Detecting Informed Trading Activities in the Options Markets *

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Abstract

Economic incentives including reduced transaction costs, low initial capital, large financial leverage and strategic incentives such as the discreteness offered by the options market might make option trading more attractive to informed agents than trading in the underlying stock. It is therefore reasonable to expect that traders privileged with superior information about important events might prefer to trade in options rather than in the underlying asset. Until now informed trading has been extensively studied in the stock market, but virtually neglected in the options market, most likely because of its challenging nature. Our main focus is on stock crashes and, therefore, abnormal transactions in put options. We perform an analysis at the level of single option contracts. Three different aspects of trading activities in the options market are analyzed in order to detect informed trading: daily increments in open interest, realized gains and hedging dimension. For the period 1996–2006, we apply our methodology to 14 companies in various business sectors. Our procedure detects several informed trades on the Chicago Board Options Exchange, the vast majority of which can be assigned to one of the following three event categories: M&A/earnings related announcements, quarterly financial statements, and the terrorist attacks of September 11th. A preliminary analysis of EUREX data is also given. This contains unusual transactions in put options with underlying Swiss Re and Munich Re stock in the days leading up to 9/11 as well as suspicious trades in puts with underlying EADS in the period April/May 2006, where executives are believed to have been involved in insider trading activities using stock and stock options. The analysis presented in this paper also investigates the presence and/or absence of a linkage between option market variables and subsequent price movements of the underlying stock thereby enhancing our understanding of the functioning of financial markets.
1 Introduction

Worldwide stock and options exchanges have been subject to impressive growth in trading volume over the last decades. High liquidity, consistently active trading, and substantial growth in financial assets were not the only features marking this period. Informed and illegal activities in financial markets have become an important issue traders and supervisory authorities have to face and deal with. Informed trading is a term subject to many definitions and contains many subclassifications. One of the most familiar subclasses of informed trading is illegal insider trading. To quote a speech from an SEC officer\footnote{http://www.sec.gov/news/speech/speecharchive/1998/srch21.htm}, “(illegal) insider trading is the trading that takes place when those privileged with confidential information about important events use the special advantage of that knowledge to reap profits or avoid losses on the stock market, to the detriment of the source of the information and to the typical investors who buy or sell their stock without the advantage of ”inside” information”. It is interesting to note that pursuant to this definition, only the stock market is considered to be a possible trading place for traders in possession of privileged information. The main conjecture of this paper is however that the options market might well be even more attractive and profitable for informed traders. In this case, it might be optimal for regulators to expend relatively more monitoring efforts on the options markets.

In M&A transactions and quarterly financial statements, the circle of involved people and institutions expands quite quickly before the announcement day. It is therefore reasonable to believe that not only directors or employees illegally trade on the knowledge of inside information, but non-insiders as well. In addition, the leakage of inside information appears to be prevalent, since the control of related transactions is almost impossible due to the fact that trading can be done via certain financial institutions\footnote{Some economists argue that laws making insider trading illegal should be revoked. They claim that insider trading based on material non-public information benefits investors, in general, by more quickly introducing new information into the market. Milton Friedman, laureate of the Nobel Memorial Prize in Economics, said: “You want more insider trading, not less. You want to give the people most likely to have knowledge about deficiencies of the company an incentive to make the public aware of that”. Friedman did not believe that the trader should be required to make his trade known to the public, because the buying or selling pressure itself is information for the market.}. Furthermore, in public databases a trader’s identity is not reported and it is therefore not possible to distinguish insider from non-insider trading activities.
We consider therefore informed trading activities, which in view of our classification of trade types, represent the set of suspicious trading activities we are able to detect using standard databases, and which corresponds to (illegal) insider and non-insider activities. The leakage of inside information is a pervasive problem which should be reflected upon in the options markets as well. For that reason we concentrate our analysis on those markets. Although our detection methodology might generate statistical evidence of informed trading activities, from a legal point of view this study does not constitute proof per se of such activities. Further investigations would require information about the trader’s identity as well as additional analysis by competent agencies.

Rule 10b-5 of the Securities Exchange Act regulates trading by insiders and requires trading by corporate officers, directors and substantial owners to be reported to the SEC. Trades channeled through third parties, or trades made by other employees who have access to privileged information are not monitored by the SEC. Thus, while trading on the basis of non-public information might be illegal, only the trading activities of registered insiders can be directly examined by regulators. The remaining activities based on inside information might be detected by market anomalies in the days leading up to a specific event. In this project we have chosen to follow this approach in order to detect such activities.

Whereas informed trading activities in the stock market is a well known and studied phenomenon (see e.g. Easley, Kiefer, and O’Hara (1997), Easley, O’Hara, and Srinivas (1998), Launois and Oppens (2003) and Bagliano, Favero, and Nicodano (2001)), less attention has been paid to such activities in the options market. Trading in options contracts might be more attractive to informed traders than trading the underlying stock for several reasons: economic incentives including reduced transaction costs, low initial capital, larger financial leverage and strategic incentives such as the discreteness offered by the options market. It is therefore reasonable to expect that traders privileged with information about important events might prefer to trade in options rather than in the underlying asset during periods of severe information asymmetry. It is important to analyze informed trading activities as it enhances our understanding of how (or if) new information is possibly reflected in an asset price. The analysis presented in this paper investigates therefore the possible linkage between option market variables and subsequent price movements of the underlying
stock thereby enhancing our understanding of the functioning of financial markets.

Option contracts have been widely accepted as one of the most useful derivative securities of the last decades. As for the stock market, daily trading volume, bid-ask quotes, prices and volatility are considered the driving components when analyzing trading activities in the options market. However, unlike the stock market in which there is a certain number of shares to be traded, options trading can involve the creation of new long/short positions whenever the parties underwrite new contracts. Therefore the open interest, i.e. the number of existing (not yet) exercised option contracts, can be quite volatile and may significantly change from one day to the other. This fact is confirmed by historical daily data from the Chicago Board Options Exchange (CBOE). Open interest is widely used by options traders and is one of the data fields on every option quote display. Together with daily trading volume, the dynamic of open interest might be considered as an indicator of different activities in the options market and of the future development of the underlying price. For example, the liquidity of an option can be described by its corresponding open interest, and trading volume in an (already existing) option can be considered unusual and exceptionally high whenever the daily volume exceeds its existing open interest. In addition, daily changes in open interest may contain/reveal what other investors think/know about the future value of the underlying stock and can help in determining how much new money is flowing into a market or out of it.

We analyze open interest as a key variable in the detection of informed trading activities. As already noted in various papers (see for example Launois and Oppens (2003), Keown and Pinkerton (1981) and Cao, Chen, and Griffin (2005)), option market anomalies are an important indicator of the information flow in the market. Launois and Oppens (2003) compare for example stock and option market activities and observe first that there are abnormal activities in both markets before the M&A announcement day. These activities turn out to be more intense in the options market. They find a dramatic increase in both open interest and volume. They point out that using open interest as an indicator has two decisive advantages: it is much less volatile than volume, and it is not affected by very short-term speculation that occurs when a trader opens a position in the morning and closes it in the evening. Considering therefore the daily increment in open interest
corresponds to analyzing the number of new option contracts issued in the market on that specific day. The dynamic of such a variable can therefore contain critical information about underlying asset movements that is not available when analyzing the stock market only.

We perform an analysis at the level of single option contracts. We consider only stock crashes and concentrate therefore on suspicious trading activities in put options. In order to check whether superior information is at the origin of a particular option trade we analyze three different aspects: first, we consider its daily increment in open interest and its volume in order to study whether this transaction can be classified as unusual, second we compute its rate of return and dollar gains, and third we check whether hedging demand was at the origin of that trade. Option trades that are delta-hedged using the underlying stock are not considered to be informed trading activities. Our selection procedure makes use of these criteria in order to detect informed activities: a trade in a specific option which exhibits an unusually high increment in open interest, generates an abnormal positive return and large gains a few days later, and is not based on hedging demands, is classified as an informed trading activity. Based on this procedure, our method has detected several suspicious trades on the CBOE, the vast majority of which can be assigned to M&A/earnings announcements, quarterly financial statements, and the terrorist attacks of September 11th. Our empirical findings suggest that impending mergers and the content of quarterly announcements seem to be poorly held secrets, and trading on this privileged information seems to occur fairly systematically. As mentioned in Cao, Chen, and Griffin (2005), takeover announcements are ideal events for studying information discovery in the security price formation process. Whereas trades made before scheduled announcements like quarterly financial and earnings statements might be based on speculative bets, takeover announcements are not planned and trades prior to such events are likely to be started by traders who possess inside information. This statement suggests that some unusual activities which we are able to classify as informed may indeed be illegal.

Our sample data range from January 1996 to April 2006 and includes 14 companies in the airline, banking and various other sectors. In total we detect 37 transactions on the CBOE which can be associated with informed trading activities: 6 occurring in the days leading up to a public M&A announcement, 14 belonging to quarterly financial/earnings related statements, 13 related to the
terrorist attacks of September 11th, and 4 which could not be identified. The fraction of events
assigned to a specific sector varies. We find that more than 50% of the selected transactions for
the airline sector (8 out of 15) can be traced back to the terrorist attacks of 9/11. Companies
like American Airlines, United Airlines, Boeing and to a lesser extent Delta Air Lines and KLM
seem to have been favorite targets for informed trading activities in the period leading up to the
attacks. In fact, the number of new put options issued during that period is unusually high and
the gains realized by exercising these options are impressive, more than $16 million in total. For
Delta Air Lines and KLM conclusions are however less obvious, since the realized gains are not
as unusually high and suspicious as those of the other companies. Four suspicious transactions
surrounding M&A announcements are detected in the airline sector. These contain large trades
in put options and an unusually high increment in option open interest with underlying American
Airlines and United Airlines stock. These transactions took place on May 10th and 11th, 2000,
namely two weeks before UAL’s acquisition of US Airways was announced, and achieved a total
gain of almost $3 million. Abnormal put transactions with underlying Delta Air Lines occurred a
few weeks before the public announcement on January 21th, 2003 of the planned alliance between
Delta, Northwest and Continental. In this case the total gains (from this strategy) were more than
$1 million. The last three transactions detected in the airline sector are related to quarterly finan-
cial/earnings related statements. For the banking sector we detected 14 informed trading activities,
6 belonging to the category of quarterly financial/earnings related announcements, 5 to the terrorist
attacks of September 11th and 3 not identifiable. We find that the number of new put options with
underlyings Bank of America, Citigroup, JP Morgan and Merrill Lynch issued in the days before
the terrorist attacks is at unusually high levels. The realized gains from such trading strategies
amount to $11 million. The last class of companies we analyze includes AT&T, Coca Cola, Hewlett

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3We computed the reported gains based on the exercise of a small number of single options. If we considered a
larger set, the realized gains would increase.

4As reported in the New York Times edition of May 25th, AMR was considered the company most threatened by
the merger, explaining therefore the 17% drop in its stock 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 real work ahead of us 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 shares which declined $7.1875 to $53.1875 on the announcement day.
Packard and Philip Morris. We suspect two informed trades in the pre-announcement period of the M&A deal between Coca Cola and Procter&Gamble announced on February 21th, 2001 (leading to gains of more than $2 million) and 5 transactions preceding the publication of quarterly financial/earnings statements. Information related to earnings shortfalls, unexpected drops in sales and production scale backs are the most common in this last category. This last category contains three informed trades in put options with underlying Philip Morris stock. These took place a few days before three separate legal cases against the company seeking a total amount of more than $50 million (in damages) for smokers’ deaths and inoperable lung cancer. The related gains from these trading strategies amounted to more than $10 million. One trade could not be identified. From a rational point of view, none of the companies belonging to this last sector should be affected by an event like the terrorist attacks of September 11th. Using our methodology, we do not detect any informed activities in the period leading up to the attacks even though the market was in decline. 

A preliminary analysis for European companies is given for Swiss Re, Munich Re and EADS. Due to the lack of high frequency data we are not able to fully apply our methodology. Liabilities for Swiss Re and Munich Re -the worlds two biggest reinsurers- were estimated to be in the amount of billions of dollars a few days after the terrorist attacks. We confirm with our procedure that in both cases abnormal transactions in put options took place on the EUREX in the period preceding September 11th, leading to net gains of more than €11.4 million. In the case of EADS, the parent of plane maker Airbus, we find that the number of put options traded between April and June 06 are at unusual levels. These trades precede the June 14th, 2006 announcement that deliveries of the superjumbo jet A380 would be delayed by a further six months, causing a 26% fall in the underlying stock. We found a total gain of €7.5 million through these trading strategies. However, if we consider a larger set of options exercised in the days after the public announcement, a total of €18.7 million is realized.

Summarizing our findings, we detect several informed activities based on the following trading strategy: first, traders in possession of privileged information aggressively enter the options market a few days before the occurrence of a specific event and bring the increment in open interest of a specific option to an unusually high level, meaning that a large number of new put options are
issued. Second, because of the publication of negative information or the occurrence of a specific event, a drop in the underlying stock follows and third, considerable gains are realized through the sequential exercise of those new options.

The paper is organized as follows. Section 2 gives an overview of the existing literature dealing with activities in the options market and the issue of insider/informed trading. Section 3 describes our methodology to detect informed trading activities. Section 4 presents the empirical results analyzing two business sectors (airline and banking) and various other firms. Section 5 concludes.

1.1 Data

Several databases are used in this empirical study. For American companies and KLM, options data are from the Chicago Board Options Exchange (CBOE) and provided by OptionMetrics. Stock prices are downloaded as well from OptionMetrics to avoid non-synchronicity issues between option and stock prices. Stock prices are adjusted for stock splits and spin-offs using information from the CRSP database. High frequency data for the underlying stock are provided by NYSE’s Trade and Quote (TAQ) database. Some adjustments were required: in OptionMetrics open interest for option contracts is lagged by one day after November 28th, 2000. Previous to this date, the open interest is not lagged. We eliminated obvious data errors such as open interest reported at zero for all existing options by excluding these days from our database. Prudence is required when merging different databases as they might not be synchronized. This is for example the case when downloading the data for J.P. Morgan from OptionMetrics and TAQ: 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. When breaking down the stock volume in its two components (buyer- and seller-initiated), it is essential to take into consideration the differences between the two databases and adjust for them. The same problem was found for BankAmerica Corporation and NationsBank Corporation, whose merger took place in 1998 under the new name of Bank of America Corporation. 14 companies from airline, banking and various other sectors are analyzed. 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. Sample data range from January 1996 to April 2006. Options data for DAL and KLM were available only for somewhat shorter periods. For the analysis of European companies, (Swiss Re, Munich RE and EADS) we used daily data from the EUREX provided by Deutsche Bank. All the options we analyze in this paper are of American style.

2 Literature review

Our paper extends existing literature in several ways. In the literature on informed trading activities, the research focus has been generally on specific types of events: the informativeness of stock and option trading activities occurring prior to M&A announcements has been widely analyzed by Keown and Pinkerton (1981), Launois and Oppens (2003) and Cao, Chen, and Griffin (2005); the behavior of markets around quarterly earnings announcements has been proposed in Schachter (1998) and Cheng and Leung (2008). Poteshman (2006) analyzes option transactions in the days leading up to September 11th. The contribution of our paper is manifold. First, we do not concentrate on a single type of event, but rather analyze a long time period, more than ten years, and detect different types of informed activities. This approach enables us to detect informed trades which would not have been detected when analyzing a period around a specific type of event. The case of EADS will be considered as an example. Second, most of the previous papers use regression models in which the underlying stock’s return is the dependent variable and option variables are explanatory variables. We use a different approach and empirically show the information content in specific trades. We select transactions which can be classified as suspicious using several criteria like abnormal increment in open interest, realized gains through exercise and returns. Third, a novel feature in our approach is that we take into consideration the hedging dimension because abnormal behavior in open interest caused by hedging demand should not be classified as an informed trading activity. Moreover we compute the realized gains from strategies using options by considering decrements in open interest as the number of options which are exercised. Our
methodology has some similarities to that of Poteshman (2006), such as using open interest to detect informed trading. However, there are also important differences concerning the data, method and aims. Poteshman (2006) focuses mainly on the airline sector and suspicious trading activities in the days leading up to the terrorist attacks of September 11th. We perform a more general analysis, considering different sectors and events. Moreover, we take into account the hedging demand in option transactions and exclude them from the set of suspicious trading activities. Our paper is also related to the literature which investigates the linkage and information flow between options and stock markets, such as Pan and Poteshman (2006), Lakonishok, Lee, Pearson, and Poteshman (2007), Easley, Kiefer, and O’Hara (1997), Easley and O’Hara (1987) and Easley, O’Hara, and Srinivas (1998). The majority of these articles take advantage of unique databases with publicly and non-publicly available information for open interest and volume of all CBOE traded options. We show empirically that daily increments in open interest and their interrelation with trading volume might have predictive power for future movements in the underlying stock even when less rich databases are used. Compared to papers dealing with illegal activities in the markets (see for example Meulbroek (1992), Bagliano, Favero, and Nicodano (2001) and Cheng and Leung (2008)), our databases do not report the identity of the trader and we cannot investigate this point. With our methodology we are able to detect several suspicious informed trades, but for further classification of legal and illegal as well as insider and non-insider trades, it would be necessary to obtain information about the trader’s identity as well as further analysis from competent agencies. Finally, our paper is related to the model of Bhuyan and Yan (2001) which forecasts the underlying stock value at maturity using their call and put option open interest based predictors. Bhuyan and Chaudhury (2001) and Srivastava (2005) make use of the same predictors and investigate whether the informational content of open interest can be used for trading purposes. In contrast to this model, our approach is more complete because we take into consideration the hedging dimension and recognize that abnormal behavior in open interest caused by hedging demand might contain limited new information, making their call and put based predictors less appealing. Finally, one relevant characteristic of our paper is the combined use of several databases including OptionMetrics, CRSP and TAQ.
3 Detecting informed trading activity

Daily increments in open interest play a major role in detecting informed trading activities in our method. It is likely that new information about the underlying security has been revealed/discovered whenever these increments are unusually high. If a large increment in put option open interest is based on privileged information, a potential crash in the underlying stock price is expected to occur subsequently, whereas the opposite scenario might arise when an unusually high increment in call options takes place. We separate these two scenarios and mainly concentrate on the analysis of put options and therefore on stock crashes.

We focus on informed trading activities in the options market which are described using three characteristics: a) aggressive trades in the options market \( (C_1) \), b) trades which are made a few days before the occurrence of a specific event and generate huge gains in the following days \( (C_2) \), and c) the positions are not hedged and not used for other hedging purposes \( (C_3) \). These three characteristics, \( C_i, i = 1, 2, 3 \), lead to the following method to detect informed trading activities: first we consider the daily increment in open interest and the corresponding volume in order to study the first characteristic, second we check the rate of return and dollar gains generated by these transactions in view of the second characteristic, and finally we analyze whether hedging demands were at the origin of the trades incorporating the last characteristic. Indeed trading in options which are delta-hedged using the underlying stock is not an informed trading activity.

Using a measure for the imbalance between newly issued puts and calls would allow for a simultaneous analysis of movements in the underlying stock in both directions: if one indirectly assumed that hedging and noise trading activities equally involve puts and calls, a strong increment in put options compared to the change in call options would reveal that the trading in put options was mainly undertaken by a third class of traders, informed/insider agents, who were in possession of privileged information. Poteshman (2006), Bhuyan and Yan (2001) and Crameri (2007) study the imbalance of puts and calls. The implementation of a put-call ratio-type statistic is straightforward but not considered in this project. In the following subsections, we introduce and discuss our three-criteria analysis.
3.1 The first criteria: Increments in open interest and volume

The first step in our analysis consists of computing the daily increments in open interest for puts: for every option available at day $t$ we compute the difference $\Delta OI_t := OI_t - OI_{t-1}$, where $OI_t$ is its open interest at day $t$. In the case that the option does not exist at time $t - 1$, we set its open interest for that day equal to zero. Since we are interested in abnormal transactions, we only consider the option with the highest increment in open interest:

$$X_t := \max_{k \in K} \Delta OI^k_t,$$

where $K$ is the set of all put options available at day $t$. The corresponding trading volume of the selected option is defined to be $V_t = Vol_t^{k^*}$, where $k^*$ corresponds to the selected option. In our approach, suspicious transactions are characterized by an unusual increment in open interest. Hence we focus on daily transactions for which the corresponding volume almost coincides with the increment in open interest. For that reason we compute $Z_t := |V_t - X_t|$ as an indicator 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 were created. In that case the originator of such transactions is not interested in short-term speculations, namely opening a position in the morning and closing it in the evening, but has reasons for keeping his position for a longer period waiting for the realization of future events.

This first dimension already allows us to classify daily transactions as potential candidates for informed trading activities. We compute the daily ex-ante probability $q_t$ as historical probability of observing larger increment $X_t$ in open interest and lower values of $Z_t$:

$$q_t := P[X \geq X_t, Z \leq Z_t]$$

$$= \frac{1}{N} \sum_{i=1}^{N} 1\{X_i \geq X_t, Z_i \leq Z_t\},$$

where $N$ represents the length of the estimating window, e.g. $N = 250$ days. By construction, low values of $q_t$ suggest that these transactions were unusual. For example when $q_t = 1/N$, it means

\footnote{Clearly we expect that $V_t \geq X_t$, but in our database we found a few cases for which this does not hold, the reason being some inconsistency in the reporting procedure of the data.}
that what occurred on day $t$ has no precedents in the previous year.

3.2 The second criteria: Realized gains and relative returns

We can go a step further in our analysis and consider a second dimension which takes into consideration the realized gains and relative returns from transactions with a lower ex-ante probability $q_t$. According to the first criteria, we have selected for every day $t$ that option with the highest increment in open interest. We compute its maximum return generated in the first two trading weeks after the transaction date:

$$R_t := \max_{j=1,...,10} \frac{P_{t+j} - P_t}{P_t},$$

where $P_t$ denotes the price of the selected option at day $t$. A high level of the statistic $R_t$ implies the arrival of an abnormal event. For the computation of realized gains, we consider the number of options exercised. This can be easily done using the daily decrements in open interest: whenever $\Delta OI_{t,k}^*$ (the increment in open interest of a specific option $k^*$) is negative, at least an amount of $|\Delta OI_{t,k}^*|$ options were exercised.\(^6\) In the following we omit the subscript $k$ and whenever we refer to a specific option we mean the one which was selected because of its highest increment in open interest. We consider for options with a particularly low ex-ante probability $q_t$ the corresponding open interest and follow its dynamic in the days after the suspicious transaction. We compute the related cumulative gains $G_{t,\tau_t}$ whenever a decrement happens:

$$G_{t,\tau_t} := - \sum_{t=\tau_t+1}^{\tau_t} \left[(K - S_{\tilde{t}})^+ - P_{\tilde{t}}\right] \cdot \Delta OI_{\tilde{t}} \cdot 1_{\left\{\Delta OI_{t}<0\right\}},$$

where $\tau_t$ is the horizon for which we have $t < \tau_t \leq T$, with $T$ being the maturity of the selected option. If the options were optimally exercised (i.e. when the underlying asset $S_{\tilde{t}}$ is in the stopping region), the payoff $(K - S_{\tilde{t}})^+$ clearly corresponds to the price of the option $P_{\tilde{t}}$. In principal one can compute the cumulative gains $G_{t,\tau_t}$ for every time $\tau_t \leq T$. This has however the disadvantage that $G_{t,\tau_t}$ might contain gains which are realized through the exercise of options which were issued before

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\(^6\)The creation of new positions, increment of open interest, and the exercise of already existing options, decrement in open interest, can of course off-set each other so that a constant level of open interest does not necessarily mean that any options were exercised. Based on our database, the only possible way of identifying the exercise of options is however to consider decrements in open interest, which can be seen as a lower bound for the effective number of exercised options.
time \( t \). Consider for example an option which exhibits an unusually high increment in open interest at time \( t \), say for example \( OI_{t-1} = 1000 \) and \( OI_t = 3000 \), resulting in \( X_t := OI_t - OI_{t-1} = 2000 \). If in the days following this transaction the level of open interest continuously decreases, and after \( h \) days reaches the level \( OI_{t+h} = 500 \), we might only consider the gains realized through exercise till time \( \tau_t \leq t + h \), where the stopping time \( \tau_t \) corresponds to that day where the negative sum of decrements in open interest in \([t+1, \tau_t]\) corresponds to the unusually high increment of \( X_t = 2000 \) observed at time \( t \). We therefore compute the stopping time \( \tau_t \) as follows:

\[
\tau_t^* := \arg \max_{l \in \{t+1, \ldots, T\}} \left\{ -\sum_{i=t+1}^{i} \Delta OI_i \cdot 1_{\{\Delta OI_i < 0\}} \leq X_t \right\} \tag{6}
\]

\[
\tau_t := \min(\tau_t^*, 30), \tag{7}
\]

giving the informed trader no more than 30 days to collect his gains. It is most likely that strictly inequality will hold in the curly brackets, meaning that the negative sum of decrements till time \( \tau_t \) will not exactly coincide with the observed increment \( X_t \), but will be slightly smaller. If this is the case, we add to \( G_t, \tau_t \) the gains realized through the fraction of the next decrement in open interest, such that the negative sum of all decrements considered (exercised options) sum up exactly to the increment \( X_t \). We define the total realized gain through the exercise of the option which exhibited the highest increment \( X_t \) at time \( t \) by \( G_t \). Based on the time series of \( G_t \), we can decide whether the options with a low ex-ante probability \( q_t \) generate a gain through exercise or not.

We have introduced a new component \( R_t \) in order to compute the ex-post probability \( p_t \) in a similar way:

\[
p_t := P[X \geq X_t, Z \leq Z_t, R \geq R_t] \tag{8}
\]

\[
= \frac{1}{N} \sum_{i=1}^{N} 1\{X_i \geq X_t, Z_i \leq Z_t, R_i \geq R_t\}. \tag{9}
\]

By construction \( p_t \leq q_t \) for all days \( t \). The higher the number of variables introduced in the joint probabilities the lower the empirical probability and more suspicious every single transaction would appear. Therefore using the ex-post probability \( p_t \) as selection criteria for suspicious transactions

\[\text{Doing so we implicitly assume that the newly issued options which caused the unusual increment } X_t \text{ in open interest are the first ones to be exercised. We believe that this might be a reasonable strategy adopted by an informed trader. If this does not hold, one can consider our } G_t \text{ as being a lower bound for the realized gains, since we assume that an informed trader knows the optimal time to exercise its options.}\]
might not be appropriate. We will consider the $1 - p_t$ as proxies for the probability of informed trading. Furthermore, an option can generate a profit when exercised or sold on the market. Computing the related gains based on the seller-initiated volume of put options could be a more accurate measure than simply looking at the number of exercised options as we do. This analysis relies however on a detailed database which contains information about the trade types (seller- or buyer-initiated). This is unfortunately not easily available. To avoid this problem one could approximately separate the total volume into buyer- and seller-initiated using high frequency data and relying on the Lee and Ready (1991). High frequency data for options are however not at our disposal.

3.3 The third criteria: Hedging demand using the underlying asset

Option trades for which the first two dimensions show abnormal behavior, cannot be immediately classified as informed trading: it can 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 a delicate step to assess whether a transaction with high increment in open interest and a large gain was hedged or not. For example, assume that a trader buys a large number of stock and hedges his exposure to stock price fluctuations by simply buying the suitable amount of put options. Using the first two dimensions of our methodology, such a transaction would be classified as suspicious whenever the underlying stock drops and the investor exercises his put options in order to cover the losses. In this case, the two criteria would suggest that the trading activities of the investor are suspicious. Another misclassification using the first two dimensions would occur in the symmetric situation when the investor buys a large amount of put options and delta hedges his position by buying the suitable amount of the underlying stock. Therefore, whenever a large trade in put options occurs, the natural step to take in order to avoid misclassification is to check whether an unusually high buyer-initiated transaction in the underlying stock took place on the same day. We estimate the distribution of the daily amount of shares bought for non-hedging purposes and compare it to the total number of buyer-initiated transactions in the underlying stock for a specific day. Higher quantiles of the latter with respect to the estimated distribution indicates that a component of the observed buyer-initiated volume in the underlying stock is due to
hedging purposes, implying a non-negligible hedging demand. In the opposite case we conclude that the new options were naked and therefore suspicious. One can argue that the day on which stocks and options were bought must not be the same. Based on our database a more precise analysis is however not possible and we assume therefore that whenever someone buys a large amount of stock, he hedges his exposure to market risk immediately by buying the corresponding number of put options. In addition, based on our databases an analysis of the hedging dimension at the level of single option is not possible. We therefore perform this analysis on an aggregate basis and test whether hedging takes place at day $t$ or not.

In what follows we explain how we implement these ideas. A main obstacle to successfully and efficiently obtaining the identification of naked option positions, is the lack of detailed information in standard available databases such as OptionMetrics. When looking at the trading volume in the underlying stock, three classes of investors can be considered at its origin: hedging-, noise- and informed traders. The goal is to measure the amount of stock bought at time $t$ by the last class of traders. The first step is to separate the total volume of the underlying stock into its two components, buyer- and seller-initiated, $V_t^{sell}$, $V_t^{buy}$ Whenever a large number of put options is traded and no corresponding action is observable in the underlying stock, we conclude that these positions are not hedged. Several obstacles are faced in arriving at this conclusion: first, since our database does not contain information regarding whether a trade is buyer- or seller-initiated, we determine the direction of the trade using the Lee and Ready (1991) algorithm. This 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 trade is excluded. The first trades of the day are omitted if they are not preceded by a quote. Second, trading volume in the underlying stock for delta-hedging options is a tiny component of the total volume. It is therefore

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8Using the TAQ and OptionMetrics databases, we checked whether $V_t^{sell} + V_t^{buy} \approx V_t$, which is achieved within reasonable terms ($V_t^{sell}$ and $V_t^{buy}$ is computed using TAQ, whereas $V_t$ is taken from OptionMetrics). Discrepancies can be due to reporting errors or the impossibility of determining the trade direction.

9Instead of excluding the trade after the first tentative, one could apply the above algorithm successively to several lags to determine in this context whether a trade was buyer- or seller-initiated.
virtually impossible to identify the exact amount. We try to overcome this problem by using the standard theory of delta-hedging and proceed in the following way: first, we decompose the daily buy-volume in the stock into its three components:

\[ V_{t}^{\text{buy}} = V_{t}^{\text{buy,hdg}} + V_{t}^{\text{buy,inf}} + V_{t}^{\text{buy,noise}}. \]

where \( V_{t}^{\text{buy,hdg}} \) represents the volume for hedging purposes in options positions, \( V_{t}^{\text{buy,inf}} \) is the volume traded by informed traders and \( V_{t}^{\text{buy,noise}} \) by noise traders. Since very sophisticated databases would be required to separately identify the last two volumes, we collect them together and call them \( V_{t}^{\text{buy,non-hdg}} \).

Using the corresponding options deltas \( \Delta_{t}^{P} \) and \( \Delta_{t}^{C} \), for every option \( k \) traded on day \( t \), we compute:

\[
\alpha_{t} := \sum_{k=1}^{K} |O_{t}^{P,k} - O_{t-1}^{P,k}| \cdot |\Delta_{t}^{P,k}|, \quad \gamma_{t} := \sum_{k=1}^{K} |O_{t}^{C} - O_{t-1}^{C}| \cdot \Delta_{t}^{C},
\]

\[
\beta_{t} := \sum_{k=1}^{K} ||\Delta_{t}^{P,k}| - |\Delta_{t-1}^{P,k}|| \cdot O_{t}^{P,k}, \quad \delta_{t} := \sum_{k=1}^{K} |\Delta_{t}^{C,k} - \Delta_{t-1}^{C,k}| \cdot O_{t}^{C,k}.
\]

The \( \alpha_{t} \) and \( \gamma_{t} \) represent the theoretical number of shares to buy for hedging the new options issued at time \( t \), whereas \( \beta_{t} \) and \( \delta_{t} \) are the theoretical number of shares to buy to rebalance the hedged portfolio of the existing options at time \( t \). The total amount of stock to buy at time \( t \) for hedging purposes, \( V_{t}^{\text{buy,hdg-th}} \), is

\[
V_{t}^{\text{buy,hdg-th}} := \alpha_{t} + \beta_{t} + \gamma_{t} + \delta_{t}.
\]

We use \( V_{t}^{\text{buy,hdg-th}} \) as an approximation for the true, unobservable number of shares bought for hedging purposes. If the first two dimensions do not show any suspicious trade at day \( t \), we assume that this was the case and conclude that \( V_{t}^{\text{buy,hdg-th}} \) provides the number of shares bought for hedging purposes, i.e. \( V_{t}^{\text{buy,hdg}} \). Then we approximate the amount of stock bought for non-hedging purposes (noise- and informed traders) as

\[
V_{t}^{\text{buy,non-hdg}} := V_{t}^{\text{buy}} - V_{t}^{\text{buy,hdg-th}}.
\]
We estimate the conditional distribution of $V_{t}^{\text{buy,non-hdg}}$ using the adjusted Nadaraja-Watson estimator. We use the bootstrap method proposed by Hall, Wolff, and Yao (1999) and adopted in Tay and Ting (2006):

$$
\tilde{F}(y|x)_{NW} = \frac{\sum_{t=1}^{T} \mathbf{1}\{Y_t \leq y\} w_t(x) K_H(X_t - x)}{\sum_{t=1}^{T} w_t(x) K_H(X_t - x)}
$$

(13)

with $Y_t := V_{t}^{\text{buy,non-hdg}}$, $X_t := (|r_t|, V_{t-1}^{\text{buy,non-hdg}})$, $K_H(.)$ being a multivariate kernel with bandwidth matrix $H$, $w_t(x)$ the weighting function (see Hall, Wolff, and Yao (1999)), and $r_t$ is the stock return at day $t$.

Now we can test the hypothesis $H_0$ that hedging does not take place at day $t$. Whenever the observed $V_{t}^{\text{buy}}$ is large enough compared to the effective (but unknown) amount of stock bought for non-hedging reasons, we conclude that a fraction of $V_{t}^{\text{buy}}$ must have been bought for hedging purposes.

Formally, we reject $H_0$ at day $t$ when

$$V_{t}^{\text{buy}} > q_{0.95}^{V_{t}^{\text{buy,non-hdg}}},$$

where $q_{0.95}^{V_{t}^{\text{buy,non-hdg}}}$ describes the 0.95-quantile of $V_{t}^{\text{buy,non-hdg}}$ estimated over the last 2 years.

### 3.4 Selection criteria

To detect informed trading activities we combine the three criteria introduced in the previous sections. We use two methods: the first one is based only on ex-ante information (variation in open interest and the possible absence of hedging) whereas the second one also makes use of the additional information available on the days after the transaction, i.e. the return and the profit generated by the investment. The first method aims at detecting suspicious transactions as soon as they take place. Based on the information available at time $t$, the question is whether a transaction can be classified as an informed trade or not. A transaction can be considered suspicious when the probability $q_t$ is sufficiently low and the hypothesis of non-hedging cannot be rejected. The second method aims at identifying suspicious transactions by making use of information available
in the weeks preceding and following a particular transaction. An informed trader with superior information can enter the market a few days before a certain event and realize the gains by either selling or exercising the options within the following days. To detect such kind of activity we propose using a two-step criteria. In what follows we denote by \( k_t \) the detected transaction which takes place at day \( t \). The main role in this procedure is played by the following four sets of events:

1. **Ex-ante selection** \((C_1, C_3)\):
   
   (a) \( \Omega_1 := \{k_t | q_t \leq 5\%\} \)
   
   (b) \( \Omega_2 := \{k_t | H_0 \text{ not rejected at day } t\} \)

2. **Ex-post selection** \((C_2)\):
   
   (a) \( \Omega_3 := \{k_t | r_{t}^{\text{max}} \geq q_{90\%}^{\text{max}}\} \)
   
   (b) \( \Omega_4 := \{k_t | G_t \geq q_{98\%}^{G_t}\} \),

where empirical quantiles are computed using the last two years of data. Transactions \( k_t \in \Omega_1 \cap \Omega_2 \cap \Omega_3 \cap \Omega_4 \) are considered in the set of potential informed trading activities. This concludes our procedure of detection.

4 Empirical results

In this section our methodology is applied to three sectors whose companies have options traded on the CBOE: airline (AMR, UAL, DAL, BA and KLM), banking (BAC, C, JPM, MER and MWD) and a third group (ATT, KO, HPQ and MO). For European companies (Swiss Re, Munich Re and EADS) we give a preliminary (and due to the lack of high frequency data, incomplete) analysis at the end of this section. In total 37 transactions on the CBOE have been identified as belonging to the set \( \Omega_1 \cap \Omega_2 \cap \Omega_3 \cap \Omega_4 \). Nearly all the events can be assigned to one of the following three event categories: M&A announcements, 6 events; quarterly financial/earnings related statements, 14 events and the terrorist attacks of September 11th, 13 events. 4 transactions could not be identified. Several conclusions can be extracted from Table[1] The fraction of events assigned to a specific sector varies. We find that more than 50% of the selected transactions for the airline sector (8 out of 15) can be
traced back to the terrorist attacks of 9/11. Companies like American Airlines, United Airlines, Boeing and to a lesser extent Delta Air Lines and KLM seem to have been favorite targets for informed trading activities in the period leading up to the attacks. Conclusions for Delta and KLM are indeed less obvious due to the relatively small gains realized. In the airline sector, the number of new put options issued during that period is unusually high and the total gains $G_t$ realized by exercising these options are impressive, more than $16 million. Four suspicious transactions around M&A announcements are detected in the airline sector. These contain large trades in put options and an unusually high increment in open interest in underlying stock of American Airlines and United Airlines on May 10th and 11th, 2000, two weeks before UAL’s acquisition of US Airways was announced (for more details see footnote 1), and abnormal put transactions in underlying Delta Air Lines stock a few weeks before a public announcement on January 21th, 2003 related to the planned alliance between Delta, Northwest and Continental. In both events, the underlying assets were strongly affected by the public announcements, generating huge gains through the subsequent exercise of these put options, $3 million in the first case and $1 million in the second one. Three transactions detected in the airline sector are related to quarterly financial/earnings related statements. In the banking sector we detected 14 informed trading activities, 6 belonging to the category of quarterly financial/earnings related announcements, 5 to the terrorist attacks of September 11th, and 3 which are unidentifiable. We found that the number of new put options with underlying stock in Bank of America, Citigroup, JP Morgan and Merrill Lynch issued in the days before the terrorist attacks was at an unusually high level. The realized gains $G_t$ from such trading strategies are huge, around $11 million. The last class of companies we analyze includes AT&T, Coca Cola, Hewlett Packard and Philip Morris. We suspect two informed trades in the pre-announcement period of the M&A deal between Coca Cola and Procter&Gamble announced on February 21th, 2001 (leading to gains of more than $2 million), and 5 transactions preceding the publication of quarterly financial/earnings statements. Information related to earnings shortfalls, unexpected drops in sales and production scale backs are the most common in this last category. This last category contains three informed trades in put options with underlying Philip Morris stock. These took place a few days before three separate legal cases against the company seeking
a total amount of more than $50 million (in damages) for smokers’ deaths and inoperable lung cancer. The realized gains amounted to more than $10 million. One trade could not be identified.

From a rational point of view, none of the companies belonging to this last sector should have been affected by an event like the terrorist attacks of September 11th. Indeed, using our methodology, we do not detect any informed activities in the period leading up to the attacks.

For every sector we report two tables which contain our findings: for the airline sector these are Tables 2 and 3; for the banking sector Tables 4 and 5; and for the last group Tables 6 and 7. Tables 2, 4 and 6 show a quantitative analysis of the suspicious events $k_t \in \Omega_1 \cap \Omega_3 \cap \Omega_4$. These contain the day on which the transaction took place ($Day$); identification number ($Id$) of the put options; the moneyness ($:= S_t/K$); its time-to-maturity ($\tau$); the level of open interest the day before the suspicious transaction ($OI_{t-1}$); the increment in open interest from day $t-1$ to day $t$ ($\Delta OI_t$); its quantile with respect to its empirical probability computed over the last two years ($q^\Delta OI_t$); the 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, $\Delta OI_{t,\text{tot}}$); the corresponding volume ($Vol_t$); the maximum return realized by the selected option in a two-week period following the transaction day ($r_t^{\text{max}}$); the number of days between transaction day $t$ and when this maximum return occurs ($\tau_2$); the gains realized through the exercise of the new option issued at time $t$ ($G_t$); the minimum between the number of days (starting from the transaction day) needed for the exercise of $\Delta OI_t$ and 30 days ($\tau_3$); the percentage of $\Delta OI_t$ exercised within the first 30 days after the transaction; the ex-ante probability ($q_t$); the p-value of the hypothesis that hedging does not take place at time $t$ and finally our proxy for the probability of informed trading ($1-p_t$). Tables 3, 5 and 7 have a more descriptive nature and report the following information for the selected events: the day on which the transaction took place ($Day$); the market condition at day $t$ measured by the average return of the underlying stock during the last two trading weeks ($\text{Market condition}$); the minimum return of the underlying stock in a two-week period following the transaction day ($\text{Return}$, comparable therefore with $r_t^{\text{max}}$ of the previous tables) and a short description of the event and why the stock dropped ($\text{Event’s description}$). In most of the cases this drop in the underlying stock is large enough that its cause is reported in the financial press such as the business section of the New York
Times. We could not identify the cause of a few events when the movements in the underlying stock were not significant (interestingly in several of these cases the hypothesis of no-hedging can be rejected at a 5% confidence level). For transactions whose days are marked with asterisks the hypothesis of no-hedging can be rejected at a 5%-level (see p-value reported on the last column of the corresponding tables).

Suspicious transactions in the days leading up to quarterly financial statements might be less surprising because the event’s day is known in advance. By definition, informed investors have either actively followed and analyzed the company’s performance or are in possession of superior information. Based on this knowledge they might therefore correctly guess the content of quarterly financial statements and develop profitable trading strategies. By contrast, the detected unusual activities in the options market before the terrorist attacks of September 11th and M&A public announcements deserve more attention. In what follows we concentrate therefore on these specific events. We analyze two cases in detail, the event of September 11th, 2001 and the transactions of May 10th and 11th, 2000 which involve AMR and UAL. For the remaining selected trades one can do a similar analysis and draw similar conclusions. Figures and tables regarding the latter ones are available from the authors upon request.

In some cases, we are not able to identify the event, mainly because the drop in the underlying stock was not large enough to be reported in the financial press. This is not inconsistent with the fact that the selected options generated impressive gains: because of the leverage effect and the strong increment in open interest, an impressive gain $G_t$ can be achieved (by construction) basically via two ways: because of a significant crash in the underlying stock and the exercise of a large number of options, or simply because a large amount of put options were exercised even if the drop in the underlying asset was relatively small. In this case it is difficult (or maybe even not possible) to assign a specific event’s description for such a day and we simply report the note "not identified".

4.1 The case of September 11th

The days leading up to the terrorist attacks of September 11th emerge in the analysis presented in the previous sections, in particular when considering the airline sector, the sector which was probably most concerned by such an event. All five companies show some anomalies in the options
market during the time frame from August 29th through September 10th, 2001.

The attacks have generated a flood of articles, in which political, strategic and economic aspects have been considered. The financial dimensions have also been studied 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 seem to dismiss charges against possible informed traders. Indeed, 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.” In Europe, the tone is the same. According to the FSA in England, “The investigations did not reveal any matters requiring further investigations.” Concerning the CONSOB in Italy, similar conclusions were obtained: “The transactions specified in the replies were basically normal, especially in view of the combination of falling prices (even before September 11th) and very high volatility. The nature of transactions and gains did not appear to justify further investigations.” From an academic point of view, this topic did not generate much research interest. The article of Poteshman (2006) is a notable exception (see section 2). Focused mainly on the airline sector, he 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 claims 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 having traded in the options market in advance of the attack”.

4.1.1 Analysis based on CBOE data

Several transactions in different companies satisfy our conditions defining informed trading activity: five airlines (AMR, UAL, DAL, BA and KLM) and four banks (BAC, C, JPM and MER).

Concerning the airline sector, AMR and UAL are the two companies whose planes were hi-

jacked and crashed by the terrorists, whereas BA was subject to impressive losses due to obvious implications such an event caused in the airline sector\textsuperscript{11}. The result for KLM might be surprising, but supports the suspicion of “insider trading in KLM shares before September 11th attacks”, reporting the conclusions of a Dutch government investigation (Associated Press Worldstream). The terrorist attacks had indirect implications for DAL, like a potential decrease in the number of passengers. Based on our methodology, American Airlines, United Airlines and Boeing show stronger evidence of informed trading than the remaining airlines. With respect to the banking sector, some interesting facts must be mentioned: Merrill Lynch was located in the World Financial Center, near the World Trade Center (WTC), Bank of America in the North Tower of the WTC and JPM in Building 5 of the WTC. The Travelers Insurance Unit of Citigroup was expected to pay $500 million in claims. Whereas the negative impact of the terrorist attacks on the airline and banking sector is obvious, from a rational point of view none of the companies belonging to the third group (namely AT&T, Coca-Cola, Hewlett Packard and Philip Morris) should have been affected by such an event. Indeed, using our methodology we do not detect any suspicious transactions in the period leading up to September 11th. This result not only confirms our intuition, but shows that our detection procedure is accurate and not distorted by global market conditions: in fact, during the weeks leading up to the terrorist attacks, the market was in decline. One could argue therefore that the unusual number of new put options was mainly issued because of market conditions at that time and not because of the possession of privileged information. The analysis of this third group shows however that our methodology is able to disentangle these two aspects and supports our findings that several transactions in the days before 9/11 are suspicious and not a natural reaction to market conditions.

In the case of American Airlines we will now report the details of the transaction which took place on September 10th. Additional tables and interpretations are available upon request from the authors. From Figures\textsuperscript{1,2} and \textsuperscript{3} several results can be extracted. The upper graphs in Figure\textsuperscript{1} show the plot of $V_t$ (the option volume) versus $X_t$ (its increment in open interest) and the selected days\textsuperscript{11} Bin Laden said that he learned the timing of attacks in Afghanistan on September 4th, Bumiller and Miller (2001). When considering transactions which took place only in September, the case of DAL would appear less suspicious, since the abnormal increment in open interest occurred on August, 29th. In addition to this, the gains realized for DAL are not comparable with the ones found for AMR and UAL.
are highlighted with the circles. The left graph covers the period from January 1997 to December 2001, and the right one from January 1997 to January 2006. We have plotted the first period in a separate figure in order to account for the impact of the internet bubble on the options market. By definition, the selected transactions are located along the diagonal. They are isolated from the remaining points. The transaction which took place on September 10th clearly does not belong to these points. For September 2001 and May 2000 Figures 2 and 3 show the dynamic of three variables: open interest, volume and the option return. As claimed in several newspapers, the volume and open interest of puts had been unusually high in the days leading up to September 11th: 1,535 put contracts were traded on the CBOE on September 10th (first high blue bar) whereas the behavior of open interest from September 7th until September 10th shows a drastic increment of 1,312 (99.5% quantile, blue line in Figure 2). 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 clearly generated an unusually high return (458% in one week). An impressive decrement in put contracts took place immediately after the attacks, when the option return exploded (blue and red lines in Figure 2). On September 17th, open interest shows a decrement of 597 contracts (first drop in the blue line in Figure 2), meaning that at least 597 put options were exercised. A few days later, another considerable number of put options were exercised (475 contracts, second drop in the blue line in Figure 2). These options generated huge gains. We computed the related net gains of such a trade and report them in table 2 (G_t). Regarding the transaction of AMR which took place on September 10th, the related net gains are impressive: one trading day after the transaction, on September 17th, the exercise of 597 put options lead to a net gain of almost $600,000. The large increment in open interest which took place on September 10th (∆OI_{10, Sep, 01} = 1,312), was set by a gradual exercising of those options in the days after the terrorist attacks. Twenty-six days later the sum of exercised options corresponded to the increment observed on September 10th and lead to a cumulative gains of more than one million (G_t = 1,179,171). The lower graph in Figure
shows the cumulative gain for all transactions selected using the three criteria. The trade in put options of AMR which took place on September 10th is represented by the light blue line and corresponds therefore to the transaction that leads to the highest gains in the shortest time interval in the period we are considering. As already mentioned, due to the lack of detailed information in our database, it is virtually impossible to identify the exact gains realized by selling options. Such trades are however reflected in the option’s trading volume, represented in Figure 2 by the blue bars. Following the trading volume after September 17th, it does not seem that an unusually high volume of put options were exchanged. We might therefore conclude that the main component of the total gains was realized through exercise. Similar conclusions can be reached for the other companies selected using our procedure. High increment in open interest a few days before the terrorist attacks and a sequential exercise of these options in the days afterwards, lead to unusual and impressively high gains. For example two trading days before the terrorist attacks a large number of new put options on Boeing were issued (4,179, 98.5% quantile). 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 already exercised leading to gains of more than five million; for Bank of America, an unusually high increment of 3,380 (96.3% quantile) in open interest 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), and a sequential exercise of those options in the following 7 days resulting in net gains of almost two million; for Merrill Lynch, one day before the attacks, on September 10th, 5,615 (99.1% quantile) new put options 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 6 days later these had already been exercised leading to gains of around $4.5 million. For the remaining companies same conclusions can be found in the reported tables. Based on Tables 2 and 4 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 almost every case the hypothesis of no-hedging cannot be rejected. This third criteria supports

\[ In the research article "Not much stock in put conspiracy: the attacks on New York City and Washington have led to a new urban legend, namely that inside traders used put options on airline stocks to line terrorist pockets" published on June 3th, 2002 by Kelly Patricia O’Meara (see http://findarticles.com/p/articles), other repeated spikes in put options on American Airlines and United Airlines during the year before September 11th are highlighted and \]
therefore our findings.

4.1.2 Analysis based on EUREX data

Several companies in the reinsurance business were expected to suffer severe losses from the terrorist attacks of September 11th. Liabilities for Germany’s Munich Re and Switzerland’s Swiss Re—the world’s two biggest reinsurers—and France’s AXA Group 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 three companies were at unusual levels in the days leading up to September 11th, divulging some rumors of informed trading activities. Any extensive 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 Terminbrse (DTB, the German derivatives exchange) and SOFFEX (Swiss Options and Financial Futures). Options on AXA are predominantly exchanged on the Euronext, a pan-European stock and derivatives exchange based in Paris with subsidiaries in Belgium, France, the Netherlands, Portugal and the United Kingdom. In this subsection we use the EUREX-database provided by Deutsche Bank to analyze transactions in put options with underlying Swiss Re and Munich Re. This database contains the usual variables like daily trading volume and open interest and allows us to perform the detection analysis we introduced in the previous sections with the exception of the hedging dimension which requires high frequency data. At this time we do not have empirical data from the Euronext in order to study AXA. This analysis might be done at a later point. Tables and figures for the following analysis are available upon request from the authors.

In the case of Munich Re, we found 4 transactions in time period from 1999 until 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 suspicious transactions surrounding the terrorist attacks in this subsection, we only used as argument that what occurred in the days leading up to 9/11 was not as unusual as other theories claim. Using our methodology however, we do not select any of those spikes because of the relatively small gains. This shows that when applying a more detailed and diversified analysis to historical data, transactions in AMR and UAL in the week before the terrorist attacks have in fact to be considered unusual and suspicious.
discuss the details of this transactions and ignore the other three transactions (these 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 an abnormal increment in open interest of 996 contracts (92.2% quantile of its historical distribution over the last trading year) on August 30th. Its price on this 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 lost more than 15% in one day (the closing price on September 10th was €261.88 and on September 11th €220.53) and the option price exploded to €89.56, corresponding to a return of 776% in 8 (trading) days. Interestingly, on September 12th, 1350 put options with the same characteristics were exercised. The gains $G_t$ related to the exercise of the 996 new put options issued on August 30th correspond to more than €3.4 million.

In the case of Swiss Re, we found 6 transactions in the time period from 1999 until 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, namely on August 20th. This option expired at the end of September, 2001, had a strike of €159.70 and showed an unusual increment in open interest of 3302 contracts (99.8% quantile) on August 20th. The Swiss Re closing share price was €166.83 on August 30th. That option was traded at €0.8 on the transaction day and exhibits an ex-ante probability $q_t$ of 0.4%, meaning that such an event happens on average once every year. On September 11th, when the stock price fell from €152.62 to €126.18, the option generated an impressive return of 4050% in three (trading) weeks, when its price exploded to €33.2. Through the subsequent exercise of these new 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 simply by using two options with underlying Munich Re and Swiss Re.

In the case of Swiss Re, we found two other abnormal transactions which belong to the set $\Omega_1 \cap \Omega_3$, one on August 29th and the second one on September 5th (with strikes €160 and €170, respectively, and stock prices €165.34 and €159.6 respectively). The first selected option matured at the end of October, 2001 and exhibits an increment in open interest of 1020 contracts (96.6% quantile). That
option was traded at €4.40 on August 29th and at €33.64 the day of the attacks. The increment in option price corresponds to a return of 665% in 9 (trading) days. Its ex-ante probability $q_t$ is 0.8%. The second option, traded on September 5th, matured in December, 2002 and exhibits an increment in open interest of 1000 contracts (94.3% quantile). Its price on September 5th was €21.37 and €48.63 on September 11th, generating a return of 128% within five days. Its ex-ante probability $q_t$ is 2%. Neither transaction belongs to the set $\Omega_4$, since no significant decrements in open interest are observable in the days after the terrorist attacks. By construction the related gains $G_t$ are therefore small, excluding these transactions from the set $\Omega_{13}$. Tables and figures are available upon request from the authors.

4.2 The case of May 2000

Other suspicious trades that we are able to detect using our methodology took place on May 10th and 11th, 2000. They involved AMR and UAL. Indeed, both companies showed some unusually high increments in open interest on these days. On May 10th and 11th, the number of new options issued with strike $35 and maturity June 2000 with underlying AMR is very large: 3,374 (99.7% quantile) on May 10th and 5,720 (99.9% quantile) the day after. These transactions correspond to those which exhibit the strongest increments in open interest during a span of five years, as displayed in the upper left graph in Figure 1. In Figure 3 this abnormal increment in open interest is again displayed by the blue line. On May 10th, the underlying stock had a value of $35.50 and the selected put was traded at $2.25. The same holds for UAL: 2505 (98.7% quantile) new put options 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 do not show any particularity: 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 are May 24th and May 25th, 2000, with the first day corresponding to the public announcement of United Airline’s proposed $4.3 billion acquisition of US Airways. As reported in the May 25, 2000
edition of the New York Times, “shares of UAL and those of its main rivals crashed.” (for more
details see footnote 4). The stock price of AMR dropped to $27.125 (-23.59% of value losses when
compared to the stock price when the transaction in puts was made) increasing the value of the
put options to $7.875 (resulting in a return of 250% in 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 $12.625 (corresponding to a return of
140.5% in two trading weeks). In the case of AMR, the decline in the underlying stock can be seen
in Figure 3 where the option’s return dramatically increased. Interestingly, the day of the public
announcement corresponds to the day in which 4,735 put options of AMR were exercised (drop in
the blue line in Figure 3). After this large decrement in open interest, 1,494 and 1,376 additional
put options were exercised in the following two days respectively (again described by additional
drastic drops in the blue line in Figure 3). The unusual increments in open interest observed on
May 10th and May 11th are therefore immediately offset by a sequential exercise of options when
the underlying crashed. The corresponding gains $G_t$ from this strategy are impressive, more than
$1.6 million within two trading weeks. These are graphically shown in the lower graph in Figure 4
from which we can see how fast these gains were realized. This is in line with the impressive and
subsequent decrements discussed before. In the case of UAL similar conclusions can be reached.
See tables 2 and 3 for more details. 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. Even in this case,
the third criteria based on the no-hedging hypothesis supports our findings, namely that suspicious
trades are naked option positions.

4.3 Other events

In most of the remaining events, it is possible to give a similar analysis. For details one can consult
Tables 6, 5 and 7. Due to space concerns, this analysis has been omitted, but is available from the
authors upon request. The key variables are the increments in open interest ($\Delta OI_t$ and their size
relative to other transactions, $q_t^{\Delta OI}$), the resulting gains ($G_t$) and the time needed to exercise the
abnormal increment in put options and lead to gains $G_t$ ($\tau_3$). Strategies similar to those preceding
the events of September 11th and May 2000 occur several times: an unusually high number of new
put options is issued, a drop in the underlying stock follows which increases the value of the option and considerable gains are realized through the sequential exercise of those new options.

4.4 May 2006: the case of EADS

European Aeronautic Defence and Space (EADS), a large European aerospace corporation and the parent of plane maker Airbus, is believed to be one of the prime examples of companies targeted by illegal insider trading activities of the last decade. On June 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 six months. Forgeard was one of a number of executives who sold his stake in EADS a few months before the public announcement allowing him to partially escape the June losses when 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 still 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.

Based on reports in the financial press, French authorities’ investigations have concentrated thus far on the questionable stock sales and stock options exercised before the announcement day. Apparently, trading strategies based on put options were ignored, despite their appealing features for investors in possession of privileged information. We apply our methodology to the case of EADS in order to check whether abnormal transactions took place on the EUREX. In what follows we provide statistical evidence of unusual activities using put options with underlying EADS in the period leading up to the announcement day. From a legal point of view this study does not constitute proof per se of such activities. Legal proof would require trader identity and their motivations, information which is not contained in our database.

The results of this analysis are impressive: For the period 2003-2009 our procedure detects six

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abnormal transactions in put options (belonging to the set $\Omega_1 \cap \Omega_3 \cap \Omega_4$), all of which took place during the time period from April 6th, 2006 until May 19th, 2006. Four of these six options had a maturity of end of June 2006, the remaining two end of May 2006 and end of July 2006. The four options maturing in June 2006 exhibited unusual increments in open interest on April 7th (3855 contracts, 99.8% quantile), on April 20th (1000 contracts, 93.4% quantile), on May 8th (810 contracts, 92.2% quantile) and on May 18th (2518 contracts, 99% quantile). These options had strikes of €32, €30, €30 and €31 and the underlying traded at €31.88, €31.3, €31.36 and €27.59 respectively on the transaction days. The maximum returns generated from these trades are huge: for example, the option selected on May 8th traded at €0.71 on that day and on June 14th its price increased to €11.27 when the stock crashed. This corresponds to a return of 1487% within five trading weeks. On the announcement day 760 contracts of that option were exercised, generating a net profit of €802,560. The option with an unusual increment in open interest on May 18th, traded at €3.46 on that day and at €12.27 on June 14th, resulting in a return of 255% within four trading weeks. On June 16th 2667 contracts were exercised. If we assume that the 2518 options issued on May 18th were exercised on that day, we reach a net gain of €1.7 million. The option with an unusual increment in open interest on May 19th and maturity end of July was bought for €0.71 on that day and had a strike of €26 when the underlying traded at €27.39. On the announcement day its value increased to €7.27, corresponding to a net return of 924% within four trading weeks. After the announcement day, this option was subsequently exercised and generated a net gain of almost €1.5 million. Similar conclusions can be drawn for the option traded on April 7th (strike €32 and underlying value €31.88): the unusual increment of 3855 contracts generated total gains of almost €1.7 million. For the remaining options, the same analysis can be made.

For a graphical visualization of the realized gains one can use Figure 5. Figures 6 and 7 show the dynamic of several variables for the transactions which took place on April 20th and May 19th. For additional information see Table 8. Based on the six detected transactions, a total gain of €7.3

\[15\] 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 announcement day. This was planned to take place 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.
million had been realized within the first 60 (trading) days after the announcement. If we consider their gains till maturity (all before August 2006) and take into account all exercised contracts for these selected options (not only those created on the days with unusually high increments) we estimate a net profit of approximately €12.7 million.

4.5 Robustness checks

The input parameters arbitrarily chosen in our detection procedure are: the length \( N \) of the estimating window, used for the computation of the ex-ante probability \( q_t \), the conditional distribution of \( V_t^{buy,non-hed} \), the quantiles \( q_{\alpha}^{max} \) and \( q_{\alpha'}^{G_t} \), previously chosen to be \( N = 500 \) trading days; the time period after the transaction day used for the computation of \( R_t \), chosen to be 10 trading days; the time frame we took for computing the stopping time \( \tau_t \) used for the calculation of the gains \( G_t \), originally chosen to be 30 trading days; the quantile levels \((\alpha, \alpha')\) in \( q_{\alpha}^{max} \) and \( q_{\alpha'}^{G_t} \) used for the computation of the sets \( \Omega_3 \) and \( \Omega_4 \), originally chosen to be 90% and 98%; the probability level \( \alpha \) based on which we select trades belonging to the set \( \Omega_1 \), chosen to be 5% in our selection procedure.

In what follows we explain how the number of detected trades changes when the input parameters

\[\text{As reported in table 8, the difference between the total increment in open interest (}\Delta OI_{tot}^t\text{) and the one in the selected option (}\Delta OI_t\text{) can be quite large: for the transaction of April 6th for example, the increment we considered in our analysis (2518 contracts) is about half of the total increment observed on that day (4988 contracts). For that reason, we computed the second largest increment in open interest (}\Delta OI_{second}^t\text{) and analyzed its contribution to the difference }\Delta OI_{tot}^t - \Delta OI_t. \text{ For the transaction on April 6th, we found }\Delta OI_{second}^t = 1750 \text{ contracts (}\Delta OI_{tot}^t - \Delta OI_t = 2470\text{), on April 7th }\Delta OI_{second}^t = 2300 \text{ contracts (}\Delta OI_{tot}^t - \Delta OI_t = 2808\text{), on April 20th }\Delta OI_{second}^t = 495 \text{ contracts (}\Delta OI_{tot}^t - \Delta OI_t = 545\text{) and on May 8th }\Delta OI_{second}^t = 560 \text{ contracts (}\Delta OI_{tot}^t - \Delta OI_t = 1110\text{). In these cases the contribution of the option with the second highest increment is significant. For the remaining two options this was not the case. For the first four transactions, we analyzed the dynamic of their open interest in order to check whether the exercise of these options lead to considerable gains which could be added to the ones computed in our analysis when considering only the options with the highest increment. In all cases we could not find abnormal decrements in open interest in the first weeks after the announcement day. By construction this implies that the resulting gains } G_t \text{ are small. However, the gains of these four options realized till their maturity (all of them before December 2006) and considering all exercises (not only those corresponding to the options created on the day where the abnormal increment was observed) amount to more than } \varepsilon 6 \text{ million, }\varepsilon 4.7 \text{ million due to the exercise of the first option. In addition, we found that for the transactions which took place on April 20th, May 8th and May 19th, the option volume during the days following the announcement was unusually high. This could imply that substantial gains were realized by selling and not by exercising these options. We can not analyze this last point in more detail due to the lack of information in our database. The total gains realized considering the options with the first and second highest increments in open interest amount therefore to nearly } \varepsilon 18.7 \text{ million, compared with the (illegal) gains of approximately } \varepsilon 20 \text{ million for which EADS executives are still under investigation.}
\]
are slightly modified. We check the robustness of our results for all companies we analyzed but report here only some of these results. The remaining results are available upon request from the authors.

When varying the length of the estimation window between 100 and 1000, (all other parameters being unchanged and fixed) the number of selected transactions does not change significantly. In the case of AMR, we selected five transactions when considering the last two trading years ($N = 500$ days); for $N \in [200, 1000]$ the number of detected informed trades ranges between 4 and 6; for UAL this number remains unchanged with respect to the original choice for $N > 450$ and decreases by one when chosen $N \in [200, 450]$. 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 $R_t$ and $\tau_t$, our results are reasonably robust. We let the length of the first period vary in the range $[1, 30]$ and the second one in $[1, 40]$. 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 and fixed). In the case of AMR, if we restrict ourselves to $(\alpha, \alpha') \in [85, 95] \times [96, 100]$, 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 $\alpha$ used in the computation of the set $\Omega_1$, our results are robust as well. When increasing the level $\alpha$ from 1% to 10%, the number of trades selected for AMR varies between 1 and 6; for UAL it ranges between 2 to 4, for BAC and AT&T from 1 to 7. We simultaneously changed many parameters and found that the number of detected transactions does not change significantly and in almost all cases in steps of one. Based on these checks, we conclude that our results are reasonably robust.

5 Conclusion

Informed trading activities constitute a criminal offense which concerns not only the financial community but also the public at large. Clearly, it is an even more serious offense if the lives of
thousands of people are involved, such as in the case of September 11th. We detect informed trading activities in the options market using three different criteria: daily increments in open interest, realized gains and hedging dimension. Based on empirical data from 1996 to 2006, our methodology was able to identify several suspicious transactions on the CBOE for 14 companies belonging to three different business sectors (airline, banking and various). Although these results provide statistical evidence of informed trading activities, from a legal point of view this study does not constitute proof per se of such activities. Legal proof would require trader identity and their motivations, information which is not contained in our database. A preliminary (and incomplete) analysis of EUREX data was presented as well. We focused mainly on stock crashes and concentrated therefore on abnormal transactions in put options. The majority of the detected transactions could be assigned to one of the following three events: M&A/earnings related announcements, quarterly financial statements, and the terrorist attacks of September 11th. We have also discovered suspicious transactions in put options with underlying EADS. These took place in the period leading up to the public announcement that deliveries of the superjumbo A380 would be delayed by a further six months, causing a 35.5% fall in the underlying stock. We used publicly available data and all the results are therefore conservative. Applying our procedure to a richer database, stronger results would most likely be obtained: the separation of insider and non-insider trades can be achieved by knowing the identity of the trader, and determining whether a transaction is legal or fraudulent requires further analysis by competent agencies. Investigating insider trading activity is costly and regulators should focus on the most cost-effective enforcement mechanism. If a large and detectable portion of trading in the options market is driven by informed and insider traders, it might be optimal for regulators to expend relatively more monitoring efforts on the options markets. Our findings suggest that with pending extreme information events, the options market plays an important role in price prediction. Furthermore, the analysis presented in this paper investigates the possible linkage between option market variables and subsequent price movements of the underlying stock enhancing thereby our understanding of the functioning of financial markets. Option pricing models should account for all information available at time $t$. The price of several detected options does not show any reaction to the large demand for new put options, represented by an unusually
high increment in open interest. In this sense the efficient-market hypothesis, namely that financial markets are "informationally efficient", and that prices of traded assets already reflect all known information, is clearly challenged.
Table 1: Number of transactions associated with informed trading activities and percentage for the three sectors and their corresponding event category. Our selection procedure makes use of three criteria in order to detect informed activities: a trade in a specific option which exhibits an unusually high increment in open interest, generates an abnormal return and large gains a few days later and is not based on hedging demands, is detected as an informed trading activity in the options market. In order to emphasize the role played by hedging demand, we report our findings when disregarding this dimension and when considering it (number in brackets when hedging demand is taken into consideration).
### Summary of Airline Sector Jan 1996 - Jan 2006

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<th>$\tau$</th>
<th>$\Delta O_{t-1}$</th>
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<th>$\Delta O_{t}^{\text{tot}}$</th>
<th>Vol$_t$</th>
<th>$\tau_{\text{max}}$</th>
<th>$\gamma_2$</th>
<th>$\gamma_3$</th>
<th>%ex.</th>
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<tr>
<td>*7 Sep 01</td>
<td>20400311</td>
<td>0.90</td>
<td>15</td>
<td>7995</td>
<td>4179</td>
<td>98</td>
<td>6</td>
<td>5775710</td>
<td>7000%</td>
<td>0.016</td>
<td>0.000</td>
<td>0.998</td>
<td></td>
</tr>
<tr>
<td>*17 Sep 01</td>
<td>20400309</td>
<td>0.90</td>
<td>5</td>
<td>116</td>
<td>5026</td>
<td>98</td>
<td>4</td>
<td>2663780</td>
<td>5000%</td>
<td>0.010</td>
<td>0.000</td>
<td>0.998</td>
<td></td>
</tr>
<tr>
<td><strong>KLM Jan 1996 - Nov 2001</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 Sep 01</td>
<td>20296159</td>
<td>0.91</td>
<td>17</td>
<td>3</td>
<td>100</td>
<td>99</td>
<td>9</td>
<td>53976</td>
<td>900%</td>
<td>0.006</td>
<td>0.368</td>
<td>0.998</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Summary of detected transactions for the airline sector. Description see next pages.
### Summary of Airline Sector Jan 1996 - Jan 2006

<table>
<thead>
<tr>
<th>Day of transaction</th>
<th>Market condition</th>
<th>Return</th>
<th>Crash in the stock</th>
<th>Event’s Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AMR Jan 1996 - Jan 2006</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 May 00</td>
<td>0.356%</td>
<td>-17.626%</td>
<td>24/25. May 00</td>
<td>Announcement 24 May 00: Airline Deal UAL’s acquisition of US Airways</td>
</tr>
<tr>
<td>11 May 00</td>
<td>0.025%</td>
<td>-17.626%</td>
<td>24/25. May 00</td>
<td>Announcement 24 May 00: Airline Deal UAL’s acquisition of US Airways</td>
</tr>
<tr>
<td>31 Aug 01</td>
<td>-0.360%</td>
<td>-39.394%</td>
<td>17. Sep 01</td>
<td>9/11 Terrorist attacks in New York</td>
</tr>
<tr>
<td>10 Sep 01</td>
<td>-1.390%</td>
<td>-39.394%</td>
<td>17. Sep 01</td>
<td>9/11 Terrorist attacks in New York</td>
</tr>
<tr>
<td>24 Aug 05</td>
<td>0.374%</td>
<td>-5.299%</td>
<td>30. Aug 05</td>
<td>August 05: Hurricane Katrina, interrupted production on the gulf coast, jet fuel prices ↑</td>
</tr>
<tr>
<td><strong>UAL Jan 1996 - Jan 2003</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11 May 00</td>
<td>0.277%</td>
<td>-11.905%</td>
<td>24 May 00</td>
<td>Announcement 24 May 00: Airline Deal UAL’s acquisition of US Airways</td>
</tr>
<tr>
<td>6 Sep 01</td>
<td>-0.954%</td>
<td>-43.219%</td>
<td>17 Sep 01</td>
<td>9/11 Terrorist attacks in New York</td>
</tr>
<tr>
<td><strong>DAL Jan 1996 - May 2005</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*01 Oct 98</td>
<td>-1.716%</td>
<td>-11.410%</td>
<td>07/08 Oct 98</td>
<td>Not identified</td>
</tr>
<tr>
<td>29 Aug 01</td>
<td>-0.034%</td>
<td>-44.591%</td>
<td>17 Sep 01</td>
<td>9/11 Terrorist attacks in New York</td>
</tr>
<tr>
<td>19 Sep 02</td>
<td>-5.182%</td>
<td>-24.435%</td>
<td>27 Sep 02</td>
<td>Announcement 27 Sep 02: Expected loss for 3rd quarter</td>
</tr>
<tr>
<td>9 Jan 03</td>
<td>2.149%</td>
<td>-15.761%</td>
<td>21/22 Jan 03</td>
<td>Announcement 21 Jan 03: Restrictions on planned alliance of Delta, Northwest and Continental</td>
</tr>
<tr>
<td><strong>BA Jan 1996 - Jan 2006</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24 Nov 98</td>
<td>-0.184%</td>
<td>-21.944%</td>
<td>02/03 Dec 98</td>
<td>Announcement 02. Dec 98: production scale back and cut in work forces</td>
</tr>
<tr>
<td>29 Aug 01</td>
<td>-0.386%</td>
<td>-25.056%</td>
<td>17/18 Sep 01</td>
<td>9/11 Terrorist attacks in New York</td>
</tr>
<tr>
<td>5 Sep 01</td>
<td>-0.771%</td>
<td>-25.056%</td>
<td>17/18 Sep 01</td>
<td>9/11 Terrorist attacks in New York</td>
</tr>
<tr>
<td>6 Sep 01</td>
<td>-0.911%</td>
<td>-25.056%</td>
<td>17/18 Sep 01</td>
<td>9/11 Terrorist attacks in New York</td>
</tr>
<tr>
<td>*7 Sep 01</td>
<td>-1.853%</td>
<td>-25.056%</td>
<td>17/18 Sep 01</td>
<td>9/11 Terrorist attacks in New York</td>
</tr>
<tr>
<td>*17 Sep 01</td>
<td>-5.591%</td>
<td>-25.056%</td>
<td>17/18 Sep 01</td>
<td>9/11 Terrorist attacks in New York</td>
</tr>
<tr>
<td><strong>KLM Jan 1996 - Nov 2001</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 Sep 01</td>
<td>-1.830%</td>
<td>-31.647%</td>
<td>17/18 Sep 01</td>
<td>9/11 Terrorist attacks in New York</td>
</tr>
</tbody>
</table>

Table 3: Summary of detected events for the airline sector. Description see next page.
Caption for Tables 2, 4 and 6: day on which the transaction took place (Day); identification number (Id) of the put options; the moneyness (:= \( S_t/K \)); its time-to-maturity (\( \tau \)); the level of open interest the day before the suspicious transaction (\( OI_{t-1} \)); the increment in open interest from day \( t-1 \) to day \( t \) (\( \Delta OI_t \)); its quantile with respect to its empirical probability computed over the last two years (\( q_t^{\Delta OI} \)); the 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, \( \Delta OI_{t}^{\text{tot}} \)); the corresponding volume (\( Vol_t \)); the maximum return realized by the selected option during the two-week period following the transaction day (\( r_t^{\text{max}} \)); the number of days between transaction day \( t \) and when this maximum return occurs (\( \tau_2 \)); the gains realized through the exercise of the new option issued at time \( t \) (\( G_t \)); the number of days (starting from the transaction day) needed for the exercise of \( \Delta OI_t \) and 30 days (\( \tau_3 \)); the percentage of \( \Delta OI_t \) exercised within the first 30 days after the transaction; the ex-ante probability (\( q_t \)); the p-value of the hypothesis that hedging does not take place at time \( t \), and finally the probability of informed trading (1 - \( p_t \)).

Caption for Tables 3, 5 and 7: day on which the transaction took place (Day); the market condition at day \( t \) measured by the average return of the underlying stock during the last two trading weeks (Market condition); the minimum return of the underlying stock during the two-week period following the transaction day (Return, comparable therefore with \( r_t^{\text{max}} \) of the previous tables) and a short description of the event and why the stock drops (Event’s description). In most of the cases this drop is large enough that its cause is reported in the financial press such as the business section of the New York Times. We could not identify the cause of a few events when the movements in the underlying stock were not significant (interestingly in several of these cases the hypothesis of no-hedging can be rejected at a 5% confidence level). For transactions whose days are marked with asterisks the hypothesis of no-hedging can be rejected at a 5% level (see p-value reported in the last column of the corresponding tables).
Table 4: Summary of detected transactions for the banking sector. Description as in Table 2.
### Table 5: Summary of detected events for the banking sector. Description as in Table 3.

<table>
<thead>
<tr>
<th>Day of transaction</th>
<th>Market condition</th>
<th>Return</th>
<th>Crash in the stock</th>
<th>Event’s Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bank of America BAC Jan 1996 - Jan 2006</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13 Jun 00</td>
<td>-1.009%</td>
<td>-14.766%</td>
<td>15/16 Jun 00</td>
<td>Announcement 15 Jun 00: Wachovia Corp. Correction of expected earnings for 2nd quarter</td>
</tr>
<tr>
<td>*13 Nov 00</td>
<td>-0.388%</td>
<td>-11.741%</td>
<td>14/15 Nov 00</td>
<td>Announcement 14 Nov 00: 3rd quarterly financial statements, potential write-offs for 4th quarter</td>
</tr>
<tr>
<td>07 Sep 01</td>
<td>-0.397%</td>
<td>-5.724%</td>
<td>17 Sep 01</td>
<td>9/11 Terrorist attacks in New York</td>
</tr>
<tr>
<td><strong>Citigroup C Jan 1996 - Jan 2006</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 Aug 01</td>
<td>-0.513%</td>
<td>-6.714%</td>
<td>17 Sep 01</td>
<td>9/11 Terrorist attacks in New York</td>
</tr>
<tr>
<td>*18 Jun 02</td>
<td>0.584%</td>
<td>-5.419%</td>
<td>26 Jun 02</td>
<td>Not identified</td>
</tr>
<tr>
<td>*17 Jul 02</td>
<td>-0.269%</td>
<td>-26.730%</td>
<td>22/23 Jul 02</td>
<td>Announcement 22 Jul 02: Senate’s investigations into Citigroup (Enron case)</td>
</tr>
<tr>
<td>28 Apr 04</td>
<td>-0.263%</td>
<td>-2.804%</td>
<td>10 May 04</td>
<td>Not identified</td>
</tr>
<tr>
<td><strong>JP Morgan JPM Jan 1996 - Jan 2006</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*05 Oct 00</td>
<td>-0.342%</td>
<td>-7.066%</td>
<td>12 Oct 00</td>
<td>Not identified</td>
</tr>
<tr>
<td>*9 Nov 00</td>
<td>-0.560%</td>
<td>-4.258%</td>
<td>15 Nov 00</td>
<td>Not identified</td>
</tr>
<tr>
<td>29 May 01</td>
<td>0.414%</td>
<td>-3.423%</td>
<td>6 Jun 01</td>
<td>Not identified</td>
</tr>
<tr>
<td>30 Aug 01</td>
<td>-0.804%</td>
<td>-7.476%</td>
<td>20 Sep 01</td>
<td>9/11 Terrorist attacks in New York</td>
</tr>
<tr>
<td>6 Sep 01</td>
<td>-1.500%</td>
<td>-7.476%</td>
<td>20 Sep 01</td>
<td>9/11 Terrorist attacks in New York</td>
</tr>
<tr>
<td>18 Jan 02</td>
<td>-1.399%</td>
<td>-6.587%</td>
<td>29 Jan 02</td>
<td>Announcement 16/22 Jan 02: financial statements for 4th quarter/losses on Enron’s loans</td>
</tr>
<tr>
<td>17 Jan 03</td>
<td>-0.682%</td>
<td>-5.253%</td>
<td>24 Jan 03</td>
<td>Announcement 22 Jan 03: bigger 4th quarter loss than forecasted</td>
</tr>
<tr>
<td><strong>Merrill Lynch MER Jan 1996 - Jan 2006</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*21 Aug 98</td>
<td>0.030%</td>
<td>-16.349%</td>
<td>28/30/31 Aug 98</td>
<td>Announcement 17 August 98: Ruble crisis, Russian crisis, Asian crisis</td>
</tr>
<tr>
<td>*25 Aug 98</td>
<td>-0.370%</td>
<td>-16.556%</td>
<td>09/10 Sep 98</td>
<td>Announcement 17 August 98: Ruble crisis, Russian crisis, Asian crisis</td>
</tr>
<tr>
<td>*1 Sep 98</td>
<td>-3.709%</td>
<td>-16.556%</td>
<td>09/10 Sep 98</td>
<td>Announcement 17 August 98: Ruble crisis, Russian crisis, Asian crisis</td>
</tr>
<tr>
<td>10 Sep 01</td>
<td>-1.198%</td>
<td>-15.488%</td>
<td>17/18 Sep 01</td>
<td>9/11 Terrorist attacks in New York</td>
</tr>
<tr>
<td>9 Apr 02</td>
<td>-0.893%</td>
<td>-7.895%</td>
<td>11 Apr 02</td>
<td>Announcement 09 Apr 02: accusations of conflicts of interest, potential fine of &gt; $100mio</td>
</tr>
<tr>
<td><strong>Morgan Stanley MWD Jan 1996 - Jan 2006</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17 Aug 98</td>
<td>0.727%</td>
<td>-17.215%</td>
<td>28/31 Aug 98</td>
<td>Announcement 17 August 98: Ruble crisis, Russian crisis, Asian crisis</td>
</tr>
<tr>
<td>*21 Aug 98</td>
<td>-0.346%</td>
<td>-17.215%</td>
<td>28/31 Aug 98</td>
<td>Announcement 17 August 98: Ruble crisis, Russian crisis, Asian crisis</td>
</tr>
<tr>
<td>03 Nov 00</td>
<td>1.336%</td>
<td>-12.246%</td>
<td>07/08/09 Nov 00</td>
<td>Not identified</td>
</tr>
<tr>
<td>*22 May 01</td>
<td>2.273%</td>
<td>-5.699%</td>
<td>30 May 01</td>
<td>Not identified</td>
</tr>
<tr>
<td>*06 Apr 05</td>
<td>0.937%</td>
<td>-2.977%</td>
<td>20 Apr 05</td>
<td>Announcement 05 Apr 05: proposal of new CEO, discover credit card unit spin off</td>
</tr>
</tbody>
</table>
Summary of various sectors Jan 1996 - Jan 2006

<table>
<thead>
<tr>
<th>Day</th>
<th>Id</th>
<th>$\tau$</th>
<th>$OI_{t-1}$</th>
<th>$\Delta OI_t$</th>
<th>$q_t^{\Delta OI}$</th>
<th>$\Delta OI_t^{tot}$</th>
<th>$Vol_t$</th>
<th>$r_t^{max}$</th>
<th>$\tau_2$</th>
<th>$G_t$</th>
<th>$\tau_3$</th>
<th>%ex.</th>
<th>$q_t$</th>
<th>$p$ – value</th>
<th>$1 - p_t$</th>
</tr>
</thead>
</table>

**AT&T Jan 1996 - Jan 2006**

*17 Apr 98 10307639 1.03 29 2178 2442 97.70% -20484 2963 441% 9 1605881 21 100% 0.014 0.022 0.998

*25 Apr 00 10667683 1.04 25 14673 8512 99.50% 9407938 19 100% 0.002 0.021 0.998

*26 Apr 00 10667683 1.02 24 23185 2637 93.90% 3422 1853 447% 9 2348288 15 100% 0.038 0.002 0.998

**Coca Cola KO Jan 1996 - Jan 2006**

*24 Aug 98 10423228 1.00 26 4338 2134 94.50% 5285 3007 577% 9 2246363 6 100% 0.034 0.000 0.998

*25 Aug 99 11199798 0.98 30 1320 756 72.80% 1060 759 166% 9 1894 26 100% 0.048 0.015 0.998

*18 Mar 99 11199798 0.98 30 1320 756 72.80% 1060 759 166% 9 1894 26 100% 0.048 0.015 0.998

*23 Aug 00 10973464 1.07 59 482257 96.10% 4890 2258 208% 7 69259 17 100% 0.002 0.004 0.998

*25 Apr 00 10667683 1.04 25 14673 8512 99.50% 9407938 19 100% 0.002 0.021 0.998

*26 Apr 00 10667683 1.02 24 23185 2637 93.90% 3422 1853 447% 9 2348288 15 100% 0.038 0.002 0.998

**Hewlett Packard HPQ Jan 1996 - Jan 2006**

*14 May 98 10552311 1.00 37 2646 2745 96.90% 9720 4943 117% 10 470119 13 100% 0.026 0.000 0.998

*15 Sep 99 10087563 1.21 66 1785 1534 85.90% 5939 20993 149% 6 6038594 13 100% 0.002 0.187 0.998

*15 Oct 99 10848801 0.97 36 3403 6194 99.30% -12522 7732 130% 9 1277513 4 100% 0.004 0.026 0.998

*28 Sep 00 11163103 0.97 23 2600 1220 85.90% 1449 1353 271% 10 1166625 3 100% 0.032 0.000 0.998

*30 Oct 00 11136235 0.96 19 5307 11513 99.90% 66131 5898 118% 10 4178669 15 100% 0.002 0.000 0.998

*31 Oct 00 10519981 1.16 18 0 13093 4453 98.50% 43002 295 449% 10 2463 19 100% 0.010 0.000 0.998

*9 Nov 00 10373575 0.95 9 17186 4453 98.50% 6502 7170 176% 3 187794 14 100% 0.012 0.000 0.998

**Philip Morris MO Jan 1996 - Jan 2006**

28 Jan 99 11211572 1.03 23 1237 3307 92.30% 3647 3314 444% 10 229156 16 100% 0.008 0.187 0.998

30 Mar 99 11439476 0.94 18 5039 20993 99.10% 43843 21330 149% 6 6038594 13 100% 0.002 0.160 0.998

21 Aug 00 10577641 1.07 26 3590 5770 97.90% 8428 6262 145% 10 892463 19 100% 0.010 0.489 0.996

*16 Mar 01 20241596 0.96 36 2902 3416 93.50% -67790 3539 122% 5 938726 16 100% 0.014 0.020 0.998

*3 Jun 02 20705047 1.04 47 16001 15344 97.90% 19945 18827 106% 10 3291798 16 100% 0.016 0.005 0.998

21 Jun 02 20705047 0.96 29 43143 7298 92.10% -82813 8816 263% 5 2079930 2 100% 0.048 0.211 0.998

Table 6: Summary of detected transactions for various sectors. Description as in Table 2.
### Summary of various sectors Jan 1996 - Jan 2006

<table>
<thead>
<tr>
<th>Day of transaction</th>
<th>Market condition</th>
<th>Return</th>
<th>Crash in the stock</th>
<th>Event’s Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AT&amp;T Jan 1996 - Jan 2006</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*17 Apr 98</td>
<td>0.3710%</td>
<td>-2.9087%</td>
<td>27 Apr 98</td>
<td>Announcement 20 Apr 98: financial statements for first quarter</td>
</tr>
<tr>
<td>*25 Apr 00</td>
<td>0.7441%</td>
<td>-19.0545%</td>
<td>02/03 May 00</td>
<td>Announcement 02 May 00: financial statements for first quarter</td>
</tr>
<tr>
<td>*26 Apr 00</td>
<td>1.5255%</td>
<td>-19.0545%</td>
<td>02/03 May 00</td>
<td>Announcement 02 May 00: financial statements for first quarter</td>
</tr>
<tr>
<td><strong>Coca Cola KO Jan 1996 - Jan 2006</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*24 Aug 98</td>
<td>0.6074%</td>
<td>-10.4811%</td>
<td>31 Aug 98</td>
<td>Announcement 17 Sept 98: international crisis (Russian, Asian) hurts KO's profit</td>
</tr>
<tr>
<td>*26 Aug 98</td>
<td>0.0289%</td>
<td>-10.4811%</td>
<td>31 Aug 98</td>
<td>Announcement 17 Sept 98: international crisis (Russian, Asian) hurts KO's profit</td>
</tr>
<tr>
<td>*18 Mar 99</td>
<td>1.4204%</td>
<td>-2.9644%</td>
<td>31 Mar 99</td>
<td>Announcement 29 Mar 99: unexpected drop in sales due to Pepsi IPO</td>
</tr>
<tr>
<td>*23 Aug 00</td>
<td>-0.8207%</td>
<td>-3.7736%</td>
<td>30 Aug 00</td>
<td>Not identified</td>
</tr>
<tr>
<td>12 Feb 01</td>
<td>0.8747%</td>
<td>-9.587%</td>
<td>21/22 Feb 01</td>
<td>Announcement 21 Feb 01: Coca-Cola/Procter&amp;Gamble deal</td>
</tr>
<tr>
<td>20 Feb 01</td>
<td>-0.4588%</td>
<td>-9.587%</td>
<td>21/22 Feb 01</td>
<td>Announcement 21 Feb 01: Coca-Cola/Procter&amp;Gamble deal</td>
</tr>
<tr>
<td>28 Jun 02</td>
<td>0.0929%</td>
<td>-3.8787%</td>
<td>12 Jul 02</td>
<td>Announcement 14 Jun 02: stock options granted to executives are recorded as expense</td>
</tr>
<tr>
<td>*9 Jul 02</td>
<td>0.1346%</td>
<td>-10.0653%</td>
<td>18/19 Jul 02</td>
<td>Announcement 17 Jul 02: financial statements for 2nd quarter</td>
</tr>
<tr>
<td>*10 Jul 02</td>
<td>-0.4834%</td>
<td>-10.0653%</td>
<td>18/19 Jul 02</td>
<td>Announcement 17 Jul 02: financial statements for 2nd quarter</td>
</tr>
<tr>
<td><strong>Hewlett Packard HPQ Jan 1996 - Jan 2006</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*14 May 98</td>
<td>-0.7339%</td>
<td>-13.8591%</td>
<td>14 May 98</td>
<td>Announcement 14 May 98: profit warning for 2nd quarter due to Asian crisis</td>
</tr>
<tr>
<td>15 Sep 99</td>
<td>-0.9639%</td>
<td>-6.2377%</td>
<td>29 Sep 99</td>
<td>Announcement 01 Oct 99: fall in 4th revenues growth</td>
</tr>
<tr>
<td>*15 Oct 99</td>
<td>-0.9539%</td>
<td>-12.5612%</td>
<td>27 Oct 99</td>
<td>Announcement 27 Oct 99: earnings shortfall in 4th quarter</td>
</tr>
<tr>
<td>*28 Sep 00</td>
<td>0.7457%</td>
<td>-12.5258%</td>
<td>29/02 Sep/Oct 00</td>
<td>Not identified</td>
</tr>
<tr>
<td>*30 Oct 00</td>
<td>-1.8404%</td>
<td>-12.7796%</td>
<td>10/13 Nov 00</td>
<td>Announcement 13 Nov 00: financial statements for 4th quarter (ended on Oct 31)</td>
</tr>
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<td>*31 Oct 00</td>
<td>-2.0350%</td>
<td>-12.7796%</td>
<td>10/13 Nov 00</td>
<td>Announcement 13 Nov 00: financial statements for 4th quarter (ended on Oct 31)</td>
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<td>*9 Nov 00</td>
<td>-0.5128%</td>
<td>-12.7796%</td>
<td>10/13 Nov 00</td>
<td>Announcement 13 Nov 00: financial statements for 4th quarter (ended on Oct 31)</td>
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<tr>
<td><strong>Philip Morris MO Jan 1996 - Jan 2006</strong></td>
<td></td>
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<td></td>
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<tr>
<td>28 Jan 99</td>
<td>0.1431%</td>
<td>-8.6777%</td>
<td>10 Feb 99</td>
<td>Announcement 10 Feb 99: punitive damages of 81 million for smoker’s death</td>
</tr>
<tr>
<td>30 Mar 99</td>
<td>-1.6248%</td>
<td>-15.1341%</td>
<td>30/31 Mar 99</td>
<td>Announcement 30 Mar 99: punitive damages of 51.5 million for inoperable lung cancer</td>
</tr>
<tr>
<td>21 Aug 00</td>
<td>0.6652%</td>
<td>-2.6263%</td>
<td>30 Aug 00</td>
<td>Not identified</td>
</tr>
<tr>
<td>*16 Mar 01</td>
<td>-0.8794%</td>
<td>-4.7508%</td>
<td>20 Mar 01</td>
<td>Not identified</td>
</tr>
<tr>
<td>*3 Jun 02</td>
<td>0.4642%</td>
<td>-2.0223%</td>
<td>6 Jun 02</td>
<td>Not identified</td>
</tr>
<tr>
<td>21 Jun 02</td>
<td>-0.9510%</td>
<td>-15.8465%</td>
<td>21/24/25 Jun 02</td>
<td>Announcement 21 Jun 02: investors reject stock because of litigation risk</td>
</tr>
</tbody>
</table>

Table 7: Summary of detected events for various sectors. Description as in Table 3.
<table>
<thead>
<tr>
<th>Day</th>
<th>K</th>
<th>τ</th>
<th>OIₜ</th>
<th>ΔOIₜ</th>
<th>qₜΔOI</th>
<th>ΔOIₜ tot</th>
<th>Volₜ</th>
<th>rₜ max</th>
<th>τ₂</th>
<th>Gₜ</th>
<th>qₜ</th>
<th>1 − pₜ</th>
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<tbody>
<tr>
<td>06 Apr 06</td>
<td>3100</td>
<td>May 2006</td>
<td>2523</td>
<td>2518</td>
<td>0.998</td>
<td>4988</td>
<td>2518</td>
<td>280%</td>
<td>29</td>
<td>665073</td>
<td>0.004</td>
<td>0.998</td>
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<tr>
<td>07 Apr 06</td>
<td>3200</td>
<td>June 2006</td>
<td>4015</td>
<td>3855</td>
<td>0.998</td>
<td>6663</td>
<td>7710</td>
<td>269%</td>
<td>29</td>
<td>1676925</td>
<td>0.004</td>
<td>0.998</td>
</tr>
<tr>
<td>20 Apr 06</td>
<td>3000</td>
<td>June 2006</td>
<td>1055</td>
<td>1000</td>
<td>0.934</td>
<td>1545</td>
<td>1000</td>
<td>389%</td>
<td>22</td>
<td>977515</td>
<td>0.016</td>
<td>0.998</td>
</tr>
<tr>
<td>08 May 2006</td>
<td>3000</td>
<td>June 2006</td>
<td>2865</td>
<td>810</td>
<td>0.922</td>
<td>1920</td>
<td>810</td>
<td>1487%</td>
<td>28</td>
<td>811670</td>
<td>0.020</td>
<td>0.998</td>
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<tr>
<td>18 May 2006</td>
<td>3100</td>
<td>June 2006</td>
<td>3040</td>
<td>2518</td>
<td>0.990</td>
<td>2519</td>
<td>2518</td>
<td>255%</td>
<td>20</td>
<td>1720467</td>
<td>0.008</td>
<td>0.996</td>
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<tr>
<td>19 May 2006</td>
<td>2600</td>
<td>July 2006</td>
<td>5236</td>
<td>4061</td>
<td>0.998</td>
<td>-220</td>
<td>4061</td>
<td>924%</td>
<td>19</td>
<td>1472680</td>
<td>0.004</td>
<td>0.998</td>
</tr>
</tbody>
</table>

Table 8: Summary of detected events for the case of EADS: Day, day of the transaction; K, strike of the selected option; τ, maturity of the selected option; OIₜ, level of open interest on the transaction day; ΔOIₜ, increment in open interest from day t − 1 to day t; qₜΔOI, historical quantile of the increment ΔOIₜ; ΔOIₜ tot, total increment in open interest; Volₜ, corresponding option volume; rₜ max, maximum return realized within 30 days of the transaction; τ₂, day of the maximum return after the transaction; Gₜ, realized cumulative gains after 60 trading days due to the exercise of these options; qₜ, ex-ante probability; 1 − pₜ, probability of informed trading.
Figure 1: Increment in Open Interest, corresponding volume and cumulative gains $G_t$ in US $\$ for the selected options of AMR. These gains correspond to the ones realized by exercising the options (daily drop in the absolute amount of open interest).
Figure 2: The graph shows the dynamic of the selected put option with underlying stock AMR in the days leading up to the terrorist attacks of September 11th. The blue line shows the daily dynamic of open interest, the blue bars shows the corresponding trading volume (left y-axis) and the red line the option’s return (right y-axis). The red point is the day of the transaction, the green point is the day of the terrorist attacks. This option had a strike of $30 and matured at the end of October 01.

Figure 3: The graph reports the behavior of a put transaction with underlying stock AMR around the announcement of the UAL proposed $4 billion acquisition of US Airways in May 2000. Same variables as in Figure 2. The red point is the day of the transaction, the green point is the day of the announcement. This option had a strike of $35 and matured at the end of June 00.
Figure 4: Increment in Open Interest and corresponding volume for EADS.

Figure 5: Cumulative gains $G_t$ for EADS. The gains correspond to the those realized by exercising the options (daily drop in the absolute amount of open interest).
Figure 6: The graph shows the dynamic of the selected put option with underlying stock EADS in the days leading up to the announcement on June 14th, 2006. The blue line shows the daily dynamic of open interest, the blue bars shows the corresponding trading volume (left y-axis) and the red line the option’s return (right y-axis). The red point is the day of the transaction, the green point is the announcement day, June 14th, 2006. This option had a strike of €300 and matured at the end of June 06.

Figure 7: Same legend as in Figure 6 for the transaction of May 19th, 2006. This option had a strike of €260 and matured at the end of July 06.
References


