 89.30% | 3071 | −26.02% | 19 | 201.59% | 10 | 3,318,600 | 7 Jul: plunge on capital concerns |
| 03 Jul 08 | −1.96% | 15 | 1.60 | 14.50 | 16 | 5116 | 94.70% | 6252 | −26.02% | 10 | 500.00% | 8 | 2,674,500 | 15 Jul: rescue plan does not convince |
| 07 Jul 08 | −1.97% | 13 | 1.90 | 11.91 | 12 | 9983 | 97.70% | 12005 | −26.02% | 9 | 273.68% | 7 | 4,009,700 | 15 Jul: rescue plan does not convince |
| 09 Jul 08 | −2.66% | 10 | 1.25 | 10.26 | 10 | 12875 | 98.50% | 24356 | −26.02% | 7 | 280.00% | 5 | 984,260 | 15 Jul: rescue plan does not convince |
| 03 Sep 08 | −1.36% | 3 | 0.90 | 5.38 | 136 | 2260 | 79.90% | 2686 | −82.75% | 6 | 211.11% | 10 | 320,760 | 7 Sept: government's takeover of FRE, FNM |
| | | | | | | Call Options (15) | | | | | | | | |
| 20 Nov 07 | −1.24% | 30 | 1.98 | 26.74 | 32 | 6159 | 99.90% | 9854 | 18.84% | 10 | 188.61% | 8 | 187,320 | 20 Nov: third quarter $2 bln loss |
| 23 Nov 07 | −1.60% | 25 | 3.60 | 26.47 | 29 | 2592 | 97.70% | 3275 | 18.84% | 8 | 234.72% | 10 | 232,670 | 20 Nov: third quarter $2 bln loss |
| 27 Nov 07 | −3.01% | 25 | 2.65 | 25.73 | 25 | 4318 | 99.70% | 4945 | 18.84% | 6 | 354.72% | 8 | 1,367,300 | 28 Nov: Cuts Dividend in Half |
| 10 Mar 08 | −1.62% | 20 | 0.55 | 17.39 | 12 | 2990 | 95.30% | 4691 | 26.19% | 9 | 2218.20% | 9 | 668,520 | 5 Mar: Fed consider rescue |
| 11 Mar 08 | −1.77% | 20 | 1.48 | 20.16 | 11 | 3394 | 96.50% | 6886 | 26.19% | 8 | 764.41% | 8 | 575,570 | 11 Mar: Carlyle fund liquidation |
| 18 Mar 08 | −1.41% | 25 | 1.55 | 26.02 | 4 | 3479 | 96.30% | 11493 | 26.19% | 3 | 396.77% | 3 | 1,569,600 | 20 Mar: reduction cushion of capital |

Table 6: Summary of detected abnormal trades for Freddie Mac. For definition of entries see Page 23.

**Goldman Sachs (GS )**

| Day | $M_t$ | $K$ | $P_t$ | $S_t$ | $\tau$ | $\Delta OI_t$ | $q_t$ | $V_t$ | $r_t^{\mathbf{s}}$ | $\tau_1$ | $r_t^{\mathbf{o}}$ | $\tau_2$ | $G_t$ | Event's description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Put Options (13) | | | | | | | | |
| 20 Feb 07 | 0.35% | 220 | 5.05 | 220.94 | 25 | 6162 | 99.50% | 7953 | −4.21% | 14 | 490.10% | 10 | 9,286,700 | |
| 20 Jul 07 | 0.20% | 200 | 5.20 | 205.94 | 29 | 4048 | 95.30% | 8594 | −2.53% | 13 | 168.27% | 10 | 2,372,800 | 19 Jul: deal for 2nd Jersey City Tower |
| 25 Jul 07 | 0.39% | 185 | 1.15 | 203.16 | 24 | 7434 | 99.50% | 12329 | −2.53% | 10 | 708.70% | 8 | 5,531,800 | 1 Jul: deal for 2nd Jersey City Tower |
| | | | | | | Call Options (15) | | | | | | | | |
| 17 Mar 08 | −0.01% | 170 | 0.85 | 151.02 | 5 | 4089 | 94.50% | 11055 | 3.42% | 13 | 970.59% | 4 | 1,560,800 | 18 Mar: beat expectations earnings |
| 11 Jun 08 | −1.12% | 170 | 3.90 | 162.40 | 10 | 11406 | 99.30% | 20313 | 16.27% | 11 | 330.77% | 7 | 8,896,900 | |
| 16 Jul 08 | 0.67% | 170 | 4.45 | 172.86 | 3 | 4685 | 95.50% | 19103 | 5.26% | 13 | 184.27% | 3 | 3,419,000 | |
| 10 Mar 09 | −0.98% | 105 | 2.71 | 85.28 | 39 | 4014 | 92.70% | 7132 | 14.35% | 14 | 375.05% | 10 | 1,286,800 | |

Table 7: Summary of detected abnormal trades for Goldman Sachs. For definition of entries see Page 23.

**J.P. Morgan (JPM)**

| Day | $M_t$ | $K$ | $P_t$ | $S_t$ | $\tau$ | $\Delta OI_t$ | $q_t$ | $V_t$ | $r_t^{\mathbf{s}}$ | $\tau_1$ | $r_t^{\mathbf{o}}$ | $\tau_2$ | $G_t$ | Event's description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Put Options (20) | | | | | | | | | | | | | | |
| 20 Jul 07 | −0.04% | 48 | 1.40 | 47.56 | 29 | 5128 | 93.90% | 8345 | −5.03% | 17 | 175.00% | 5 | 1,039,200 | |
| 01 Feb 08 | 0.54% | 48 | 1.08 | 48.25 | 15 | 11340 | 98.10% | 12911 | −5.04% | 5 | 365.12% | 10 | 3,452,900 | |
| 31 Dec 08 | 0.13% | 30 | 2.37 | 31.53 | 52 | 2852 | 60.10% | 2859 | −20.73% | 15 | 158.44% | 8 | 890,540 | 15 Jan: profit drops 76% |
| 02 Jan 09 | −0.04% | 32 | 3.25 | 31.35 | 50 | 6953 | 88.10% | 8218 | −20.73% | 14 | 143.08% | 10 | 4,040,000 | 15 Jan: profit drops 76% |
| 06 Jan 09 | 0.66% | 30 | 4.08 | 29.88 | 74 | 40772 | 99.30% | 43454 | −20.73% | 12 | 201.23% | 10 | 12,084,000 | 15 Jan: profit drops 76% |
| 11 Feb 09 | 0.47% | 26 | 3.01 | 26.09 | 38 | 8368 | 88.70% | 10789 | −13.99% | 18 | 132.95% | 8 | 1,272,400 | |
| Call Options (12) | | | | | | | | | | | | | | |
| 23 Sep 08 | 0.60% | 43 | 2.30 | 40.56 | 25 | 8433 | 93.50% | 10800 | 16.75% | 1 | 258.39% | 8 | 2,061,700 | |
| 05 Mar 09 | −0.76% | 18 | 1.46 | 16.60 | 16 | 9604 | 93.10% | 16918 | 24.67% | 15 | 566.67% | 10 | 1,393,400 | |
| 06 Mar 09 | −0.73% | 21 | 1.22 | 15.93 | 43 | 10656 | 94.90% | 19395 | 24.67% | 14 | 481.97% | 9 | 6,178,200 | 16 Apr: anticipating profits |
| 09 Mar 09 | −0.91% | 18 | 1.94 | 15.90 | 40 | 10000 | 93.50% | 10338 | 24.67% | 13 | 401.29% | 8 | 8,694,100 | 16 Apr: anticipating profits |

Table 8: Summary of detected abnormal trades for J.P. Morgan. For definition of entries see Page 23.

**Lehman Brothers (LEH)**

| Day | $M_t$ | $K$ | $P_t$ | $S_t$ | $\tau$ | $\Delta OI_t$ | $q_t$ | $V_t$ | $r_t^{\mathbf{s}}$ | $\tau_1$ | $r_t^{\mathbf{o}}$ | $\tau_2$ | $G_t$ | Event's description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Put Options (8) | | | | | | | | | | | | | | |
| 29 Feb 08 | −0.28% | 50 | 2.68 | 50.99 | 22 | 15279 | 99.10% | 27054 | −19.13% | 14 | 182.24% | 7 | 2,243,500 | 28 Mar: investors sold off stocks |
| 13 Mar 08 | −1.61% | 50 | 6.15 | 45.99 | 37 | 13431 | 98.50% | 15704 | −19.13% | 5 | 219.51% | 3 | 12,680,000 | 28 Mar: investors sold off stocks |
| 15 May 08 | 0.69% | 45 | 3.18 | 44.77 | 37 | 5374 | 84.90% | 5825 | −13.64% | 21 | 193.70% | 7 | 4,055,300 | 10 Jun: Loss of 3 billion |
| 16 May 08 | 0.46% | 41 | 1.99 | 43.64 | 36 | 10905 | 96.10% | 11537 | −13.64% | 20 | 207.79% | 6 | 6,332,300 | 10 Jun: Loss of 3 billion |
| 21 May 08 | −0.15% | 35 | 1.65 | 39.56 | 31 | 9234 | 94.30% | 16594 | −13.64% | 17 | 266.67% | 9 | 4,808,800 | 10 Jun: Loss of 3 billion |
| Call Options (12) | | | | | | | | | | | | | | |
| 17 Mar 08 | −1.05% | 35 | 3.08 | 31.75 | 5 | 8836 | 99.50% | 22144 | 46.43% | 4 | 343.90% | 4 | 8,450,400 | 19 Mar: earnings |
| 15 Jul 08 | −1.31% | 15 | 0.68 | 13.22 | 4 | 16938 | 99.30% | 41781 | 25.95% | 4 | 503.70% | 4 | 5,731,200 | 17 Jul: biggest one-day rally |

Table 9: Summary of detected abnormal trades for Lehman Brothers. For definition of entries see Page 23.

**Merrill Lynch (MER)**

| Day | $M_t$ | $K$ | $P_t$ | $S_t$ | $\tau$ | $\Delta OI_t$ | $q_t$ | $V_t$ | $r_t^{\mathbf{s}}$ | $\tau_1$ | $r_t^{\mathbf{o}}$ | $\tau_2$ | $G_t$ | Event's description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Put Options (15) | | | | | | | | |
| 18 Jun 07 | −0.09% | 90 | 2.30 | 90.00 | 33 | 5532 | 96.90% | 6221 | −3.54% | 18 | 195.65% | 10 | 1,990,500 | 20 Jun: hedge funds losses |
| 10 Oct 07 | 0.25% | 70 | 1.50 | 74.94 | 38 | 2362 | 79.50% | 2593 | −7.90% | 20 | 273.33% | 8 | 1,040,700 | 5 Oct: $5.5 billion loss |
| 23 Oct 07 | −0.34% | 63 | 1.60 | 67.12 | 25 | 9120 | 98.90% | 15002 | −7.90% | 11 | 343.75% | 10 | 1,827,300 | 24 Oct: biggest quarterly loss |
| 11 Jan 08 | −1.19% | 55 | 2.18 | 54.69 | 8 | 7375 | 95.70% | 12695 | −10.24% | 7 | 152.87% | 5 | 1,021,300 | 15 Jan: 21 bln infusion |
| 02 Jun 08 | −0.61% | 43 | 1.93 | 42.62 | 19 | 10060 | 95.50% | 19021 | −6.80% | 21 | 268.83% | 8 | 2,614,200 | 2 Jun: ratings cut by S&P |
| 03 Sep 08 | 0.25% | 23 | 0.19 | 28.33 | 17 | 14031 | 94.70% | 18682 | −19.59% | 21 | 3018.40% | 8 | 1,847,900 | 15 Sept: BAC acquires Merrill |
| | | | | | | Call Options (17) | | | | | | | | |
| 14 Jul 08 | −1.13% | 25 | 3.60 | 25.88 | 33 | 9133 | 97.50% | 5413 | 13.41% | 5 | 151.39% | 8 | 618,760 | Raise Capital |
| 15 Jul 08 | −0.97% | 25 | 4.03 | 24.69 | 95 | 5408 | 92.30% | 6169 | 13.41% | 4 | 144.10% | 7 | 779,060 | Raise Capital |

Table 10: Summary of detected abnormal trades for Merrill Lynch. For definition of entries see Page 23.

**Morgan Stanley (MS)**

| Day | $M_t$ | $K$ | $P_t$ | $S_t$ | $\tau$ | $\Delta OI_t$ | $q_t$ | $V_t$ | $r_t^{\mathbf{s}}$ | $\tau_1$ | $r_t^{\mathbf{o}}$ | $\tau_2$ | $G_t$ | Event's description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Put Options (21) | | | | | | | | |
| 21 Jun 07 | 0.21% | 85 | 1.25 | 87.29 | 30 | 7347 | 98.90% | 10368 | −14.96% | 10 | 130.00% | 4 | 6,868,600 | 22 Jun: Blackstone Rival Plans Own I.P.O |
| 26 Oct 07 | 0.20% | 60 | 2.20 | 64.78 | 57 | 4570 | 96.10% | 6601 | −7.20% | 7 | 338.64% | 9 | 1,523,000 | 7 Nov: Write-Down Expected |
| 30 Oct 07 | −0.18% | 65 | 3.70 | 65.49 | 53 | 3045 | 92.70% | 3207 | −7.20% | 5 | 277.03% | 7 | 2,333,900 | 7 Nov: Write-Down Expected |
| 31 Oct 07 | 0.16% | 65 | 2.88 | 67.26 | 52 | 8100 | 98.50% | 11093 | −7.20% | 4 | 385.22% | 6 | 9,177,000 | 7 Nov: Write-Down Expected |
| 15 May 08 | 0.55% | 45 | 1.35 | 47.71 | 37 | 8745 | 96.70% | 9126 | −8.48% | 18 | 211.11% | 7 | 3,535,000 | 2 Jun: ratings cut by S&P |
| 16 May 08 | 0.38% | 45 | 1.53 | 47.21 | 36 | 4877 | 91.10% | 4978 | −8.48% | 17 | 175.41% | 6 | 1,527,300 | 2 Jun: ratings cut by S&P |
| 05 Jun 08 | −0.75% | 43 | 2.35 | 44.59 | 44 | 12093 | 98.90% | 12614 | −8.48% | 4 | 191.49% | 5 | 3,856,400 | 2 Jun: ratings cut by S&P |
| 04 Sep 08 | 0.02% | 37 | 0.95 | 40.34 | 16 | 10713 | 96.50% | 12073 | −24.22% | 12 | 1568.40% | 10 | 8,582,700 | 18 Sept: plan to merger with Wachovia |
| 05 Sep 08 | 0.03% | 36 | 1.30 | 41.36 | 43 | 1250 | 45.90% | 1251 | −24.22% | 11 | 1157.70% | 9 | 1,451,100 | 18 Sept: plan to merger with Wachovia |
| 15 Sep 08 | −0.39% | 30 | 3.75 | 32.19 | 33 | 10704 | 96.30% | 20113 | −25.89% | 21 | 216.00% | 3 | 1,920,200 | 18 Sept: plan to merger with Wachovia |
| | | | | | | Call Options (19) | | | | | | | | |
| 13 Mar 08 | −0.57% | 45 | 1.40 | 41.60 | 37 | 13151 | 99.90% | 21130 | 17.81% | 6 | 342.86% | 6 | 1,324,500 | 19 Mar: profits |
| 17 Mar 08 | −0.14% | 40 | 1.00 | 36.38 | 5 | 4122 | 95.10% | 8154 | 17.81% | 4 | 895.00% | 4 | 2,893,900 | 20 Mar: profits |
| 09 Oct 08 | −2.50% | 18 | 1.33 | 12.45 | 9 | 26507 | 99.30% | 7920 | 86.98% | 5 | 254.72% | 4 | 3,311,900 | 13 Oct: sell 1/5 to a big Japanese bank |
| 10 Oct 08 | −3.41% | 10 | 2.75 | 9.68 | 8 | 10675 | 98.10% | 23102 | 86.98% | 4 | 336.36% | 3 | 8,553,700 | 13 Oct: sell 1/5 to a big Japanese bank |

Table 11: Summary of detected abnormal trades for Morgan Stanley. For definition of entries see Page 23.

**Wachovia Bank (WB)**

| Day | $M_t$ | $K$ | $P_t$ | $S_t$ | $\tau$ | $\Delta OI_t$ | $q_t$ | $V_t$ | $r_t^{\mathbf{s}}$ | $\tau_1$ | $r_t^{\mathbf{o}}$ | $\tau_2$ | $G_t$ | Event's description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Put Options (12) | | | | | | | | | | | | | | |
| 01 Feb 08 | 0.05% | 38 | 0.98 | 38.76 | 15 | 12383 | 99.10% | 19142 | −8.33% | 4 | 305.13% | 10 | 2,317,400 | |
| 27 May 08 | −0.06% | 25 | 2.10 | 24.77 | 53 | 8872 | 95.30% | 12472 | −6.76% | 11 | 197.62% | 10 | 679,660 | |
| 03 Jun 08 | −0.92% | 20 | 0.55 | 21.92 | 18 | 14629 | 98.70% | 25778 | −6.76% | 6 | 286.36% | 9 | 2,220,700 | |
| 08 Sep 08 | −0.38% | 19 | 1.20 | 18.99 | 12 | 15420 | 96.90% | 18341 | −81.60% | 18 | 729.17% | 8 | 4,325,800 | 29 Sep: taken over of Wachovia |
| 09 Sep 08 | −0.69% | 16 | 1.15 | 16.24 | 11 | 20643 | 97.90% | 24149 | −81.60% | 17 | 504.35% | 7 | 20,656 | 29 Sep: taken over of Wachovia |
| 16 Sep 08 | 0.04% | 8 | 1.45 | 11.51 | 32 | 12138 | 93.90% | 19833 | −81.60% | 12 | 293.10% | 10 | 2,900,300 | 29 Sep: taken over of Wachovia |
| 22 Sep 08 | −1.72% | 18 | 5.55 | 14.81 | 117 | 48400 | 99.70% | 846 | −81.60% | 8 | 181.08% | 6 | 12,502,000 | 29 Sep: taken over of Wachovia |
| 25 Sep 08 | 1.62% | 20 | 7.00 | 13.70 | 58 | 6568 | 83.30% | 6593 | −81.60% | 5 | 158.57% | 3 | 4,121,800 | 29 Sep: taken over of Wachovia |
| Call Options (15) | | | | | | | | | | | | | | |
| 11 Jul 08 | −0.86% | 13 | 1.70 | 11.54 | 36 | 5282 | 90.70% | 7417 | 27.51% | 7 | 211.76% | 9 | 1,080,400 | 17 Jul: quarterly announcement |
| 15 Jul 08 | −1.70% | 10 | 0.35 | 9.08 | 4 | 15541 | 98.70% | 29187 | 27.51% | 5 | 842.86% | 3 | 4,103,800 | 17 Jul: quarterly announcement |
| 18 Jul 08 | −3.21% | 13 | 2.18 | 12.97 | 29 | 51958 | 99.90% | 53660 | 27.51% | 2 | 143.68% | 4 | 5,007,000 | 17 Jul: quarterly announcement |
| 21 Jul 08 | −2.14% | 15 | 1.03 | 13.18 | 26 | 25982 | 99.50% | 48387 | 27.51% | 1 | 329.27% | 10 | 1,773,600 | 17 Jul: quarterly announcement |
| 30 Sep 08 | 1.17% | 5 | 0.73 | 3.50 | 53 | 14438 | 97.30% | 20253 | 90.22% | 3 | 168.97% | 4 | 700,240 | 6 Oct: offer to buy Wachovia |
| 01 Oct 08 | −0.68% | 5 | 0.68 | 3.55 | 52 | 21237 | 98.90% | 35462 | 90.22% | 2 | 188.89% | 3 | 894,280 | 6 Oct: offer to buy Wachovia |

Table 12: Summary of detected abnormal trades for Wachovia Bank. For definition of entries see Page 23.

**Wells Fargo Company (WFC)**

| Day | $M_t$ | $K$ | $P_t$ | $S_t$ | $\tau$ | $\Delta OI_t$ | $q_t$ | $V_t$ | $r_t^{\mathbf{s}}$ | $\tau_1$ | $r_t^{\mathbf{o}}$ | $\tau_2$ | $G_t$ | Event's description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Put Options (14) | | | | | | | | |
| 27 Dec 07 | −0.04% | 30 | 1.03 | 30.30 | 23 | 70717 | 99.90% | 8710 | −6.10% | 15 | 256.10% | 8 | 19,158,000 | |
| 01 Feb 08 | 0.48% | 33 | 0.83 | 33.65 | 15 | 8353 | 95.30% | 13513 | −6.72% | 4 | 281.82% | 6 | 1,497,000 | |
| 04 Nov 08 | −0.31% | 37 | 3.30 | 35.11 | 18 | 6130 | 78.50% | 6424 | −18.97% | 21 | 190.91% | 7 | 4,824,000 | 10 Nov: sells 11bln in stock |
| 06 Jan 09 | 0.82% | 28 | 3.95 | 27.54 | 46 | 78828 | 99.90% | 87010 | −23.82% | 12 | 259.49% | 10 | 66,232,000 | 28 Jan: loss of fourth quarter |
| 07 Jan 09 | 0.49% | 28 | 4.80 | 25.87 | 45 | 24733 | 97.50% | 25940 | −23.82% | 11 | 195.83% | 9 | 21,451,000 | 28 Jan: loss of fourth quarter |
| 08 Jan 09 | 0.26% | 25 | 3.20 | 25.72 | 44 | 53561 | 99.30% | 64303 | −23.82% | 10 | 251.56% | 8 | 28,476,000 | 28 Jan: loss of fourth quarter |
| 28 Jan 09 | −2.31% | 19 | 2.20 | 21.19 | 52 | 5080 | 67.30% | 5540 | −14.22% | 12 | 115.91% | 7 | 294,980 | 28 Jan: loss of fourth quarter |
| | | | | | | Call Options (15) | | | | | | | | |
| 18 Jan 08 | −0.60% | 25 | 1.70 | 25.48 | 29 | 7419 | 97.50% | 9104 | 9.02% | 5 | 423.53% | 9 | 2,878,300 | |
| 07 Jul 08 | −0.49% | 28 | 1.10 | 23.52 | 103 | 11313 | 97.50% | 13990 | 32.77% | 10 | 165.91% | 9 | 156,000 | 17 Jul: biggest one-day rally |
| 15 Jul 08 | −0.36% | 23 | 1.03 | 20.51 | 32 | 22712 | 99.50% | 29515 | 32.77% | 4 | 690.24% | 6 | 16,583,000 | 17 Jul: biggest one-day rally |
| 10 Mar 09 | −3.28% | 11 | 2.70 | 11.81 | 39 | 13573 | 92.90% | 15588 | 23.87% | 12 | 159.26% | 10 | 8,697,000 | 9 Apr: bank predicted record profit |
| 16 Mar 09 | −1.05% | 18 | 0.75 | 13.70 | 33 | 5524 | 77.70% | 5030 | 31.70% | 21 | 193.33% | 6 | 440,250 | 10 Apr: bank predicted record profit |
| 01 Apr 09 | 1.90% | 20 | 0.88 | 14.48 | 45 | 35308 | 97.10% | 42665 | 31.70% | 9 | 165.71% | 7 | 3,895,600 | 11 Apr: bank predicted record profit |
| 21 Apr 09 | 1.16% | 20 | 2.23 | 18.81 | 60 | 12849 | 91.10% | 13257 | 23.66% | 12 | 156.18% | 10 | 166,010 | 8 May: Ready Investors |
| 23 Apr 09 | 1.55% | 23 | 1.08 | 20.09 | 23 | 19491 | 95.30% | 39358 | 23.66% | 10 | 337.21% | 10 | 4,108,900 | 8 May: Ready Investors |
| 28 Apr 09 | 1.48% | 18 | 3.85 | 19.48 | 53 | 5494 | 73.10% | 5690 | 23.66% | 7 | 163.64% | 9 | 256,750 | 8 May: Ready Investors |
| 30 Apr 09 | 1.80% | 25 | 0.23 | 20.01 | 16 | 15771 | 93.90% | 21883 | 23.66% | 5 | 1366.70% | 7 | 618,110 | 8 May: Ready Investors |

Table 13: Summary of detected abnormal trades for Wells Fargo Company. For definition of entries see Page 23.

**UBS**

| Day | $M_t$ | $K$ | $P_t$ | $S_t$ | $\tau$ | $\Delta OI_t$ | $q_t$ | $V_t$ | $r_t^{\mathbf{s}}$ | $\tau_1$ | $r_t^{\mathbf{o}}$ | $\tau_2$ | $G_t$ | Event's description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Put Options (16) | | | | | | | | | | | | | | |
| 13 Feb 07 | 0.21% | 78 | 1.53 | 76.00 | Mar 07 | 5100 | 97.80% | 5349 | −3.86% | 21 | 398.69% | 16 | 3,597,400 | |
| 6 Jul 07 | −0.10% | 72 | 1.15 | 74.40 | Aug 07 | 5153 | 95.80% | 5617 | −2.99% | 15 | 462.61% | 17 | 3,787,200 | |
| 12 Oct 07 | 0.43% | 66 | 0.24 | 67.95 | Oct 07 | 8327 | 93.00% | 9288 | −4.44% | 15 | 420.83% | 6 | 818,960 | 30 Oct: announcement of losses |
| 16 Oct 07 | 0.51% | 68 | 3.06 | 66.50 | Dec 07 | 35563 | 99.80% | 10 | −4.44% | 13 | 457.52% | 19 | 11,765,000 | 30 Oct: announcement of losses |
| 25 Oct 07 | 0.06% | 60 | 4.04 | 62.45 | Jun 08 | 26487 | 99.40% | 0 | −4.65% | 20 | 250.00% | 20 | 12,290,000 | 30 Oct: announcement of losses |
| 11 Dec 07 | 0.49% | 56 | 1.04 | 56.95 | Dec 07 | 46430 | 99.80% | 997 | −3.56% | 3 | 299.04% | 9 | 14,088,000 | 10 Dec: posts 10 bn writedown |
| 30 Jan 08 | -0.51% | 46 | 2.86 | 46.06 | Mar 08 | 5271 | 81.80% | 5534 | −8.32% | 12 | 261.54% | 18 | 4'289'921 | 15 Feb: worst quarterly loss |
| 11 Feb 08 | -0.82% | 36 | 1.51 | 39.74 | Mar 08 | 3036 | 63.00% | 3100 | −8.32% | 4 | 286.75% | 20 | 1,609,460 | 15 Feb: worst quarterly loss |
| 12 Feb 08 | -1.03% | 40 | 0.81 | 40.94 | Feb 08 | 3374 | 65.80% | 4654 | −8.32% | 3 | 391.36% | 4 | 1,033,808 | 15 Feb: worst quarterly loss |
| 22 Feb 08 | −1.28% | 33 | 0.96 | 35.68 | Mar 08 | 6000 | 83.00% | 6000 | −7.42% | 15 | 785.42% | 17 | 2,832,300 | 15 Mar: bank run at Bear Stearn |
| 27 Feb 08 | −1.12% | 24 | 0.37 | 37.48 | Jun 08 | 15000 | 96.20% | 15000 | −7.42% | 12 | 818.92% | 14 | 1,785,000 | 15 Mar: bank run at Bear Stearn |
| 04 Mar 08 | −1.24% | 30 | 1.50 | 32.08 | Apr 08 | 9827 | 91.40% | 12032 | −7.42% | 9 | 308.00% | 10 | 1,206,100 | 15 Mar: bank run at Bear Stearn |
| 16 May 08 | −0.12% | 32 | 1.38 | 32.16 | Jun 08 | 19193 | 96.60% | 20127 | −6.95% | 8 | 193.48% | 7 | 5,102,400 | 26 May: more mortgage losses possible |
| Call Options (13) | | | | | | | | | | | | | | |
| 27 Sep 07 | −0.05% | 66 | 0.21 | 62.15 | Oct 2007 | 12495 | 97.40% | 2647 | 3.04% | 3 | 1090.50% | 8 | 2,476,000 | |
| 23 Nov 07 | −1.27% | 54 | 1.41 | 49.74 | Jan 08 | 13495 | 95.80% | 14355 | 6.65% | 4 | 258.87% | 12 | 4,140,600 | |
| 19 Aug 09 | 0.89% | 17 | 0.26 | 16.74 | Aug 09 | 38269 | 99.80% | 50240 | 6.40% | 3 | 523.08% | 3 | 4,676,400 | |

Table 14: Summary of detected abnormal trades for UBS. For definition of entries see Page 23.

**Credit Suisse Group (CS)**

| Day | $M_t$ | $K$ | $P_t$ | $S_t$ | $\tau$ | $\Delta OI_t$ | $q_t$ | $V_t$ | $r_t^{\mathbf{s}}$ | $\tau_1$ | $r_t^{\mathbf{o}}$ | $\tau_2$ | $G_t$ | Event's description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Put Options (16) | | | | | | | | |
| 13 Jul 07 | −0.14% | 76 | 2.73 | 82.19 | Jun 08 | 11863 | 98.20% | 12000 | −3.44% | 10 | 135.90% | 12 | 581,290 | |
| 12 Oct 07 | 0.26% | 80 | 2.12 | 75.02 | Dec 07 | 9929 | 95.00% | 9949 | −3.73% | 15 | 423.11% | 20 | 1,705,300 | |
| 01 Nov 07 | −0.23% | 70 | 1.01 | 68.95 | Dec 07 | 9382 | 94.20% | 9500 | −3.73% | 1 | 754.46% | 16 | 2,526,500 | |
| 07 Jan 08 | −0.11% | 60 | 1.97 | 58.84 | Mar 08 | 9779 | 92.60% | 11050 | −8.41% | 11 | 397.46% | 11 | 868,470 | |
| 19 Feb 08 | 0.50% | 52 | 2.46 | 48.72 | Mar 09 | 13240 | 97.00% | 14705 | −6.61% | 1 | 180.08% | 20 | 1,150,200 | 20 Feb: new 2 bln write down |
| | | | | | | Call Options (13) | | | | | | | | |
| 16 Mar 07 | −0.22% | 88 | 1.29 | 75.50 | Apr 07 | 5107 | 95.40% | 5668 | 3.26% | 5 | 230.23% | 6 | 1,175,400 | |
| 23 Nov 07 | −1.01% | 68 | 1.85 | 57.87 | Jan 08 | 11118 | 97.00% | 11475 | 4.72% | 4 | 162.70% | 14 | 3,060,800 | |
| 23 Apr 08 | 0.20% | 51 | 2.23 | 48.31 | May 08 | 5006 | 86.60% | 5056 | 5.98% | 7 | 240.36% | 7 | 1,351,300 | |
| 10 Sep 08 | −0.06% | 54 | 0.74 | 49.92 | Sep 08 | 9850 | 93.00% | 10300 | 18.63% | 8 | 170.27% | 8 | 1,201,000 | |
| 18 Sep 08 | −0.38% | 58 | 1.32 | 45.36 | Dec 08 | 10010 | 93.00% | 10010 | 27.92% | 18 | 346.21% | 12 | 1,396,600 | 13 Oct 08 oct: swiss banks raise emergency |

Table 15: Summary of detected abnormal trades for Credit Suisse Group. For definition of entries see Page 23.

**Deutsche Bank (DBK)**

| Day | $M_t$ | $K$ | $P_t$ | $S_t$ | $\tau$ | $\Delta OI_t$ | $q_t$ | $V_t$ | $r_t^{\mathbf{s}}$ | $\tau_1$ | $r_t^{\mathbf{o}}$ | $\tau_2$ | $G_t$ | Event's description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Put Options (16) | | | | | | | | |
| 29 Jun 07 | −0.23% | 100 | 1.82 | 107.09 | Sep 07 | 12660 | 96.60% | 171 | −3.55% | 20 | 175.27% | 20 | 4,793,800 | |
| 09 Jan 08 | −0.12% | 80 | 1.42 | 84.55 | Feb 08 | 15157 | 94.20% | 18422 | −6.30% | 9 | 507.75% | 11 | 5,655,400 | |
| 14 May 08 | 0.22% | 76 | 5.02 | 76.24 | Jul 08 | 3648 | 71.40% | 3698 | −5.93% | 13 | 180.08% | 20 | 4,134,800 | |
| 19 May 08 | 0.09% | 76 | 6.51 | 76.64 | Dec 08 | 6700 | 89.00% | 8570 | −5.93% | 10 | 133.03% | 18 | 4,852,300 | |
| 30 May 08 | −0.24% | 68 | 1.91 | 68.98 | Jul 08 | 5596 | 86.20% | 5775 | −5.93% | 1 | 468.06% | 20 | 3,987,000 | |
| 08 Aug 08 | 0.72% | 58 | 1.06 | 63.07 | Sep 08 | 5759 | 86.60% | 7277 | −5.28% | 4 | 228.30% | 10 | 1,131,000 | |
| 18 Sep 08 | −0.56% | 46 | 3.52 | 48.84 | Dec 08 | 10425 | 94.60% | 13405 | −14.79% | 17 | 369.60% | 17 | 3,447,800 | |
| 19 Sep 08 | −0.65% | 54 | 2.27 | 58.18 | Oct 08 | 5889 | 87.80% | 7050 | −14.79% | 16 | 903.96% | 16 | 10,753,000 | |
| 01 Oct 08 | −0.73% | 32 | 1.23 | 51.46 | Dec 08 | 5424 | 85.40% | 5932 | −14.79% | 8 | 796.75% | 20 | 1,523,800 | |
| | | | | | | Call Options (3) | | | | | | | | |
| 30 Mar 07 | 0.07% | 100 | 2.61 | 100.70 | Apr 07 | 6094 | 91.00% | 540 | 3.43% | 14 | 384.29% | 14 | 5,834,600 | |

Table 16: Summary of detected abnormal trades for Deutsche Bank. For definition of entries see Page 23.

**Société Générale (GL)**

| Day | $M_t$ | $K$ | $P_t$ | $S_t$ | $\tau$ | $\Delta OI_t$ | $q_t$ | $V_t$ | $r_t^{\mathbf{s}}$ | $\tau_1$ | $r_t^{\mathbf{o}}$ | $\tau_2$ | $G_t$ | Event's description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Put Options (16) | | | | | | | | |
| 25 Jul 07 | −0.20% | 130 | 2.72 | 131.28 | AUG07 | 3020 | 98.20% | 0 | −4.84% | 12 | 168.75% | 4 | 2,631,284 | |
| 9 Jan 08 | −0.54% | 88 | 1.67 | 94.99 | FEB08 | 326 | 52.60% | 0 | −8.72% | 9 | 531.14% | 9 | 317,002 | 18 Jan: speculation of huge writedowns |
| 16 Jan 08 | −0.25% | 92 | 3.95 | 94.93 | MAR08 | 856 | 77.60% | 0 | −8.72% | 4 | 444.05% | 9 | 1,446,670 | 18 Jan: speculation of huge writedowns |
| 05 May 08 | 0.79% | 77 | 1.19 | 78.45 | MAY08 | 520 | 61.10% | 50 | −3.16% | 4 | 410.92% | 7 | 187,170 | 14 May: First Quarter Profit Drops 23.4% |
| 16 May 08 | 0.18% | 70 | 2.12 | 71.85 | JUN08 | 400 | 48.20% | 50 | −3.81% | 16 | 169.81% | 10 | 325,128 | 14 May: First Quarter Profit Drops 23.4% |
| 8 Sep 08 | −0.46% | 58 | 0.85 | 66.81 | OCT08 | 500 | 54.70% | NaN | −9.59% | 6 | 642.35% | 8 | 661,000 | 15 Sept: collapse of Lehman Brothers |
| 9 Sep 08 | −0.23% | 67 | 1.42 | 68.50 | SEP08 | 2285 | 96.20% | NaN | −9.59% | 5 | 817.61% | 7 | 311,230 | 15 Sept: collapse of Lehman Brothers |
| | | | | | | Call Options (8) | | | | | | | | |
| 28 Sep 07 | 0.22% | 130 | 1.15 | 117.68 | NOV07 | 3155 | 98.90% | 550 | 4.11% | 3 | 228.70% | 6 | 2,404,519 | |
| 24 Jan 08 | −1.04% | 90 | 1.26 | 75.81 | MAR08 | 3000 | 97.00% | 0 | 10.63% | 4 | 372.22% | 7 | 5,264,540 | 12 Feb: seeks to raise $8 Billion |
| 29 Jan 08 | −1.55% | 100 | 0.94 | 78.45 | MAR08 | 1500 | 86.50% | 120 | 10.63% | 1 | 189.36% | 4 | 4'186'500 | 12 Feb: seeks to raise $8 Billion |
| 18 Sep 08 | −0.61% | 72 | 0.41 | 55.86 | Oct 08 | 1120 | 71.20% | 241 | 19.16% | 2 | 563.41% | 2 | 1,706,445 | |
| 28 Oct 08 | −2.19% | 48 | 0.60 | 33.34 | Nov 08 | 963 | 60.30% | 200 | 11.87% | 6 | 431.67% | 7 | 1,761,747 | |

Table 17: Summary of detected abnormal trades for Société Générale. For definition of entries see Page 23.

**BNP Paribas (BN)**

| Day | $M_t$ | $K$ | $P_t$ | $S_t$ | $\tau$ | $\Delta OI_t$ | $q_t$ | $V_t$ | $r_t^{\mathbf{s}}$ | $\tau_1$ | $r_t^{\mathbf{o}}$ | $\tau_2$ | $G_t$ | Event's description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Put Options (16) | | | | | | | | |
| 14 Jan 08 | −0.37% | 70 | 1.10 | 73.72 | FEB08 | 271 | 38.90% | 0 | −10.20% | 6 | 618.18% | 6 | 130,601 | 30 Jan: quarterly profit will slump over 40%. |
| 15 Jan 08 | −0.27% | 68 | 0.98 | 72.25 | Feb 08 | 2458 | 95.40% | 68 | −10.20% | 5 | 546.94% | 5 | 1,777,858 | 30 Jan: quarterly profit will slump over 40%. |
| 16 Jan 08 | −0.23% | 64 | 2.78 | 73.17 | Jun 08 | 4139 | 99.00% | 120 | −10.20% | 4 | 172.30% | 4 | 559,877 | 30 Jan: quarterly profit will slump over 40%. |
| 18 Jan 08 | −0.15% | 64 | 1.68 | 69.39 | Mar 08 | 1000 | 66.00% | 20 | −10.20% | 2 | 175.60% | 4 | 98,734 | 30 Jan: quarterly profit will slump over 40%. |
| 26 May 08 | 0.02% | 68 | 2.67 | 66.60 | Jun 08 | 1000 | 69.60% | 5 | −4.08% | 10 | 176.40% | 10 | 659,500 | |
| 30 May 08 | −0.04% | 66 | 1.61 | 66.34 | Jun 08 | 2445 | 94.60% | NaN | −4.08% | 6 | 294.41% | 9 | 1,335,947 | |
| 03 Oct 08 | 0.32% | 70 | 3.08 | 71.35 | Oct 08 | 141 | 27.60% | 2 | −13.47% | 18 | 386.69% | 10 | 156,023 | 28 Oct: crash |
| 07 Oct 08 | 0.36% | 66 | 3.03 | 68.43 | Oct 08 | 511 | 51.80% | NaN | −13.47% | 16 | 263.37% | 8 | 412,633 | 28 Oct: crash |
| 21 Oct 08 | −0.83% | 58 | 5.56 | 59.00 | Nov 08 | 2500 | 93.00% | 100 | −13.47% | 6 | 96.28% | 6 | 3,326,778 | 28 Oct: crash |
| | | | | | | Call Options (13) | | | | | | | | |
| 26 Jul 07 | −0.29% | 80 | 3.34 | 79.12 | Sep 07 | 600 | 73.50% | 0 | 6.08% | 17 | 247.62% | 10 | 1,195,800 | |
| 04 Dec 07 | 0.41% | 70 | 2.50 | 74.00 | Feb 08 | 1464 | 86.60% | 0 | 2.77% | 2 | 197.56% | 5 | 954,371 | |
| 23 Sep 08 | 0.73% | 60 | 1.90 | 64.53 | Oct 08 | 638 | 62.70% | 656 | 8.23% | 9 | 544.83% | 9 | 1,137,240 | Positive signals from US bailout program |
| 25 Sep 08 | 0.70% | 66 | 4.51 | 67.21 | Dec 08 | 3045 | 92.50% | 1000 | 8.23% | 7 | 173.21% | 9 | 8,279,315 | Positive signals from US bailout program |

Table 18: Summary of detected abnormal trades for BNP Paribas. For definition of entries see Page 23.

**HSBC (HSB)**

| Day | $M_t$ | $K$ | $P_t$ | $S_t$ | $\tau$ | $\Delta OI_t$ | $q_t$ | $V_t$ | $r_t^{\mathbf{s}}$ | $\tau_1$ | $r_t^{\mathbf{o}}$ | $\tau_2$ | $G_t$ | Event's description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Put Options (12) | | | | | | | | | | | | | | |
| 12 Oct 07 | 0.41% | 940 | 5.00 | 953.00 | Oct 07 | 3000 | 93.50% | 0 | −2.73% | 15 | 230.00% | 6 | 3,450'000 | |
| 11 Dec 07 | 0.16% | 850 | 12.50 | 851.50 | Dec 07 | 1200 | 69.70% | 0 | −2.64% | 3 | 112.00% | 5 | 840,000 | |
| 07 Jan 08 | 0.14% | 840 | 28.50 | 833.00 | Feb 08 | 56 | 20.30% | 0 | −6.38% | 11 | 212.28% | 8 | 374,200 | recession hurts demand for loans |
| 10 Jan 08 | −0.18% | 840 | 29.50 | 814.00 | Jan 08 | 23 | 8.30% | 0 | −6.38% | 8 | 193.22% | 5 | 131,100 | recession hurts demand for loans |
| 14 Jan 08 | −0.23% | 780 | 13.50 | 811.00 | Feb 08 | 461 | 40.50% | 106 | −6.38% | 6 | 459.26% | 6 | 1,452,400 | recession hurts demand for loans |
| Call Options (5) | | | | | | | | | | | | | | |
| 10 Sep 07 | −0.14% | 880 | 18.00 | 870.00 | Sep 07 | 3000 | 95.80% | 25 | 2.63% | 18 | 111.54% | 8 | 16,500'000 | |
| 25 Sep 07 | 0.05% | 900 | 12.50 | 909.00 | Oct 07 | 888 | 66.20% | 5 | 2.63% | 7 | 122.22% | 9 | 3,937,000 | |

Table 19: Summary of detected abnormal trades for HSBC. For definition of entries see Page 23.

**Summary of Airline Sector Jan 1996 - Apr 2006**

| *Day* | *Id* | $S/K$ | $\tau$ | $OI_{t-1}$ | $\Delta OI_t$ | $q_t^{\Delta OI}$ | $\Delta OI_t^{\text{tot}}$ | $\text{Vol}_t$ | $r_t^{\max}$ | $\tau_2$ | $G_t$ | $\tau_3$ | *%ex.* | $q_t$ | $p$-value | $1-p_t$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **American Airlines (AMR) Jan 1996 - Apr 2006** | | | | | | | | | | | | | | | | |
| 10 May 00 | 10821216 | 1.01 | 38 | 20 | 3374 | 99.7% | 3378 | 3290 | 106% | 9 | 906,763 | 11 | 100% | 0.002 | 0.286 | 0.998 |
| 11 May 00 | 10821216 | 1.02 | 37 | 3394 | 5720 | 99.9% | 5442 | 5320 | 98% | 10 | 1,647,844 | 11 | 100% | 0.002 | 0.349 | 0.998 |
| 31 Aug 01 | 20399554 | 0.91 | 22 | 96 | 473 | 95.7% | 571 | 500 | 455% | 7 | 662,200 | 11 | 100% | 0.016 | 0.645 | 0.984 |
| 10 Sep 01 | 20428354 | 0.99 | 40 | 258 | 1312 | 98.5% | 1701 | 1535 | 453% | 2 | 1,179,171 | 26 | 100% | 0.012 | 0.096 | 0.998 |
| 24 Aug 05 | 27240699 | 0.97 | 24 | 1338 | 4378 | 93.5% | 8395 | 5319 | 163% | 8 | 575,105 | 17 | 100% | 0.048 | 0.123 | 0.952 |
| **United Airlines (UAL) Jan 1996 - Jan 2003** | | | | | | | | | | | | | | | | |
| 11 May 00 | 11332850 | 0.95 | 37 | 35 | 2505 | 98.7% | 2534 | 2505 | 132% | 10 | 1,156,313 | 26 | 100% | 0.002 | 0.373 | 0.998 |
| 6 Sep 01 | 20444473 | 1.06 | 44 | 21 | 1494 | 96.3% | 1189 | 2000 | 1322% | 7 | 1,980,387 | 28 | 100% | 0.030 | 0.165 | 0.998 |
| **Delta Air Lines (DAL) Jan 1996 - May 2005** | | | | | | | | | | | | | | | | |
| *1 Oct 98 | 10904865 | 1.01 | 16 | 140 | 974 | 97.7% | 483 | 924 | 261% | 6 | 537,594 | 12 | 100% | 0.016 | 0.000 | 0.996 |
| 29 Aug 01 | 20402792 | 0.98 | 24 | 1061 | 202 | 89.7% | 224 | 215 | 1033% | 9 | 328,200 | 13 | 100% | 0.044 | 0.528 | 0.998 |
| 19 Sep 02 | 20718332 | 0.99 | 30 | 275 | 1728 | 98.7% | 550 | 1867 | 132% | 7 | 331,676 | 22 | 100% | 0.004 | 0.190 | 0.998 |
| 9 Jan 03 | 21350972 | 1.10 | 44 | 274 | 3933 | 99.7% | 4347 | 4512 | 112% | 9 | 1,054,217 | 30 | 100% | 0.002 | 0.065 | 0.998 |
| **Boeing (BA) Jan 1996 - Apr 2006** | | | | | | | | | | | | | | | | |
| 24 Nov 98 | 10948064 | 0.99 | 53 | 3758 | 1047 | 93.5% | 1285 | 1535 | 467% | 7 | 883,413 | 24 | 100% | 0.040 | 0.481 | 0.996 |
| 29 Aug 01 | 20400312 | 0.92 | 24 | 1019 | 2828 | 96.7% | 3523 | 3805 | 382% | 10 | 1,972,534 | 8 | 100% | 0.028 | 0.252 | 0.998 |
| 5 Sep 01 | 20429078 | 1.01 | 45 | 472 | 1499 | 92.1% | 2538 | 1861 | 890% | 8 | 1,805,929 | 22 | 100% | 0.048 | 0.085 | 0.998 |
| 6 Sep 01 | 11839316 | 0.75 | 135 | 13228 | 7105 | 99.3% | 13817 | 7108 | 118% | 7 | 2,704,701 | 3 | 100% | 0.006 | 0.150 | 0.998 |
| *7 Sep 01 | 20400311 | 0.90 | 15 | 7995 | 4179 | 98.5% | 4887 | 5675 | 306% | 6 | 5,775,710 | 7 | 100% | 0.016 | 0.000 | 0.998 |
| *17 Sep 01 | 20400309 | 0.90 | 5 | 116 | 5026 | 98.9% | 2704 | 5412 | 124% | 4 | 2,663,780 | 5 | 100% | 0.010 | 0.000 | 0.998 |
| **KLM Jan 1996 - Nov 2001** | | | | | | | | | | | | | | | | |
| 5 Sep 01 | 20296159 | 0.91 | 17 | 3 | 100 | 99.3% | 34 | 100 | 467% | 9 | 53976 | 9 | 100% | 0.006 | 0.368 | 0.998 |

Table 20: Detected option abnormal trades for the airline sector. For definition of entries see Page 23.

**Summary of Airline Sector Jan 1996 - Apr 2006**

| Day of transaction | Market condition | Return | Crash in stock | Event's description |
|---|---|---|---|---|
| **American Airlines (AMR) Jan 1996 - Apr 2006** | | | | |
| 10 May 00 | 0.4% | −17.6% | 24/25 May 00 | Announcement 24 May 00: Airline Deal UAL's acquisition of US Airways |
| 11 May 00 | 0.0% | −17.6% | 24/25 May 00 | Announcement 24 May 00: Airline Deal UAL's acquisition of US Airways |
| 31 Aug 01 | −0.4% | −39.4% | 17 Sep 01 | 9/11 Terrorist attacks in New York |
| 10 Sep 01 | −1.4% | −39.4% | 17 Sep 01 | 9/11 Terrorist attacks in New York |
| 24 Aug 05 | 0.4% | −5.3% | 30 Aug 05 | August 05: Hurricane Katrina, interrupted production on the gulf coast, jet fuel prices ↑ |
| **United Airlines (UAL) Jan 1996 - Jan 2003** | | | | |
| 11 May 00 | 0.3% | −12% | 24 May 00 | Announcement 24 May 00: Airline Deal UAL's acquisition of US Airways |
| 6 Sep 01 | −1.0% | −43.2% | 17 Sep 01 | 9/11 Terrorist attacks in New York |
| **Delta Air Lines (DAL) Jan 1996 - May 2005** | | | | |
| *1 Oct 98 | −1.7% | −11.4% | 07/08 Oct 98 | Not identified |
| 29 Aug 01 | 0.0% | −44.6% | 17 Sep 01 | 9/11 Terrorist attacks in New York |
| 19 Sep 02 | −5.2% | −24.4% | 27 Sep 02 | Announcement 27 Sep 02: Expected loss for 3rd quarter |
| 9 Jan 03 | 2.1% | −15.7% | 21/22 Jan 03 | Announcement 21 Jan 03: Restrictions on planned alliance of Delta, Northwest and Continental |
| **Boeing (BA) Jan 1996 - Apr 2006** | | | | |
| 24 Nov 98 | −0.2% | −22.0% | 02/03 Dec 98 | Announcement 02 Dec 98: production scale back and cut in work forces |
| 29 Aug 01 | −0.4% | −25.0% | 17/18 Sep 01 | 9/11 Terrorist attacks in New York |
| 5 Sep 01 | −0.8% | −25.0% | 17/18 Sep 01 | 9/11 Terrorist attacks in New York |
| 6 Sep 01 | −0.9% | −25.0% | 17/18 Sep 01 | 9/11 Terrorist attacks in New York |
| *7 Sep 01 | −1.9% | −25.0% | 17/18 Sep 01 | 9/11 Terrorist attacks in New York |
| *17 Sep 01 | −5.6% | −25.0% | 17/18 Sep 01 | 9/11 Terrorist attacks in New York |
| **KLM Jan 1996 - Nov 2001** | | | | |
| 5 Sep 01 | −1.9% | −31.6% | 17/18 Sep 01 | 9/11 Terrorist attacks in New York |

Table 21: Description of detected option abnormal trades for the airline sector. For definition of entries see Page 23.

**Summary of Banking Sector Jan 1996 - Apr 2006**

| *Day* | *Id* | $S/K$ | $\tau$ | $OI_{t-1}$ | $\Delta OI_t$ | $q_t^{\Delta OI}$ | $\Delta OI_t^{\text{tot}}$ | $\text{Vol}_t$ | $r_t^{\max}$ | $\tau_2$ | $G_t$ | $\tau_3$ | $\%ex.$ | $q_t$ | $p$-value | $1-p_t$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bank of America (BAC) Jan 1996 - Apr 2006** | | | | | | | | | | | | | | | | |
| 13 Jun 00 | 10196393 | 0.93 | 39 | 272 | 1996 | 94.10% | 1883 | 2124 | 154% | 7 | 1,505,256 | 28 | 100% | 0.026 | 0.170 | 0.998 |
| *13 Nov 00 | 11596097 | 1.00 | 5 | 1747 | 6273 | 99.10% | 6240 | 7270 | 522% | 5 | 3,081,216 | 5 | 100% | 0.006 | 0.047 | 0.998 |
| 7 Sep 01 | 20400334 | 0.98 | 15 | 8720 | 3380 | 96.30% | 3607 | 4303 | 241% | 7 | 1,774,525 | 7 | 100% | 0.026 | 0.091 | 0.994 |
| **Citigroup (C) Jan 1996 - Apr 2006** | | | | | | | | | | | | | | | | |
| 30 Aug 01 | 20201221 | 1.07 | 23 | 9394 | 4373 | 94.50% | 8880 | 5427 | 622% | 10 | 2,045,940 | 12 | 100% | 0.044 | 0.096 | 0.998 |
| *18 Jun 02 | 20576902 | 0.96 | 95 | 3552 | 9984 | 97.90% | −8249 | 10090 | 114% | 7 | 7,661,724 | 30 | 65% | 0.002 | 0.000 | 0.998 |
| *17 Jul 02 | 20732009 | 0.92 | 31 | 4467 | 4923 | 91.30% | 9420 | 5148 | 227% | 5 | 3,579,435 | 5 | 100% | 0.028 | 0.000 | 0.996 |
| 28 Apr 04 | 21436285 | 0.97 | 24 | 38184 | 17803 | 99.90% | 24618 | 21429 | 102% | 9 | 3,172,024 | 18 | 100% | 0.002 | 0.197 | 0.998 |
| **J.P. Morgan (JPM) Jan 1996 - Apr 2006** | | | | | | | | | | | | | | | | |
| *5 Oct 00 | 11674068 | 0.99 | 16 | 4632 | 2957 | 94.70% | 3587 | 2843 | 391% | 10 | 1,411,934 | 12 | 100% | 0.030 | 0.004 | 0.998 |
| *9 Nov 00 | 11848514 | 0.98 | 37 | 9303 | 9564 | 99.30% | 10949 | 10681 | 164% | 10 | 1,937,044 | 12 | 100% | 0.004 | 0.000 | 0.998 |
| 29 May 01 | 11848586 | 0.99 | 18 | 22044 | 4290 | 95.70% | 6603 | 5569 | 204% | 9 | 1,508,490 | 10 | 100% | 0.026 | 0.060 | 0.996 |
| 30 Aug 01 | 20435891 | 0.98 | 51 | 1370 | 3145 | 90.90% | 2854 | 3407 | 153% | 10 | 1,318,638 | 30 | 99% | 0.026 | 0.058 | 0.998 |
| 6 Sep 01 | 20207536 | 0.92 | 16 | 22459 | 4778 | 96.30% | −9130 | 5359 | 178% | 8 | 1,415,825 | 8 | 100% | 0.014 | 0.075 | 0.998 |
| 18 Jan 02 | 20556357 | 1.03 | 29 | 6543 | 6168 | 97.10% | −85172 | 8421 | 225% | 7 | 2,007,110 | 20 | 100% | 0.024 | 0.145 | 0.996 |
| 17 Jan 03 | 21343021 | 0.95 | 36 | 5159 | 9597 | 99.10% | −133082 | 10527 | 117% | 9 | 2,414,176 | 24 | 100% | 0.006 | 0.061 | 0.998 |
| **Merrill Lynch (MER) Jan 1996 - Apr 2006** | | | | | | | | | | | | | | | | |
| *21 Aug 98 | 10840556 | 1.05 | 29 | 211 | 3679 | 99.50% | −6048 | 4165 | 428% | 10 | 5,318,200 | 20 | 100% | 0.002 | 0.000 | 0.998 |
| *25 Aug 98 | 10963647 | 1.02 | 25 | 1410 | 1962 | 95.90% | 2486 | 2207 | 629% | 9 | 2,378,481 | 14 | 100% | 0.020 | 0.000 | 0.998 |
| *28 Aug 98 | 10840556 | 0.92 | 22 | 5138 | 2951 | 98.70% | 2735 | 4703 | 186% | 9 | 2,143,600 | 15 | 100% | 0.012 | 0.000 | 0.996 |
| *1 Sep 98 | 11499596 | 0.96 | 18 | 349 | 2224 | 96.70% | −1534 | 2548 | 136% | 7 | 1,567,550 | 8 | 100% | 0.014 | 0.000 | 0.998 |
| 10 Sep 01 | 20408663 | 0.94 | 12 | 6210 | 5615 | 99.10% | 9898 | 7232 | 243% | 5 | 4,407,171 | 6 | 100% | 0.008 | 0.080 | 0.998 |
| 9 Apr 02 | 20642300 | 1.04 | 39 | 2549 | 3118 | 94.50% | 5545 | 3513 | 129% | 3 | 1,591,786 | 20 | 100% | 0.010 | 0.135 | 0.998 |
| **Morgan Stanley (MWD) Jan 1996 - Apr 2006** | | | | | | | | | | | | | | | | |
| 17 Aug 98 | 10174742 | 1.02 | 33 | 1003 | 1650 | 99.50% | 1779 | 1660 | 341% | 10 | 2,050,938 | 15 | 100% | 0.004 | 0.197 | 0.998 |
| *21 Aug 98 | 10148491 | 1.03 | 29 | 293 | 2064 | 99.70% | −3616 | 2362 | 554% | 10 | 1,906,663 | 20 | 100% | 0.004 | 0.005 | 0.998 |
| 25 Aug 98 | 10174742 | 0.98 | 25 | 2586 | 1291 | 98.70% | 1638 | 2170 | 674% | 9 | 1,467,850 | 6 | 100% | 0.014 | 0.173 | 0.998 |
| *28 Aug 98 | 11599638 | 0.93 | 22 | 2010 | 2010 | 99.50% | 862 | 2010 | 265% | 9 | 1,580,556 | 15 | 100% | 0.002 | 0.000 | 0.998 |
| 3 Nov 00 | 10297869 | 1.04 | 15 | 4154 | 2297 | 97.90% | 3285 | 3518 | 437% | 8 | 1,947,447 | 11 | 100% | 0.020 | 0.161 | 0.998 |
| *22 May 01 | 20310213 | 1.06 | 25 | 1098 | 1816 | 90.30% | 2284 | 1929 | 472% | 6 | 1,871,086 | 18 | 100% | 0.024 | 0.041 | 0.998 |
| *6 Apr 05 | 31518375 | 1.03 | 10 | 14497 | 13807 | 99.90% | 18342 | 18163 | 576% | 8 | 2,780,148 | 8 | 100% | 0.002 | 0.026 | 0.998 |

Table 22: Detected option abnormal trades for the banking sector. For definition of entries see Page 23.

**Summary of Banking Sector Jan 1996 - Apr 2006**

| Day of transaction | Market condition | Return | Crash in stock | Event's Description |
|---|---|---|---|---|
| **Bank of America (BAC) Jan 1996 - Apr 2006** | | | | |
| 13 Jun 00 | −1.0% | −14.8% | 15/16 Jun 00 | Announcement 15 Jun 00: Wachovia Corp. Correction of expected earnings for 2nd quarter |
| *13 Nov 00 | −0.4% | −11.7% | 14/15 Nov 00 | Announcement 14 Nov 00: 3rd quarterly financial statements, potential write-offs for 4th quarter |
| 7 Sep 01 | −0.4% | −5.7% | 17 Sep 01 | 9/11 Terrorist attacks in New York |
| **Citigroup (C) Jan 1996 - Apr 2006** | | | | |
| 30 Aug 01 | −0.5% | −6.7% | 17 Sep 01 | 9/11 Terrorist attacks in New York |
| *18 Jun 02 | 0.6% | −5.4% | 26 Jun 02 | Not identified |
| *17 Jul 02 | −0.3% | −26.7% | 22/23 Jul 02 | Announcement 22 Jul 02: Senate's investigations into Citigroup (Enron case) |
| 28 Apr 04 | −0.3% | −2.8% | 10 May 04 | Not identified |
| **J.P. Morgan (JPM) Jan 1996 - Apr 2006** | | | | |
| *5 Oct 00 | −0.3% | −7.0% | 12 Oct 00 | Not identified |
| *9 Nov 00 | −0.6% | −4.2% | 15 Nov 00 | Not identified |
| 29 May 01 | 0.4% | −3.4% | 6 Jun 01 | Not identified |
| 30 Aug 01 | −0.8% | −7.5% | 20 Sep 01 | 9/11 Terrorist attacks in New York |
| 6 Sep 01 | −1.5% | −7.5% | 20 Sep 01 | 9/11 Terrorist attacks in New York |
| 18 Jan 02 | −1.4% | −6.6% | 29 Jan 02 | Announcement 16/22 Jan 02: financial statements for 4th quarter/losses on Enron's loans |
| 17 Jan 03 | −0.7% | −5.3% | 24 Jan 03 | Announcement 22 Jan 03: bigger 4th quarter loss than forecasted |
| **Merrill Lynch (MER) Jan 1996 - Apr 2006** | | | | |
| *21 Aug 98 | 0.0% | −16.3% | 28/30/31 Aug 98 | Announcement 17 August 98: Ruble crisis, Russian crisis, Asian crisis |
| *25 Aug 98 | −0.4% | −16.6% | 09/10 Sep 98 | Announcement 17 August 98: Ruble crisis, Russian crisis, Asian crisis |
| *28 Aug 98 | −2.6% | −16.6% | 09/10 Sep 98 | Announcement 17 August 98: Ruble crisis, Russian crisis, Asian crisis |
| *1 Sep 98 | −3.7% | −16.6% | 09/10 Sep 98 | Announcement 17 August 98: Ruble crisis, Russian crisis, Asian crisis |
| 10 Sep 01 | −1.2% | −15.5% | 17/18 Sep 01 | 9/11 Terrorist attacks in New York |
| 9 Apr 02 | −0.9% | −7.9% | 11 Apr 02 | Announcement 09 Apr 02: accusations of conflicts of interest, potential fine of > $100mio |
| **Morgan Stanley (MWD) Jan 1996 - Apr 2006** | | | | |
| 17 Aug 98 | 0.7% | −17.2% | 28/31 Aug 98 | Announcement 17 August 98: Ruble crisis, Russian crisis, Asian crisis |
| *21 Aug 98 | −0.3% | −17.2% | 28/31 Aug 98 | Announcement 17 August 98: Ruble crisis, Russian crisis, Asian crisis |
| 25 Aug 98 | −0.5% | −17.2% | 28/31 Aug 98 | Announcement 17 August 98: Ruble crisis, Russian crisis, Asian crisis |
| *28 Aug 98 | −3.3% | −17.2% | 28/31 Aug 98 | Announcement 17 August 98: Ruble crisis, Russian crisis, Asian crisis |
| 3 Nov 00 | 1.3% | −12.2% | 07/08/09 Nov 00 | Not identified |
| *22 May 01 | 2.3% | −5.7% | 30 May 01 | Not identified |
| *6 Apr 05 | 1.0% | −3.0% | 20 Apr 05 | Announcement 05 Apr 05: proposal of new CEO, discover credit card unit spin off |

Table 23: Description of detected option abnormal trades for the banking sector. For definition of entries see Page 23.

**Summary of various sectors Jan 1996 - Apr 2006**

| *Day* | *Id* | $S/K$ | $\tau$ | $OI_{t-1}$ | $\Delta OI_t$ | $q_t^{\Delta OI}$ | $\Delta OI_t^{\text{tot}}$ | $\text{Vol}_t$ | $r_t^{\max}$ | $\tau_2$ | $G_t$ | $\tau_3$ | $\%ex.$ | $q_t$ | $p$-value | $1-p_t$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **AT&T (ATT) Jan 1996 - Apr 2006** | | | | | | | | | | | | | | | | |
| *17 Apr 98 | 10307639 | 1.03 | 29 | 2178 | 2442 | 97.70% | −20484 | 2963 | 441% | 9 | 1,605,881 | 21 | 100% | 0.014 | 0.022 | 0.998 |
| *25 Apr 00 | 10667683 | 1.04 | 25 | 14673 | 8512 | 99.50% | 9847 | 12786 | 593% | 10 | 9,407,938 | 19 | 100% | 0.002 | 0.021 | 0.998 |
| *26 Apr 00 | 10667683 | 1.02 | 24 | 23185 | 2637 | 93.90% | 3422 | 1853 | 447% | 9 | 2,348,288 | 15 | 100% | 0.038 | 0.002 | 0.998 |
| **Coca Cola (KO) Jan 1996 - Apr 2006** | | | | | | | | | | | | | | | | |
| *24 Aug 98 | 10423228 | 1.00 | 26 | 4338 | 2134 | 94.50% | 5285 | 3007 | 577% | 9 | 2,246,363 | 6 | 100% | 0.034 | 0.000 | 0.998 |
| *26 Aug 98 | 10423228 | 0.99 | 24 | 7033 | 1439 | 88.90% | 2910 | 1792 | 547% | 7 | 1,381,344 | 4 | 100% | 0.048 | 0.015 | 0.998 |
| *18 Mar 99 | 11199798 | 0.98 | 30 | 1320 | 1902 | 93.10% | 993 | 2082 | 175% | 10 | 616,950 | 21 | 100% | 0.006 | 0.000 | 0.998 |
| *23 Aug 00 | 10973464 | 1.07 | 59 | 48 | 2257 | 96.10% | 4890 | 2258 | 208% | 7 | 698,259 | 17 | 100% | 0.002 | 0.004 | 0.998 |
| 12 Feb 01 | 11851575 | 1.01 | 96 | 8130 | 756 | 72.80% | 1060 | 759 | 166% | 9 | 665,280 | 26 | 100% | 0.012 | 0.117 | 0.996 |
| 20 Feb 01 | 20207914 | 0.97 | 25 | 945 | 1796 | 93.10% | 3153 | 2349 | 254% | 10 | 1,340,364 | 19 | 100% | 0.042 | 0.248 | 0.998 |
| 28 Jun 02 | 20556780 | 1.12 | 50 | 12516 | 4664 | 98.70% | 6891 | 5130 | 312% | 10 | 1,935,470 | 17 | 100% | 0.010 | 0.100 | 0.998 |
| *9 Jul 02 | 20556781 | 1.03 | 39 | 4755 | 2659 | 97.30% | 8167 | 3243 | 669% | 9 | 789,515 | 29 | 100% | 0.016 | 0.000 | 0.998 |
| *10 Jul 02 | 20703870 | 0.99 | 10 | 5514 | 3013 | 97.70% | 4528 | 5533 | 641% | 8 | 779,200 | 4 | 100% | 0.022 | 0.002 | 0.998 |
| **Hewlett Packard (HPQ) Jan 1996 - Apr 2006** | | | | | | | | | | | | | | | | |
| *14 May 98 | 10552311 | 1.00 | 37 | 2646 | 2745 | 96.90% | 9720 | 4943 | 117% | 10 | 1,470,119 | 13 | 100% | 0.026 | 0.000 | 0.998 |
| 15 Sep 99 | 10087563 | 1.21 | 66 | 1785 | 1554 | 93.90% | 4079 | 1917 | 200% | 7 | 1,501,894 | 26 | 100% | 0.022 | 0.344 | 0.998 |
| *15 Oct 99 | 10848801 | 0.97 | 36 | 3403 | 6194 | 99.30% | −12522 | 7732 | 130% | 9 | 1,277,513 | 4 | 100% | 0.004 | 0.026 | 0.998 |
| *28 Sep 00 | 11163103 | 0.97 | 23 | 2600 | 1220 | 85.90% | 1449 | 1353 | 271% | 10 | 1,166,625 | 3 | 100% | 0.032 | 0.000 | 0.998 |
| *30 Oct 00 | 11136235 | 0.96 | 19 | 5307 | 11513 | 99.90% | 66131 | 5898 | 118% | 10 | 4,178,669 | 15 | 100% | 0.002 | 0.000 | 0.998 |
| *31 Oct 00 | 10519981 | 1.16 | 18 | 0 | 13093 | 99.90% | 43002 | 295 | 449% | 10 | 3,917,616 | 14 | 100% | 0.002 | 0.000 | 0.998 |
| *9 Nov 00 | 10373575 | 0.95 | 9 | 17186 | 4453 | 98.50% | 6502 | 7170 | 176% | 3 | 1,847,794 | 4 | 100% | 0.012 | 0.000 | 0.998 |
| **Philip Morris (MO) Jan 1996 - Apr 2006** | | | | | | | | | | | | | | | | |
| 28 Jan 99 | 11211572 | 1.03 | 23 | 1237 | 3307 | 92.30% | 3647 | 3314 | 444% | 10 | 2,329,156 | 16 | 100% | 0.008 | 0.187 | 0.998 |
| 30 Mar 99 | 11439476 | 0.94 | 18 | 5939 | 20993 | 99.10% | 43843 | 21330 | 149% | 6 | 6,038,594 | 13 | 100% | 0.002 | 0.160 | 0.998 |
| 21 Aug 00 | 10577641 | 1.07 | 26 | 3590 | 5770 | 97.90% | 8428 | 6262 | 145% | 10 | 892,463 | 19 | 100% | 0.010 | 0.489 | 0.996 |
| *16 Mar 01 | 20241596 | 0.96 | 36 | 2902 | 3416 | 93.50% | −67790 | 3539 | 122% | 5 | 938,726 | 16 | 100% | 0.014 | 0.020 | 0.998 |
| *3 Jun 02 | 20705047 | 1.04 | 47 | 16001 | 15344 | 97.90% | 14567 | 16767 | 106% | 10 | 3,291,798 | 16 | 100% | 0.016 | 0.005 | 0.998 |
| 21 Jun 02 | 20705047 | 0.96 | 29 | 43143 | 7298 | 92.10% | −82813 | 8816 | 263% | 5 | 2,079,930 | 2 | 100% | 0.048 | 0.211 | 0.998 |

Table 24: Detected option abnormal trades for various sectors. For definition of entries see Page 23.

**Summary of various sectors Jan 1996 - Apr 2006**

| Day of transaction | Market condition | Return | Crash in stock | Event's Description |
|---|---|---|---|---|
| **AT&T (ATT) Jan 1996 - Apr 2006** | | | | |
| *17 Apr 98 | 0.4% | −2.9% | 27 Apr 98 | Announcement 20 Apr 98: financial statements for first quarter |
| *25 Apr 00 | 0.7% | −19.0% | 02/03 May 00 | Announcement 02 May 00: financial statements for first quarter |
| *26 Apr 00 | 1.5% | −19.0% | 02/03 May 00 | Announcement 02 May 00: financial statements for first quarter |
| **Coca Cola (KO) Jan 1996 - Apr 2006** | | | | |
| *24 Aug 98 | 0.6% | −10.5% | 31 Aug 98 | Announcement 17 Sept 98: international crisis (Russian, Asian) hurts KO's profit |
| *26 Aug 98 | 0.0% | −10.5% | 31 Aug 98 | Announcement 17 Sept 98: international crisis (Russian, Asian) hurts KO's profit |
| *18 Mar 99 | 1.4% | −3.0% | 31 Mar 99 | Announcement 29 Mar 99: unexpected drop in sales due to Pepsi IPO |
| *23 Aug 00 | −0.9% | −3.8% | 30 Aug 00 | Not identified |
| 12 Feb 01 | 0.9% | −9.6% | 21/22 Feb 01 | Announcement 21 Feb 01: Coca-Cola/Procter&Gamble deal |
| 20 Feb 01 | −0.5% | −9.6% | 21/22 Feb 01 | Announcement 21 Feb 01: Coca-Cola/Procter&Gamble deal |
| 28 Jun 02 | 0.1% | −3.9% | 12 Jul 02 | Announcement 14 Jun 02: stock options granted to executives are recorded as expense |
| *9 Jul 02 | 0.1% | −10.0% | 18/19 Jul 02 | Announcement 17 Jul 02: financial statements for 2nd quarter |
| *10 Jul 02 | −0.5% | −10.0% | 18/19 Jul 02 | Announcement 17 Jul 02: financial statements for 2nd quarter |
| **Hewlett Packard (HPQ) Jan 1996 - Apr 2006** | | | | |
| *14 May 98 | −0.7% | −13.9% | 14 May 98 | Announcement 14 May 98: profit warning for 2nd quarter due to Asian crisis |
| 15 Sep 99 | −0.1% | −6.2% | 29 Sep 99 | Announcement 01 Oct 99: fall in 4th revenues growth |
| *15 Oct 99 | −1.0% | −12.6% | 27 Oct 99 | Announcement 27 Oct 99: earnings shortfall in 4th quarter |
| *28 Sep 00 | 0.7% | −12.5% | 29/02 Sep/Oct 00 | Not identified |
| *30 Oct 00 | −1.8% | −12.8% | 10/13 Nov 00 | Announcement 13 Nov 00: financial statements for 4th quarter (ended on Oct 31) |
| *31 Oct 00 | −2.0% | −12.8% | 10/13 Nov 00 | Announcement 13 Nov 00: financial statements for 4th quarter (ended on Oct 31) |
| *9 Nov 00 | −0.5% | −12.8% | 10/13 Nov 00 | Announcement 13 Nov 00: financial statements for 4th quarter (ended on Oct 31) |
| **Philip Morris (MO) Jan 1996 - Apr 2006** | | | | |
| 28 Jan 99 | 0.1% | −8.7% | 10 Feb 99 | Announcement 10 Feb 99: punitive damages of 81 million for smoker's death |
| 30 Mar 99 | −1.6% | −15.1% | 30/31 Mar 99 | Announcement 30 Mar 99: punitive damages of 51.5 million for inoperable lung cancer |
| 21 Aug 00 | 0.7% | −2.6% | 30 Aug 00 | Not identified |
| *16 Mar 01 | −0.9% | −4.8% | 20 Mar 01 | Not identified |
| *3 Jun 02 | 0.5% | −2.0% | 6 Jun 02 | Not identified |
| 21 Jun 02 | −1.0% | −15.8% | 21/24/25 Jun 02 | Announcement 21 Jun 02: investors reject stock because of litigation risk |

Table 25: Description of detected option abnormal trades for various sectors. For definition of entries see Page 23.

**Accuracy of the hedging detection method for Citigroup on 17 Dec 2001**

| | $h_i$ | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 0.05 | 0.10 | 0.15 | 0.20 | 0.25 | 0.30 | 0.35 | 0.40 | 0.45 | 0.50 |
| *Percentiles* | | | | | | | | | | | |
| 20 20 | 0.051 | 0.052 | 0.077 | 0.089 | 0.094 | 0.124 | 0.151 | 0.193 | 0.227 | 0.277 | 0.306 |
| 20 40 | 0.046 | 0.058 | 0.079 | 0.106 | 0.116 | 0.174 | 0.196 | 0.235 | 0.287 | 0.290 | 0.299 |
| 20 60 | 0.051 | 0.063 | 0.070 | 0.100 | 0.131 | 0.156 | 0.157 | 0.210 | 0.210 | 0.265 | 0.282 |
| 20 80 | 0.069 | 0.072 | 0.072 | 0.075 | 0.076 | 0.076 | 0.076 | 0.077 | 0.095 | 0.125 | 0.180 |
| 40 20 | 0.055 | 0.057 | 0.064 | 0.087 | 0.117 | 0.124 | 0.168 | 0.185 | 0.198 | 0.207 | 0.223 |
| 40 40 | 0.053 | 0.055 | 0.090 | 0.096 | 0.147 | 0.158 | 0.167 | 0.182 | 0.219 | 0.239 | 0.272 |
| 40 60 | 0.056 | 0.064 | 0.081 | 0.120 | 0.125 | 0.159 | 0.183 | 0.218 | 0.253 | 0.284 | 0.298 |
| 40 80 | 0.041 | 0.104 | 0.188 | 0.190 | 0.201 | 0.231 | 0.254 | 0.265 | 0.282 | 0.291 | 0.306 |
| 60 20 | 0.051 | 0.052 | 0.059 | 0.078 | 0.098 | 0.102 | 0.161 | 0.180 | 0.198 | 0.200 | 0.217 |
| 60 40 | 0.049 | 0.066 | 0.070 | 0.098 | 0.119 | 0.125 | 0.136 | 0.161 | 0.161 | 0.249 | 0.253 |
| 60 60 | 0.051 | 0.051 | 0.062 | 0.065 | 0.065 | 0.065 | 0.097 | 0.114 | 0.125 | 0.126 | 0.138 |
| 60 80 | 0.050 | 0.055 | 0.074 | 0.075 | 0.099 | 0.114 | 0.151 | 0.153 | 0.157 | 0.192 | 0.208 |
| 80 20 | 0.049 | 0.088 | 0.131 | 0.147 | 0.153 | 0.156 | 0.166 | 0.178 | 0.189 | 0.195 | 0.210 |
| 80 40 | 0.049 | 0.056 | 0.063 | 0.075 | 0.116 | 0.136 | 0.158 | 0.179 | 0.183 | 0.192 | 0.195 |
| 80 60 | 0.049 | 0.071 | 0.085 | 0.085 | 0.092 | 0.100 | 0.110 | 0.136 | 0.150 | 0.183 | 0.183 |
| 80 80 | 0.033 | 0.070 | 0.070 | 0.080 | 0.084 | 0.099 | 0.099 | 0.099 | 0.151 | 0.154 | 0.231 |

Table 26: Entries are the probabilities of rejecting the hypothesis $H_0$ of no hedging when abnormal trades occur for the Citigroup stock on day $i$ = December 17th, 2001, i.e., $\mathbb{A}(h_i)$ in (1), for various levels of $h_i$ and $\mathbf{X}_i$. $h_i$ is the ratio between volume due to hedging and volume due to non-hedging. $\mathbf{X}_i = (|r_i|, V_{i-1}^{\text{buy,non-hedge}})$ are the conditioning variables, i.e., stock return on day $i$ and buyer-initiated volume due to non-hedging on day $i-1$, respectively. *Percentiles* are the levels of percentiles for the distributions of $|r_i|$ and $V_{i-1}^{\text{buy,non-hedge}}$, respectively, used as values of the conditioning variables in adjusted Nadaraya–Watson estimator as in the main paper.

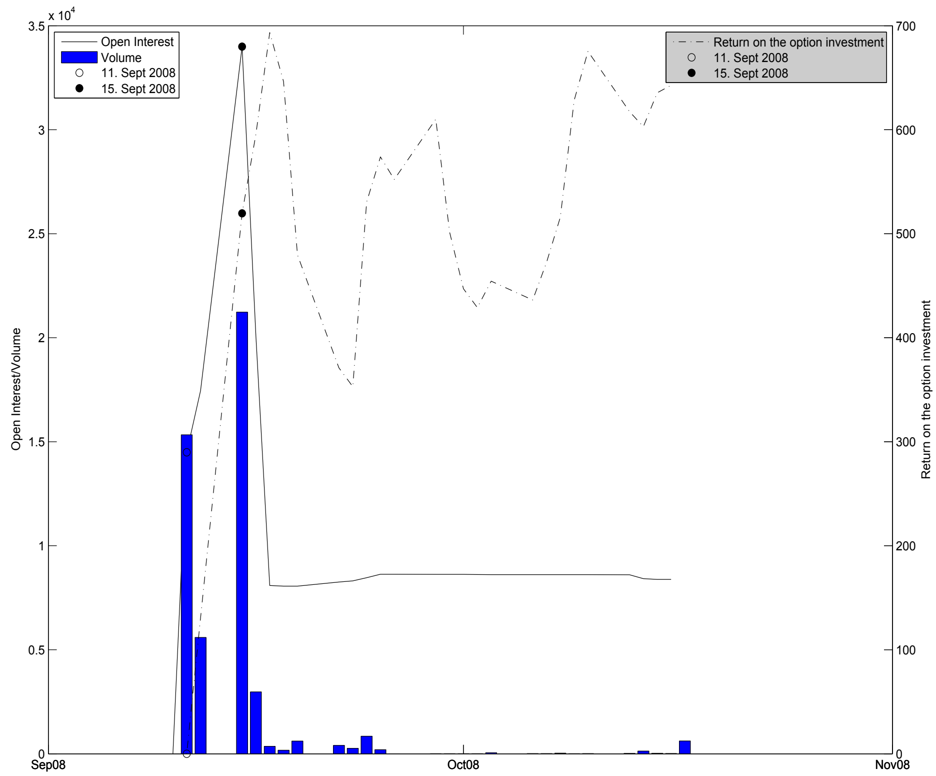


Figure 1: Selected put option with underlying stock AIG before the Federal Reserve Board announced that it would take a nearly 80% equity stake in AIG—effectively taking over the firm—and would provide an $85 billion loan on September 15th, 2008. The solid line shows the daily dynamic of open interest, the bar the corresponding trading volume (left y-axis) and the dash-dot line, the option return (right y-axis). The empty circle is the day of the transaction, the filled circle is the announcement day, September 15th, 2008. This put option had a strike of $8 and matured at the end of October 2008.

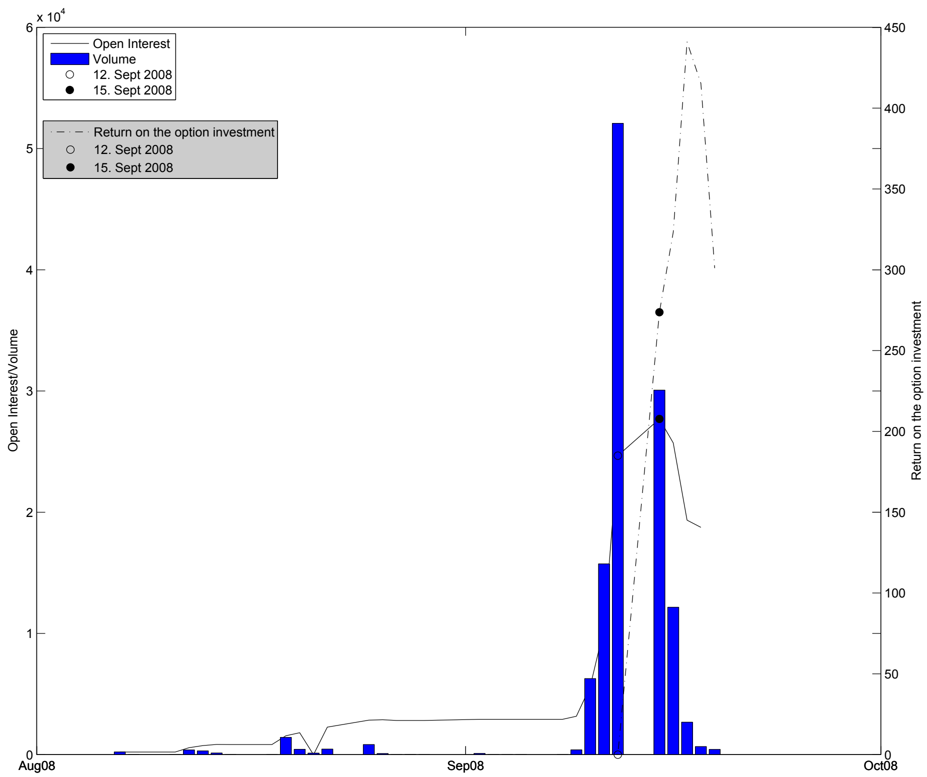


Figure 2: Selected put option with underlying stock AIG before the Federal Reserve Board announced that it would take a nearly 80% equity stake in AIG—effectively taking over the firm—and would provide an $85 billion loan on September 15th, 2008. The solid line shows the daily dynamic of open interest, the bar the corresponding trading volume (left y-axis) and the dash-dot line, the option return (right y-axis). The empty circle is the day of the transaction, the filled circle is the announcement day, September 15th, 2008. This put option had a strike of $10 and matured at the end of September 2008.

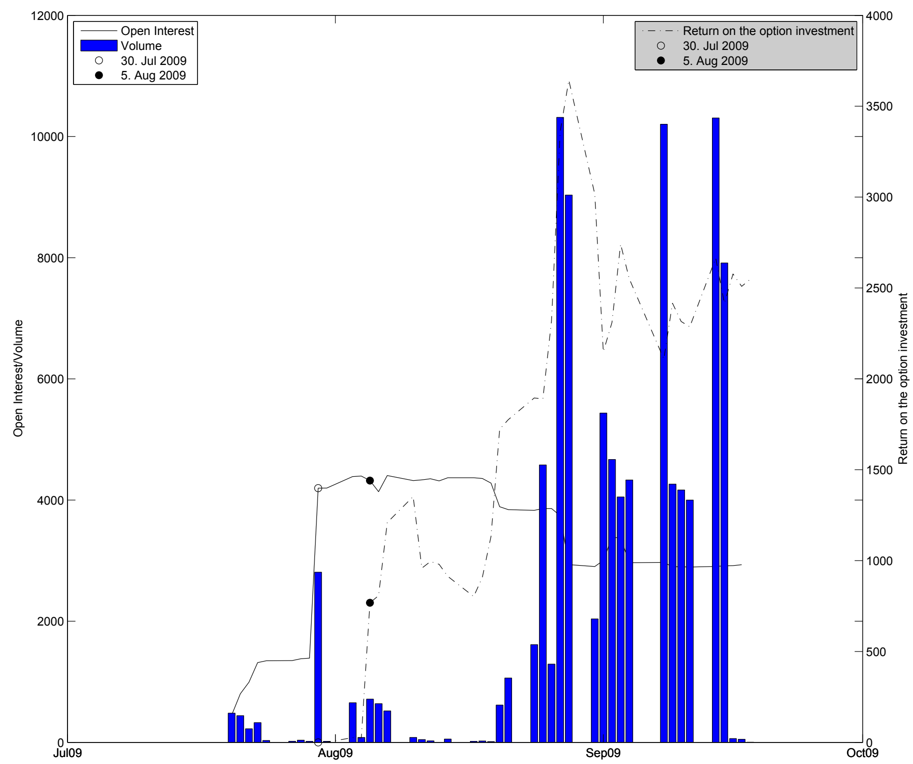


Figure 3: Selected call option with underlying stock AIG before the August 7th, 2009 quarterly profit announcement that almost doubled the stock value. The solid line shows the daily dynamic of open interest, the bar the corresponding trading volume (left y-axis) and the dash-dot line, the option return (right y-axis). The empty circle is the day of the transaction, the filled circle is the announcement day, August 7th, 2009. This call option had a strike of $15 and matured at the end of September 2009.

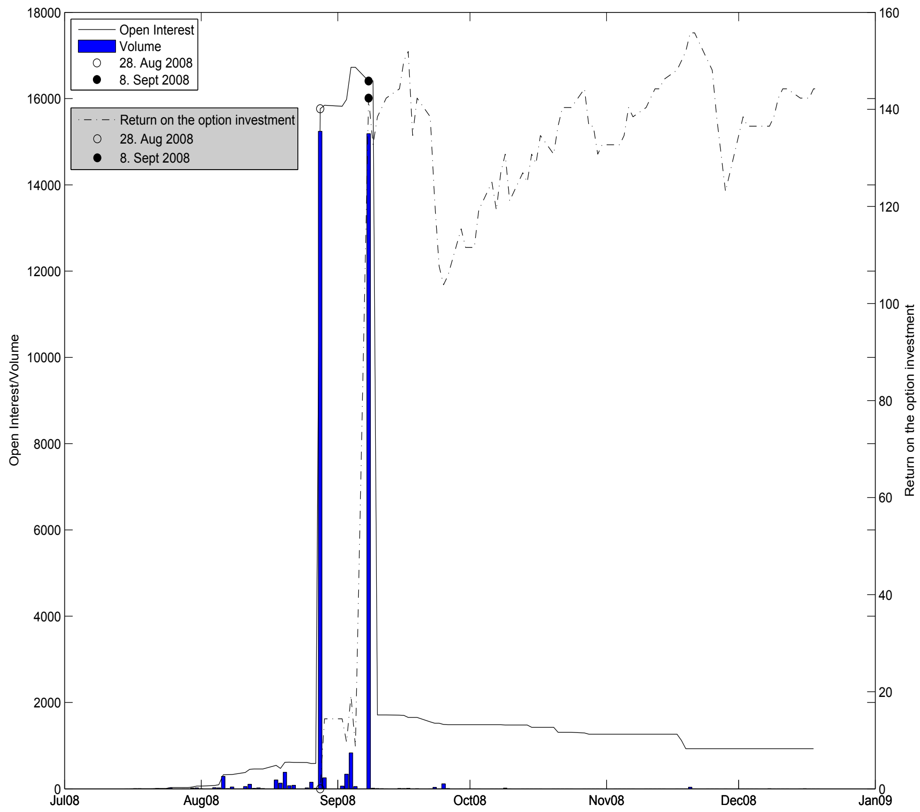


Figure 4: Selected put option with underlying stock Fannie Mae before the federal takeover on September 5th, 2008. The abnormal option trade takes place on August 28th, 2008. The solid line shows the daily dynamic of open interest, the bar the corresponding trading volume (left y-axis) and the dash-dot line the option return (right y-axis). The empty circle is the day of the transaction, August 28th, 2008, and the filled circle is Monday, September 8, when the stock price of Fannie Mae crashed by almost 90% to under $1. This put option had a strike of $7 and a time-to-maturity of more than 100 days.

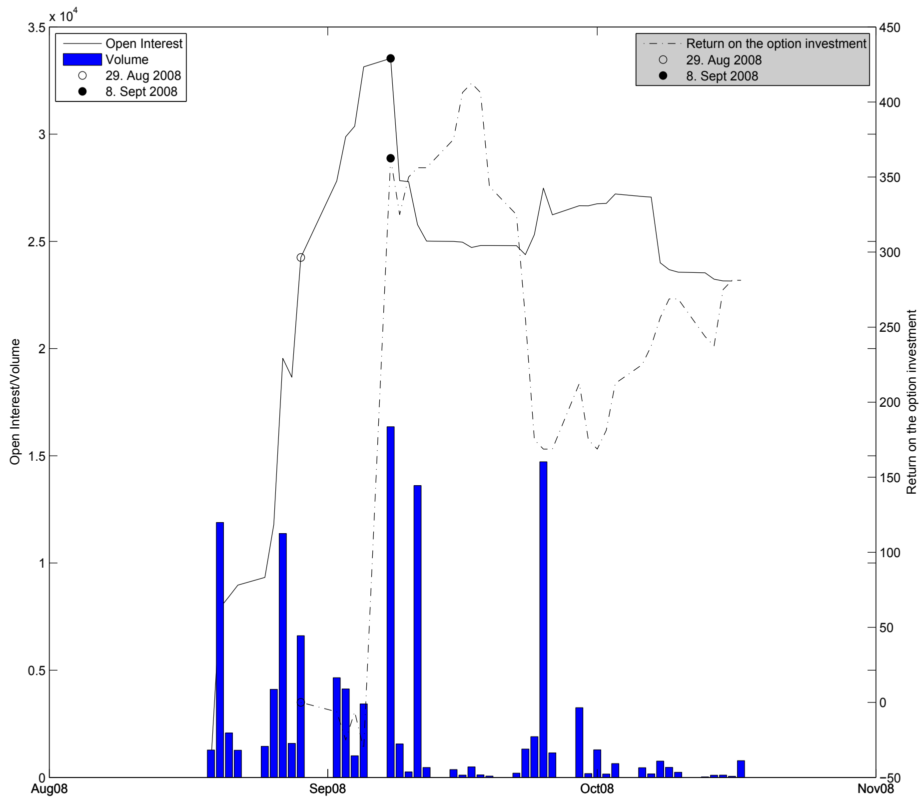


Figure 5: Selected put option with underlying stock Fannie Mae before the federal takeover on September 5th, 2008. The abnormal option trade takes place on August 29th, 2008. The solid line shows the daily dynamic of open interest, the bar the corresponding trading volume (left y-axis) and the dash-dot line the option return (right y-axis). The empty circle is the day of the transaction, August 29th, 2008, and the filled circle is Monday, September 8th, when the stock price of Fannie Mae crashed by almost 90% to under $1. This put option had a strike of $3 and a maturity at the end of October 2008.

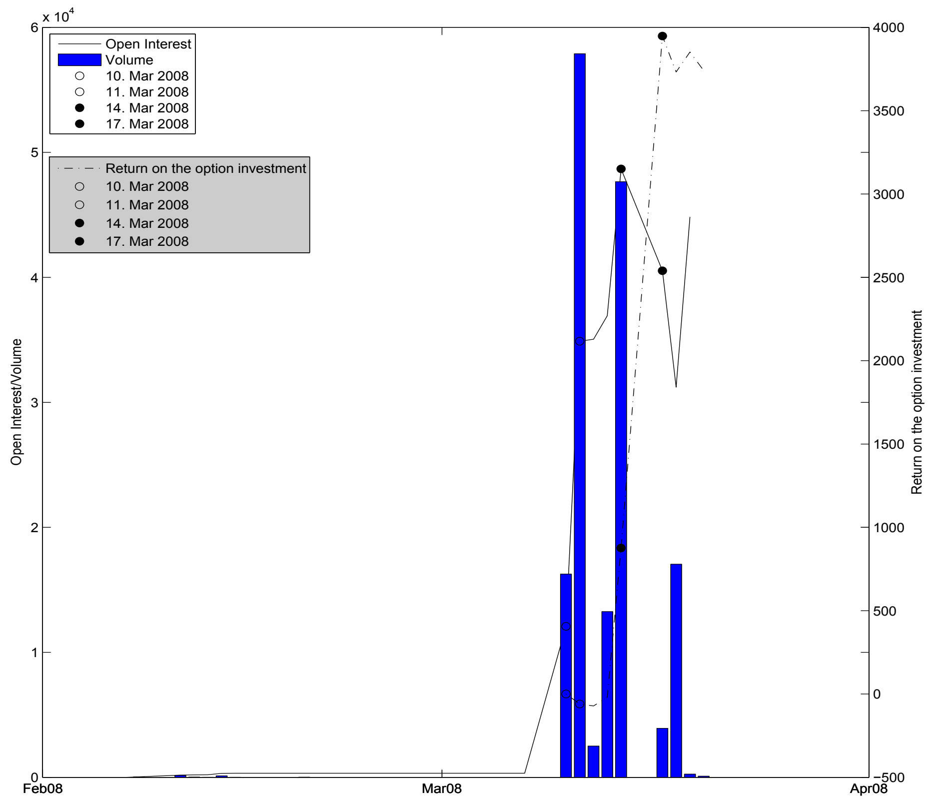


Figure 6: Selected put option with underlying stock Bear Stearns before the company collapse on March 17th, 2008. The abnormal option trade takes place on March 10th, 2008. The solid line shows the daily dynamic of open interest, the bar the corresponding trading volume (left y-axis) and the dash-dot line, the option return (right y-axis). The empty circle is the day of the transaction, the filled circle is Monday, March 17th, the day Bear Stearns shares dropped nearly 90% to $2.86. This put option had a strike of $30 and matured at the end of March 2008.

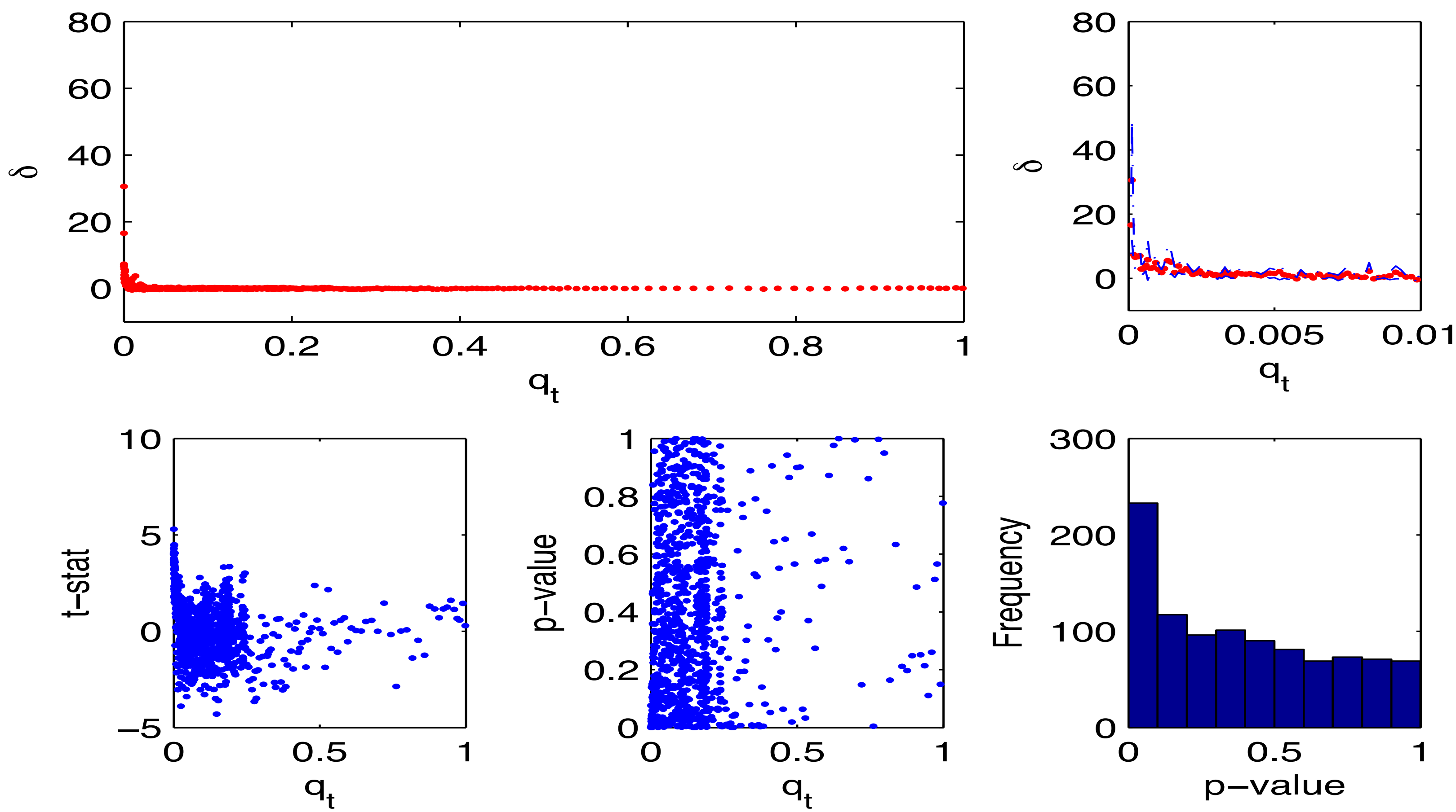


Figure 7: False Discovery Rate for Lehman Brothers. The upper-left graph shows on the x-axis the probability $q_t$ (the right-end point in each subinterval $I_m$), and on the y-axis the corresponding average option returns $\delta_m$ associated to the $m$th option trader. The upper-right graph shows the same quantities when $0 \leq q_t \leq 0.01$. Dashed-dotted lines represent 95% confidence intervals for $\delta_m$. The lower graphs, from left to right, show $t$-statistics of option returns associated to the $M$ option traders for the null hypothesis $H_0 : \delta_m = 0, m = 1, \ldots, M$, corresponding $p$-values, and histogram of $p$-values, respectively.

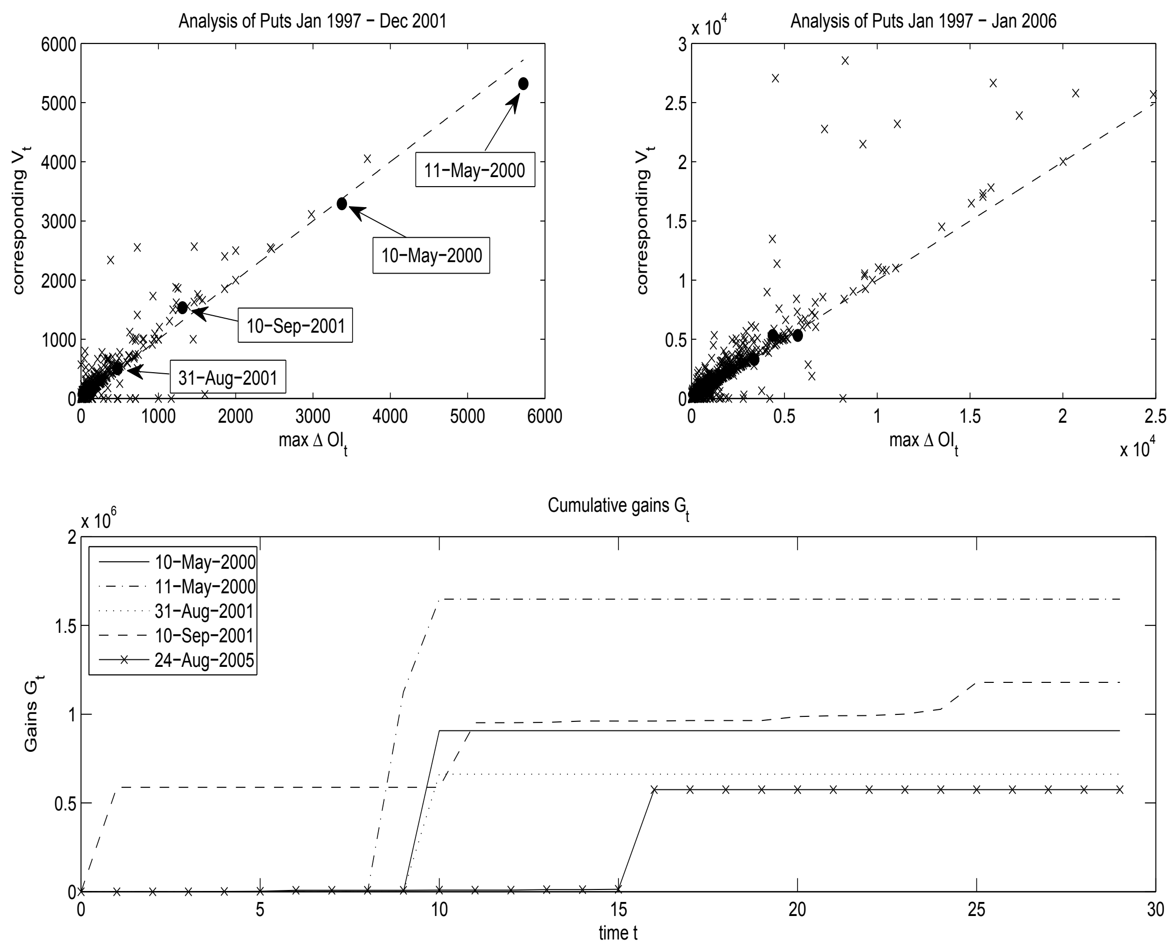


Figure 8: Upper graphs show on the x-axis maximal daily increment in open interest across all put options with underlying American Airlines (AMR), and on the y-axis the corresponding trading volume. Upper-left graph covers the period January 1997 – December 2001, upper-right graphs the period January 1997 – January 2006. Lower graph shows cumulative gains $G_t$ in USD for detected option abnormal trade on AMR. Gains correspond to those realized by daily exercising/selling the options.

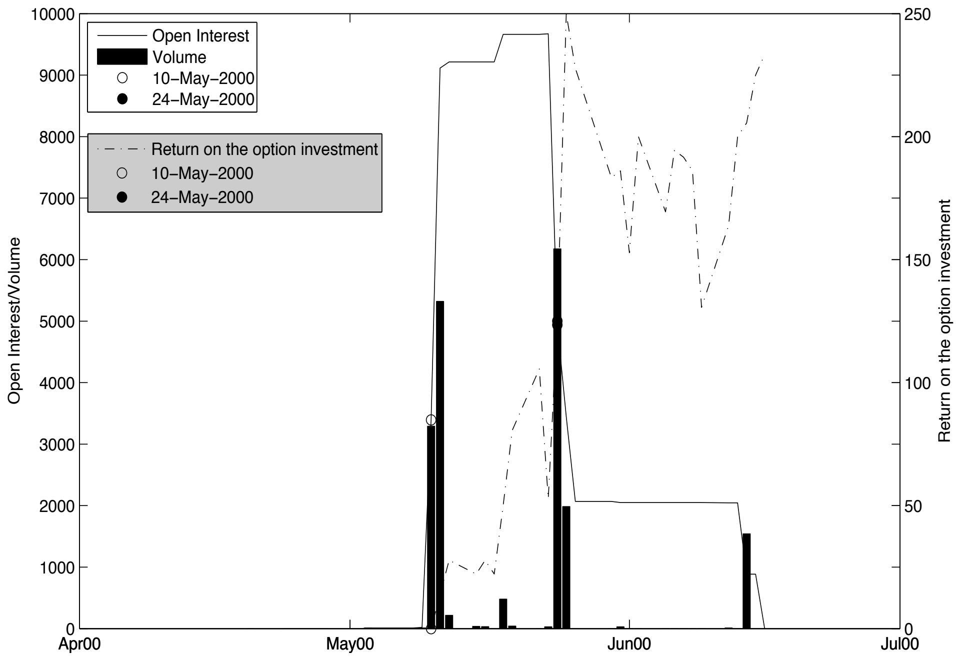


Figure 9: Selected put option for abnormal trading with underlying stock American Airlines (AMR) before the United Airlines (UAL) announcement of $4.3 billion acquisition of US Airways in May 2000. The solid line shows the daily dynamic of open interest, the bars show the corresponding trading volume (left y-axis) and the dash-dot line the option return (right y-axis). The empty circle is the day of the transaction, the filled circle is the day of the announcement (partially covered by the highest bar). This put option had a strike of $35 and matured at the end of June 2000.