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The Impact of Risk, Uncertainty, and the Perceived Threat of Terrorist Attacks on Equity Markets

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Information provided by the U.S. Department of Homeland Security regarding potential terrorist attacks significantly affects U.S. equities. When the government announces heightened terror alert levels, investors' perceptions of risk increase as measured by both conditional volatility of equity returns and implied volatility on Standard &Poor's 500 Index options. We also find evidence that informed traders are more active when there is an increased threat of an attack; however, equity market responses to these threat-related announcements have declined monotonically over time.

1. Introduction

One of the key questions investors face in the early stages of the 21st century is the following: How do financial markets respond to sudden, large increases in uncertainty caused by the possibility of terrorist activity on a global scale? This type of difficult-to-quantify uncertainty stands in contrast to more-quantifiable forms of uncertainty that investors typically face, such as the risks of corporate earnings shortfalls, higher inflation rates, or an economic downturn. As Knight (1921) first noted, one can distinguish between uncertainty (e.g., randomness with difficult-to-quantify or unknowable probabilities) and risk (i.e., randomness with quantifiable or knowable probabilities). This distinction is an important one because increases in an investor's level of uncertainty can translate into heightened perceptions of risk that, in turn, affect the pricing of risky assets.[1] Hence, we investigate the relationship between uncertainty and risk in both the first and second moments of U.S. equity returns by examining how changes in the perceived threat of terrorism affect realized returns, conditional and implied volatility, and the level of informed trading activity.

Caballero and Krishnamurthy (2008) model financial crises on Knightian uncertainty and demonstrate that an "uncertainty shock" results in agents behaving as they would during a flight-to-quality episode. Basili (2006) also shows several theoretical analyses of the impact of Knightian uncertainty on financial markets and notes that an agent's attitude towards ambiguity has a crucial role in asset price determination and portfolio choice. In addition, Easley and O'Hara (2007) examine the important role ambiguity and uncertainty can play in determining the specific structure of financial markets. Interestingly, the effects of uncertainty on asset prices and market structure exist even when investors can quantify the probabilities of most, but not all, possible future states

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of the economy. Consequently, we examine how the level and volatility of U.S. stock returns are affected by perceptions of terrorist threats.

One can view the increased possibility of global terrorist activity at the beginning of the 21st century as a worldwide increase in Knightian uncertainty. This situation, coupled with the fundamental concept that systematic and (possibly) nonsystematic risks can affect asset prices and the risk-return relationship, makes it important to understand how greater uncertainty affects both of these forms of risk. The evolution of terrorism from primarily a regional phenomenon to an international problem makes it difficult for investors to diversify some of these risks on a global scale. At the same time, the ability of investors to estimate the financial impact of future terrorist activity can be severely tested in this environment. However, investors must still try to manage portfolio exposure to systematic risk through judicious asset allocation or the use of hedging instruments. Analyzing the effects of terrorism uncertainty on financial risks is particularly difficult for investors because specific details regarding possible impending attacks are not well known outside of national security circles (or at all). While this does not bode well for average investors and liquidity traders, it does create an environment that may allow informed traders to successfully trade on private information without being recognized.

In light of the above issues, the U.S. government disseminates as much information on terrorist threats as possible, to the extent that releasing the information will not interfere with ongoing surveillance and terror attack preventative measures. The U.S. Department of Homeland Security (DHS) threat level announcement system is the conduit used to pass potential terror attack activity to the public. If DHS is effectively analyzing and communicating increases or decreases in terrorist attack threat levels, then the mean and/or variance of equity returns should reflect any changes in systematic and nonsystematic risks associated with these threat levels. In addition to the impact on risk perceptions, the DHS terror alerts might influence the degree of informed trading present in financial markets and, thus, spur more trading by better-informed market participants.

Consistent with the issues raised above with respect to terrorism’s potential effects on the first two moments of equity returns, we use announced changes in terrorism threat levels from the DHS Homeland Security Advisory System to estimate the impact of perceived terrorism uncertainty on daily equity returns, conditional volatility of equity returns, implied volatility (proxied by the Chicago Board of Options Exchange Volatility Index, VIX), and the probability of informed trading (PIN). We find strong, robust evidence that increases in the DHS threat level positively affect both conditional and implied volatility of equity returns. However, the impact of these threat-related announcements on U.S. equities has declined monotonically since 2002. The increases in both conditional and implied equity volatility suggest that the short-term adjustment to changes in the terror threat level is not trivial, as investors try to alter their portfolios quickly, based on any relevant information gleaned from the terror alert system.

Contrary to the results related to volatility, the level of aggregate stock returns responds inconsistently to changes in the advisory system and, at times, with unexpected signs. For example, we find that announcements of increases in the general threat condition are negatively related to airline stock returns (as proxied by the American Stock Exchange Airline Index), while the Standard & Poor's 500 Index responds positively to increases in the threat level. Overall, the mixed and generally weak relationship between changes in the threat level and daily equity returns indicates that investors might be able to adjust their portfolios in ways that neutralize most of the potentially negative short-term effects of these terror alerts (albeit with the side effect of heightened volatility).[2]

We also find that PIN (as derived by Easley et al., 1996) is positively related to increases in the terrorism threat level. That is, PIN is consistently higher during periods when the advisory system warns of high, or severe, risk of a terrorist attack. This suggests that investors with superior information (i.e., better-informed traders) take advantage of the heightened uncertainty and greater volatility because these traders' presence in the U.S. equity market rises simultaneously with each increase in the terror threat level. This finding is consistent with Admati and Pfleiderer (1988), who show that informed traders are likely to trade during periods of greater trading volatility by attempting to "hide" their trades and profit from their informational advantage. Thus, the perceived threat of terrorism affects both the volatility of equities and the informational content of trades in the U.S. (i.e., the alerts coincide with increased trading activity by informed traders, which, in turn, can lead to more-informative prices, as other investors observe and learn from this trading activity).

In sum, we contribute to the literature in three ways. First, we show that, when terrorism uncertainty affects financial risk (as measured by conditional volatility and implied volatility), changes in perceived threat levels can influence the level of equity prices, sometimes in unexpected ways. Second, this study is the first to report that the time variation in conditional and implied volatility measures are positively related to changes in terrorist threat levels. Lastly, the paper presents the first investigation of a potential positive relationship between PIN and the Homeland Security Advisory System's announced threat level. Overall, the U.S. equity market appears to respond fairly well to sudden increases in Knightian uncertainty caused by a greater threat of terrorist activity. For example, investors seem to react rationally to this increased uncertainty by adjusting their portfolios to protect against any potentially negative effects from a heightened threat of terrorist activity (e.g., possibly by selling airline stocks and purchasing defense-related stocks). In addition, informed traders respond logically to the terror-induced greater volatility by using this opportunity to trade more actively.

The remainder of this paper is organized as follows. Section 2 details the Homeland Security Advisory System. Section 3 reviews the literature, while Section 4 discusses the data and methodology. Section 5 provides empirical estimates, and Section 6 offers policy and portfolio management implications. Section 7 provides our conclusions and suggestions for future research.

2. The Homeland Security Advisory System

On March 12, 2002, Tom Ridge, the former governor of Pennsylvania and the first secretary of DHS, announced the creation of the Homeland Security Advisory System. This system was devised to protect U.S. cities, resources, and people from the threat of terrorism. The system is designed to “measure and evaluate terrorist threats and communicate them to the public in a timely manner” (Ridge, 2002). The end goal of the advisory system is to make America safer and more aware of the threat of terrorism through timely communications to the general public.

The attorney general of the United States at the time, John Ashcroft, said information is the best friend of prevention. Given that terrorist activities (such as the September 11, 2001, attacks on the U.S.) may affect economic growth, any information helping to prevent such an attack can have economic value and, therefore, possibly affect asset prices.

The Homeland Security Advisory System comprises five threat conditions, or alert levels: low, guarded, elevated, high, and severe. Each threat level is represented by a color: green, blue, yellow, orange, and red, respectively. Since its introduction, one important modification has been made to the threat advisory system: On August 1, 2004, Secretary Ridge announced that the Homeland Security Advisory System was targeting an increase in the threat condition for the financial services sector in northern New Jersey, Washington, D.C., and New York City.[3] In addition, all future changes in the threat status from August 1, 2004, through the end of 2006 were targeted to specific industries or geographic areas. Table 1 provides the threat level, whether the threat level was increased or decreased, the threat target, the reason for the change in threat level, and information regarding the threat situation. Over the period of this study, DHS changed the terror alert level on 16 occasions. The only announcement of severe (red) risk of terrorist activities occurred on August 10, 2006, in response to possible airline attacks originating from the United Kingdom. In that instance, DHS stated that an attack employing liquid explosives had been thwarted. Consequently, the threat level was lowered a few days later on August 13, 2006.

Table 1: Terror Alert System Status from March 12, 2002 to December 31, 2006

This table summarizes all of the changes in the terror threat level issued by the U.S. Department of Homeland Security from March 12, 2002 to December 31, 2006.

Date	Threat Level	Raised/ Lowered	Threat Target	Reason for Action	Reason for Intelligence
3/12/02	Yellow	Introduction			
9/10/02	Orange	Raised			Possible attacks to coincide with 9/11/2001 anniversary.
9/24/02	Yellow	Lowered			Reduced threat with passing of 9/11/2001 anniversary.
2/7/03	Orange	Raised		Bombings of a resort hotel in Kenya and nightclub in Indonesia.	Al Qaeda planning attacks on apartment buildings and hotels.
2/27/03	Yellow	Lowered		Passing of Hajj and counter-terrorism actions.	Review of intelligence.
3/17/03	Orange	Raised		U.S. led military campaign against Saddam Hussein.	Increased threat associated with U.S. campaign in Iraq.
4/16/03	Yellow	Lowered			Review of intelligence.
5/20/03	Orange	Raised		Bombings in Saudi Arabia and Morocco.	Target key assets (nuclear power plants, dams, government facilities, energy sector, transportation sector, and financial institutions.
5/30/03	Yellow	Lowered			Number of indications and warnings have decreased since Memorial Day
12/21/03	Orange	Raised			Increased volume of threats
1/9/04	Yellow	Lowered			Threat conditions diminished following holidays.
8/1/04	Orange	Raised	Financial services in NYC, northern NJ and Washington, DC		
11/10/04	Yellow	Lowered	Financial services in NYC, northern NJ, and Washington, DC	Permanent protective measures implemented.	
7/7/05	Orange	Raised	Mass transit	Mass transit attacks in UK.	
8/12/05	Yellow	Lowered	Mass transit	Sustainable mass transit security measures implemented	
8/10/06	Red/ Orange	Raised	Flights from UK to US/Commercial Aviation to US	Plot to detonate liquid explosives on aircraft from	

				UK to US thwarted.
8/13/06	Orange/ Orange	Lowered/ Unchanged	Flights from UK to US/Commercial aviation to US	Plot to detonate liquid explosives on aircraft from UK to US thwarted.

It should also be noted that, although there were not many alert changes (ex post) during the period 2002–2006, our sample covers over 1,200 trading days; thus, we have a very large sample of possible days when alert changes could have happened (ex ante) even though, ex post, only 16 days actually had alert changes. Therefore, the large number of days in our sample (which includes both days with alert changes and days without any changes) yields a representative set of stock price behavior during the post-9/11 era because, ex ante, investors are not certain when an attack is going to occur even in the presence of the warning system. Accordingly, we use the terror alert announcements as a proxy for the likelihood of an attack.[4]

3. Related Work

The growing interest regarding the economic costs resulting from terrorist activities has spawned new lines of academic research. Mooney et al. (2006) and Karakas (2007) use event studies to examine the impact of changes in threat levels on asset prices. These two papers both focus on the level of equity prices rather than the volatility of these prices and find that changes in threat levels have no effect on the prices of domestic and foreign-based airlines, insurance companies, and broader stock market measures. We extend this research by showing that, contrary to previous studies, if uncertainty influences financial risk measures, such as conditional volatility and implied volatility, then changes in threat levels may affect the level and / or variability of asset prices.

Motivation for our analysis can also be found in recent research on the influence of terrorism on economic activity. These studies find short-run negative macroeconomic effects associated with acts of terrorism.[5] In addition, several studies investigate the impact of specific terrorist attacks on stock prices. For example, Karolyi and Martell (2010) use a sample of 75 terrorist attacks on individual firms between 1995 and 2002 and find an average negative stock price reaction of -0.83% on the day of attack. Other papers by Quigg (2007), Chen and Siems (2004), and Eldor and Melnick (2004) also find that terrorist activity can have significant effects on financial markets around the world.

Rigobon and Sack (2005) measure the effects of war-related news on U.S. financial markets. They argue that the second moments of financial variables are more informative than changes in mean values because good news can cancel out the effects of bad news across different sectors of the market. Supporting their argument, the authors show that average changes in broader financial variables, such as the U.S. Dollar Index and the Standard & Poor’s (S&P) 500 Index, are not significantly different between war-related news days and other days. However, the variances of the U.S.

dollar and S&P 500 returns are different on days with war news compared with other days. Consequently, they use a heteroskedasticity-based model to estimate a war risk factor.

Given the typically sudden, episodic nature of terrorism activity as well as the empirical evidence of time-varying volatility found in studies of financial returns such as Rigobon and Sack (2005), it is appropriate to model the explicit relationship between asset prices and conditional variance via a GARCH-type method in order to obtain a more accurate estimate of the effects of the terror alert system on U.S. equities. In particular, the Exponential GARCH-in-Mean (EGARCH-M) model has been used to examine the relationship between volatility and stock returns in numerous countries (see Koulakiotis et al., 2006, which most closely follows our approach). We chose the EGARCH-M approach because it provides a more flexible functional form for analyzing the time variation in volatility, while retaining the benefits of a more basic GARCH model.[6] Further, EGARCH allows asymmetric shocks to volatility.[7]

4. Data, Methodology, and Hypotheses

4.1. Data

We use seven equity indexes to carry out the investigation: the American Stock Exchange (AMEX) Airline Index, Bloomberg New York City (NYC) Regional Stock Index, Center for Research in Security Prices (CRSP) Equally Weighted Index and Value-Weighted Index, Nasdaq Composite Index, Russell 2000 Index, and the S&P 500 Index. We chose these indexes for three reasons: first, to capture industry- and region-specific information or risks from targeted threat announcements via the AMEX Airline and Bloomberg NYC Index; second, to measure more robustly the systematic, market-wide responses to general threat announcements via the S&P 500 Index, as well as the CRSP Equally Weighted Index and Value-Weighted Index; and third, to identify any possible differential effects on small firms relative to large firms by studying the Nasdaq Composite Index and the Russell 2000 Index.

We retrieved daily index values from the Bloomberg financial data service and the CRSP database for the AMEX Airline Index, CRSP Equally Weighted Index, CRSP Value-Weighted Index, Nasdaq Composite Index, Russell 2000 Index, and the S&P 500 Index for the period of August 3, 2001 to December 31, 2006 (resulting in 1,358 observations). However, we focus on the time period beginning with the introduction of the terror alert system on March, 12, 2002, and extending through December 31, 2006, using 1,212 observations for most of the estimations. The time period prior to March 12, 2002, is used solely to inspect conditional volatility leading up to the introduction of the terror alert system. We obtained prices for the Bloomberg NYC Regional Stock Index from the Bloomberg data service and values for the VIX from the CBOE web site.

The probability of informed trading is estimated using trades and quotes data. We gathered intraday trades and quotes for the S&P 500 SPDR Exchange Traded Fund (SPY) from the NYSE TAQ database, with these trades and quotes being sampled every minute from 9:20 a.m. to 4:00 p.m, resulting in 400 observations per day.

4.2. Methodology

We use both univariate and multivariate tests in order to describe as fully as possible how investors react, if at all, to changes in terror threat levels by examining the effects of these perceptions on the realized returns, volatility, and informed trading activity of U.S. equities. Based on the findings of Rigobon and Sack (2005) and other research noted in Section 3, we employ EGARCH-M models to estimate multivariate relationships. We compute an AR(1), EGARCH-M(1,1) via the maximum likelihood method for the entire period of March 12, 2002, to December 29, 2006.

The AR(1), EGARCH-M(1,1) model is defined below as our equation (1):

$$\begin{aligned}
(y_t - R_f) &= \beta_0 + \beta_1(R_m - R_f) + \beta_2 SMB + \beta_3 HML + \beta_4 y_{t-1} + \beta_5 Gen_Incr + \beta_6 Finl_Serv_Incr + \\
&\beta_7 Mass_Trans_Incr + \beta_8 Airlines_Incr + \beta_9 Gen_Decr + \beta_{10} Finl_Serv_Decr + \\
&\beta_{11} Mass_Trans_Decr + \beta_{12} Airlines_Decr + \lambda \ln(h_t) + \varepsilon_t \qquad (1)\\
\varepsilon_t &= \sqrt{h_t} \cdot e_t \\
\ln(h_t) &= \delta_0 + \delta_1 \ln(h_{t-1}) + \theta_1 g(z_{t-1}) \\
g(z_t) &= \gamma_0 z_t + \gamma_1 \left[|z_t| - \mathrm{E}|z_t| \right] \\
z_t &= \varepsilon_t \big/ \sqrt{h_t} \, ,
\end{aligned}$$

where E|z_t| depends upon the density function for the standardized disturbances, $z_t = \varepsilon_t/(h_t)^{1/2}$. Here E|$z_t$|=$e_t$ has the unit normal density $e^{-(\varepsilon_t^2/2)}/(2\pi)^{1/2}$, ($y_t$ – R_f) is the daily excess return on each respective index at time-t, and h_t is the conditional variance. We include variables to capture the separate (and possibly asymmetric) effects of increases and decreases in the threat level on announcement day equity returns.

We hypothesize that increases in threat levels are typically unanticipated. However, decreases in threat levels may be partially anticipated due to the passing of some benchmark event; e.g., a religious or national holiday. *Gen_Incr* is a dummy variable equal to one on trading days when the general terror alert status was increased, while *Gen_Decr* is a dummy variable set to one on trading days when the general terror alert status was decreased and $\gamma_1 = 1$. Industry-specific dummy variables are also included, separating increases from decreases based on three specific industries that have been highlighted in some of the terror alert announcements: the financial services, mass transit, and airline industries. These dummy variables are denoted as *Finl_Serv_Incr* / *Finl_Serv_Decr*, M*ass_Trans_Incr* / *Mass_Trans_Decr*, and *Airlines_Incr* / *Airlines_Decr,* respectively. The impact of conditional volatility on the returns process is captured by λ. For robustness, we include the Fama-French (1993) factors to control for market risk, firm size, and book-to-market equity effects.

In the above specification, the parameter estimates for β_5 through β_{12} are of particular importance because they capture the marginal effects of changes in terror alert levels, based on their general direction (e.g., increases versus decreases), as well as the specific industries that might be most adversely affected by terrorist activity.

Beyond the return-related models noted above, we also investigate the impact of changes in the perceived threat level on volatility expectations (i.e., future volatility) using the CBOE VIX. An autoregressive AR (1) model with a specific event window and annual dummy variables is used to model fluctuations in the VIX volatility measure, also referred to as the "fear index" in the business media. Numerous windows surrounding each change in the terror threat level are estimated based on equation (2):

$$\begin{aligned} VIX_t = \mu + \beta_1 VIX_{t-1} + \beta_2 \left| \sum_{i=1}^{10} Incr_{t+i} + \sum_{j=1}^{X} Incr_{t-j} \right| + \beta_3 \left| \sum_{i=1}^{10} Decr_{t+i} + \sum_{j=1}^{Y} Decr_{t-j} \right| + \\ \beta_4 Incr2003 + \beta_5 Incr2004 + \beta_6 Incr2005 + \beta_7 Incr2006 + \beta_8 Decr2003 + \\ \beta_9 Decr2004 + \beta_{10} Decr2005 + \beta_{11} Decr2006 + \varepsilon_t \end{aligned} \qquad (2)$$

where $Incr_M$ and $Decr_N$ represent event-specific dummy variables that equal one when the threat level increases (decreases) on, or close to, trading day-M (-N), while *Incr2003–Incr2006* and *Decr2003–Decr2006* denote annual time dummies that equal one when the threat level increases or decreases during a particular year, respectively.

We check for diminishing marginal effects of increase/decrease announcements on volatility by including annual dummy variables for all years following 2002. As no "macro-terrorism" events have immediately followed an increase in the threat level, investors may have begun to question the quality of the information contained in terror alert announcements. In other words, investors may believe the DHS has been "crying wolf."

Alternatively, but with the same result, investors may simply have become complacent, believing that the U.S. government is effectively preventing terrorist attacks but still alerts the public in case an attack cannot be thwarted. Yet another argument, based on investor rationality, indicates that the alerts have less significance in later periods because investors have already adjusted their expectations earlier in 2002 to reflect a more uncertain world in which terrorism risk remains heightened for the foreseeable future. It is also possible that the probability of attack stays relatively stable when the threat level increases due to heightened security measures implemented during higher alert levels. Further, the effectiveness of security personnel and federal and local law enforcement could have improved over time, thus decreasing the likelihood of a successful attack or even an attempted attack.[8]

Lastly, if the DHS alert system effectively communicates new information regarding the possibility of a terrorist attack, then those investors with superior information (i.e., informed traders) might trade more actively following these announcements. To estimate the likelihood of information-based trading in a specific set of stock indexes, we compute the PIN described in Easley et al. (1996). This model relies upon the notion that trading results from: (a) the submission of market buy and sell orders by a large number of traders, and (b) trades from potentially informed traders. As we will discuss later in Section 5, Tables 7 and 8 report the empirical results based on this technique.

4.3. Hypotheses

To summarize the implications of the above models, we present in Table 2 a set of 12 testable hypotheses. Given the richness of the models described in the previous section, we have numerous hypotheses that can formalize the potential effects of changes in terror alerts on stock returns, volatility, and informed trading activity within the U.S. equity markets. We display both the null and alternative hypotheses in order to facilitate the analysis of our empirical results later in Section 5. As can be seen from this summary, Hypotheses 1–4 examine whether any changes in the threat level affect announcement-day returns and volatility, while Hypothesis 5 explores whether GARCH-type effects are present. Hypotheses 6–11 help identify whether there are asymmetric effects associated with threat level increases versus decreases (possibly due to partially anticipated responses to alert downgrades), and if stock market responses to terror alerts have remained constant over time. Lastly, Hypothesis 12 examines how changes in the threat level have affected trading by informed investors.

Table 2: Testable Hypotheses, Signs, and Result Location

Hypotheses	Null Hypotheses	Result
1	Announcement returns do not respond to decreases in threat levels	Table 3
2	Announcement returns do not respond to increases in threat levels	Table 3
3	Returns volatility do not respond to decreases in threat levels	Table 3
4	Returns volatility do not respond to increases in threat levels	Table 3
5	Conditional variance is not related to returns $\lambda = 0$	Table 4
6	Change from general to specific threats does not affect the returns $\beta_1 = \beta_2 = \lambda = 0$	Table 4
7	Announcements of increased threat levels do not affect returns $\beta_1 = \beta_2 = \beta_3 = \beta_4 = 0$	Table 4
8	Announcements of decreased threat levels do not affect returns $\beta_5 = \beta_6 = \beta_7 = \beta_8 = 0$	Table 4
9	Changes to threat levels do not affect volatility expectations $\beta_2 = \beta_3 = 0$	Table 5
10	Volatility responses to increases in threat levels stay constant $\beta_4 = \beta_5 = \beta_6 = \beta_7 = 0$	Table 6
11	Volatility responses to threat level decreases are constant $\beta_8 = \beta_9 = \beta_{10} = \beta_{11} = 0$	Table 6
12	Threat level announcements contain no new information PIN at higher threat level = PIN at lower threat level	Tables 7/8

Table 2 Continued

Hypotheses	Alternative Hypotheses, Signs, and Result Location	Result
1	Announcement returns are positive for decreases in threat levels	Table 3
2	Announcement returns are negative for increases in threat levels	Table 3
3	Returns volatility responds to decreases in threat levels	Table 3
4	Returns volatility responds to increases in threat levels	Table 3
5	Conditional variance is positively related to returns $\lambda > 0$	Table 4
6	Change from general to specific threats affects the returns process $\beta_1 \neq 0$, $\beta_2 \neq 0$, $\lambda > 0$	Table 4
7	Announcements of increased threat levels decrease returns $\beta_1 < 0$, $\beta_2 < 0$, $\beta_3 < 0$, $\beta_4 < 0$	Table 4
8	Announcements of decreased threat levels increase returns $\beta_5 > 0$, $\beta_6 > 0$, $\beta_7 > 0$, $\beta_8 > 0$	Table 4
9	Threat level increases/decreases raise/lower volatility expectations $\beta_2 > 0$, $\beta_3 < 0$	Table 5
10	Volatility responses to increases in threat levels decline monotonically $0 > \beta_4 > \beta_5 > \beta_6 > \beta_7$	Table 6
11	Volatility responses to threat level decreases decline monotonically $0 < \beta_8 < \beta_9 < \beta_{10} < \beta_{11}$	Table 6
12	Threat level announcements contain new information PIN at higher threat level > PIN at lower threat level	Tables 7/8

5. Results

5.1. Univariate Results

Table 3 provides daily return summary statistics for the seven indexes from March 12, 2002, through December 31, 2006. A priori, on threat level announcement days, we expect returns to be negative when the threat level increases and positive when the threat level decreases. Panel A of Table 3 shows that, on non-event days (i.e., when there are no changes to the terror alert level), average daily returns range from -0.005% to +0.078% for the AMEX Airline Index and CRSP Equally Weighted Index, respectively. Counterintuitively, when the general threat level is lowered, median daily returns are negative for all indexes, except for the Nasdaq Composite. Median daily losses range from -0.034% to -2.261% for the CRSP Equally Weighted and AMEX Airline Index, respectively.[9] In addition, median returns when the threat level is increased are positive for six of the seven indexes.[10]

Table 3: Index Return Summary Statistics for the Period March 12, 2002 to December 31, 2006

Panel A of this table reports descriptive statistics for equity returns on seven stock indexes, including test results for normality (*Normal*) with p-values (*ProbN*). F-tests for unequal variances between non-event (NE) days and perceived decreases (lower) and increases (raise) in general threat levels, i.e., threat level announcement days, are reported.
Panel B reports daily returns for single industry specific threat level announcements, lowering (Lower) or raising (Raise) the threat level.

Panel A: Multiple	N	Mean	Med	Min	Max	SD	SK	Ku	Normal	Prob
Airline/ NE	1196	-0.01%	-0.12%	-10.32%	13.79%	2.62%	0.2369	2.2150	0.9786	0.000
Gen Lower	5	-2.49	-2.26	-7.16	-0.07	2.81	-1.4990	2.5060	0.8482	0.188
Gen Raise	5	-0.88	-2.00	-3.91	3.92	3.02	1.1798	1.3115	0.9149	0.497
Bloomberg NYC/NE	1196	0.02	0.08	-19.65	5.30	1.11	-4.4986	82.0166	0.8018	0.000
Gen Lower	5	0.02	-0.47	-1.40	1.90	1.46	0.5115	-2.3623	0.8941	0.378
Gen Raise	5	0.57	0.28	-1.11	3.22	1.61*	1.3721	2.7971	0.8795	0.307
CRSP EW/ NE	1196	0.08	0.13	-3.12	3.48	0.77	-0.1367	0.8948	0.9914	0.000
Gen Lower	5	0.18	-0.03	-1.13	1.54	0.99	0.1185	0.3937	0.9785	0.926
Gen Raise	5	0.30	0.28	-0.82	1.74	0.93	0.8330	2.0629	0.9205	0.533
CRSP VW/ NE	1196	0.03	0.07	-3.82	5.30	0.97	0.2757	2.8985	0.9649	0.000
Gen Lower	5	-0.11	-0.62	-1.51	1.49	1.33*	0.4053	-2.7042	0.8851	0.332
Gen Raise	5	0.65	0.39	-1.03	3.26	1.59**	1.3229	2.6076	0.8931	0.372
Nasdaq Comp/ NE	1196	0.02	0.05	-4.18	7.78	1.34	0.3149	2.1143	0.9754	0.000
Gen Lower	5	0.46	0.27	-0.63	1.55	0.96*	0.1675	-2.5386	0.9144	0.494
Gen Raise	5	0.74	0.25	-1.48	3.88	2.00**	1.0007	1.5612	0.9416	0.677
Russell 2000/ NE	1196	0.04	0.05	-4.12	4.85	1.22	-0.0206	0.2738	0.9977	0.090
Gen Lower	5	0.21	-0.49	-0.76	1.93	1.18	0.9390	-1.2404	0.8359	0.153
Gen Raise	5	0.51	0.43	-1.63	3.11	1.69*	0.6645	2.1568	0.9039	0.431
S&P 500/ NE	1196	0.02	0.06	-4.15	5.73	1.01	0.3302	3.4769	0.9561	0.000
Gen Lower	5	-0.24	-0.89	-1.73	1.47	1.46*	0.4399	-2.8974	0.8574	0.219
Gen Raise	5	0.71	0.39	-1.01	3.54	1.71**	1.4125	2.6531	0.8870	0.342

Panel B: Single Threat Level Changes	Lower	Raise	Lower	Raise	Lower	Raise
Airline	1.63%	1.34%	-1.17%	-0.45%	-3.22%	-1.61%
Bloomberg NYC	0.08%	0.58%	-0.40%	0.04%	-0.03%	0.57%
CRSP EW	0.02%	0.25%	-0.43%	0.14%	0.47%	-0.14%
CRSP VW	0.06%	0.38%	-0.51%	0.27%	0.03%	0.35%
Nasdaq Comp	0.55%	0.56%	-0.81%	0.34%	-0.43%	0.25%
Russell 2000	0.40%	0.77%	-0.96%	0.16%	0.49%	0.12%
S&P 500	0.12%	0.46%	-0.60%	0.25%	-0.10%	0.44%
Mean	0.41%	0.62%	-0.70%	0.10%	-0.40%	0.00%
Median	0.12%	0.56%	-0.60%	0.16%	-0.03%	0.25%
Std	0.58%	0.36%	0.29%	0.26%	1.29%	0.75%

*, **, *** F-test for Difference Relative to Non-Event Days at the 10%, 5%, and 1% level

Panel B of Table 3 provides the returns for single-event threat level changes. Mean, median, and standard deviation of returns across the seven indexes are also reported. Again, we expect that returns should be negative when perceived threat levels increase but positive when threat levels decline. Contrary to expectations, the median daily return for these indexes is positive for increased threat levels to airlines, mass transit, and financial services. Only the positive response of the indexes to a lower threat level regarding airlines is consistent with expectations. Due to the statistical insignificance of these returns relative to non-event days, the univariate statistics for daily average returns are inconclusive regarding the relationship between changes in the perceived threat of a terrorist attack and U.S. equity returns.

The standard deviation of returns tells a different story. Relative to days with no announcements, the standard deviation of daily returns for the S&P 500 is 70% higher when the general threat level increases (i.e., 1.71% versus 1.01% in panel A of Table 3). Ex ante, we expect that any announcements regarding perceived threat levels will induce trading and increase volatility in response to the greater uncertainty engendered by these announcements. To check if these differences in the standard deviation of returns are statistically significant, we present results of F-tests of the differences between standard deviations of returns on non-event days compared with higher or lower threat level days in panel A of Table 3. For five of seven indexes, standard deviations of returns are significantly higher when general threat levels increase. The average increase in volatility of returns when the general threat level is increased is approximately 43% across all seven stock indexes.[11] This evidence suggests that, while changes in the perceived threat of a terrorist attack ambiguously affect the mean of equity returns, they are likely to increase the volatility of returns, especially when perceived threat levels increase. This is our first piece of evidence that perceived threats of terrorist attacks can affect systematic and nonsystematic risks.

Table 4 presents summary statistics for the CBOE VIX. Panel A separates industry-specific threat announcements from general threat announcements, while panel B treats general and industry-specific threats equally. In addition, both panels report F-tests for unequal variances between non-event (*NE*) days and general decreases (*Gen_Lower*) as well as general increases (*Gen_Raise*).

Table 4: VIX Summary Statistics for the Period March 12, 2002 to December 31, 2006

This table reports descriptive summary statistics for the CBOE Volatility Index (VIX). Panel A separates industry-specific threat announcements from general threat announcements. Panel B treats general and industry-specific threats equally. F-tests for unequal variances between non-event (NE) days and general decreases (Gen Lower) and general increases (Gen Raise) are reported in Panel A. P-values for t-tests of differences in mean values of VIX between NE days and Gen Lower and Gen Raise days are also provided. Panel B reports the same statistics but categorizes industry-specific threats as general threats.

							t-test of Means Unequal σ^2			F-test for Unequal σ^2		
Panel A	N	Mean	SD	Std Mean	Max	Min	*p*	*t*	*df*	*F*	*CV* @ 10%	*CV* @ 5%
Non-Event	1196	17.87	7.09	0.20	45.08	15.61					1.85	2.21
Gen	5	25.96	9.64	4.31	40.52	22.52	0.0059	-3.01	25	1.85		
Gen	5	27.81	8.18	3.66	35.08	31.75	0.1288	-1.57	27	1.33		
Airlines Lower	1	14.26										
Airlines Raise	1	14.46										
MassTrans	1	12.74										
Mass Trans	1	12.49										
Finl Serv	1	13.08										
Finl Serv	1	15.37										
Non-Event	1196	17.87	7.09	0.20	45.08	15.61					1.85	2.21
Lower Threat	8	21.23	9.79	3.46	40.52	18.11	0.0018	-3.59	20	1.91		
Raise Threat	8	22.67	9.44	3.34	35.08	19.12	0.0030	-3.35	22	1.77		

Panel A of Table 4 shows that there is a significant difference at the 10% level between days when the general threat level is lowered and days when the threat level stays the same (non-event). Consequently, we employ *t*-tests of differences in means assuming unequal variances. At the 1% level of significance, the mean value of VIX on days of general decreases in the threat level (25.96%) is significantly greater than the mean value on non-event days (17.87%).

When we include the industry-specific announcements with all general announcements in panel B, the results become more robust. The mean VIX values on both lower-threat (21.23%) and higher-threat days (22.67%) are statistically different from non-event threat days (17.87%) at the 1% level. Thus, although these simple univariate tests do not capture the stochastic nature of volatility, they do suggest that perceived increases and decreases in the threat level affect implied volatility.

5.2. Effects on equity conditional volatility and expected returns

To examine the potential positive relationship between terror threats and conditional volatility more formally, we present in Table 5 the AR(1), EGARCH-M (1,1) model estimates for each index's returns based on equation (1). For most indexes, the autoregressive, heteroskedastic nature of the daily volatility estimates is supported by the statistically significant parameter estimates for $ln(h_{t-1})$ and $g(z_{t-1})$ (denoted as δ_1

and θ_1, respectively). The direct effects of conditional volatility on daily returns are summarized by the estimates of $ln(h_t)$, λ. Although many of the estimates of δ_1, θ_1, and λ are statistically significant at the 1% level, the parameter signs are mixed.[12]

Table 5: EGarch-M Fama-French 3-Factor Model of Equity Returns for the Period March 12, 2002 to December 29, 2006 with Increases and Decreases in Terror Status

This table reports the estimates of conditional models of equity returns for seven indexes including changes in the level of the terror alert system. *Gen_Incr* = 1 when there is an increase in the general threat level, otherwise it equals 0. *FinlServIncr* = 1 when there is an increase in the threat of a terrorist attack on financial services companies in New York City, northern New Jersey, and/or Washington, D.C., otherwise it equals 0. *MassTransIncr* = 1 when the threat of attack on mass transit assets increases, otherwise zero. *AirlinesIncr* =1 when the threat of attack on airlines increases. Alternatively, when threat levels decline, *Gen_Decr* = 1, *FinlServDecr* = 1, *MassTransDecr* = 1, and *AirlinesDecr* =1.

The values beneath the parameter estimates represent the t-statistics and the significance of these test statistics. *, **, *** represent significance at the 10%, 5%, and 1% levels.

$$(y_t - R_f) = \beta_0 + \beta_1(R_m - R_f) + \beta_2 SMB + \beta_3 HML + \beta_4 y_{t-1} + \beta_5 Gen\_Incr + \beta_6 Finl\_Serv\_Incr +$$
$$\beta_7 Mass\_Trans\_Incr + \beta_8 Airlines\_Incr + \beta_9 Gen\_Decr + \beta_{10} Finl\_Serv\_Decr +$$
$$\beta_{11} Mass\_Trans\_Decr + \beta_{12} Airlines\_Decr + \lambda \ln(h_t) + \varepsilon_t$$
$$\varepsilon_t = \sqrt{h_t} \cdot e_t$$
$$\ln(h_t) = \delta_0 + \delta_1 \ln(h_{t-1}) + \theta_1 g(z_{t-1})$$
$$g(z_t) = \gamma_0 z_t + \gamma_1 \left[|z_t| - \mathrm{E}|z_t| \right]$$
$$z_t = \varepsilon_t \big/ \sqrt{h_t} \, ,$$

N=1212 Variable	AMEX Airline	Bloomberg Regional NYC	CRSP Equally Weighted	CRSP Value Weighted	Nasdaq Composite	Russell 2000	S&P 500
Intercept	-0.0045	-0.0001	0.0002	-0.0000	-0.0000	-0.0002	-0.0003
	(-0.01)	(-1.08)	(0.90)	(-592, ***)	(-0.23)	(-0.00)	(-4.93)
R_m-R_f	1.5454	0.9396	0.6842	0.9991	1.1110	1.1238	1.0256
	(4.85, ***)	(146, ***)	(158, ***)	(6217, ***)	(100, ***)	(9.51, ***)	(419, ***)
SMB	0.6780	0.1132	0.4664	0.0013	0.2549	0.9728	-0.1746
	(2.13, **)	(9.14, ***)	(62.9, ***)	(52.6, ***)	(16.2, ***)	(8.23, ***)	(-43.7, ***)
HML	-0.3028	0.2082	0.1520	0.0004	-0.6054	0.1475	-0.0896
	(-0.95)	(18,***)	(16.6,***)	(18.6,***)	(-57.8,***)	(1.25)	(-16.3,***)
y_{t-1}	0.0329	-0.0109	-0.3731	0.0089	0.0172	0.0118	0.0609
	(0.10)	(-15.2,***)	(-13.2,***)	(122,***)	(0.96,***)	(1.10)	(1.95,*)

Table 5 (continued)

The values beneath the parameter estimates represent the t-statistics and the significance of these test statistics. *, **, *** represent significance at the 10%, 5%, and 1% levels.

N=1212 Variable	AMEX Airline	Bloomberg Regional NYC	CRSP Equally Weighted	CRSP Value Weighted	Nasdaq Composite	Russell 2000	S&P 500
Gen_Incr	-0.0194	0.0000	-0.0007	0.0000	-0.0010	0.0009	0.0000
	(-0.06)	(0.02)	(-1.09)	(0.73)	(-0.69)	(0.01)	(0.08)
FinlServIncr	-0.0106	0.0079	-0.0042	0.0000	0.0032	0.0015	0.0005
	(-0.03)	(8.5, ***)	(-28.4, ***)	(0.05)	(12.4, ***)	(0.01)	(0.68)
MassTransIncr	0.0028	-0.0039	-0.0006	0.0000	-0.0002	0.0001	-0.0007
	(0.01)	(-1.29)	(-0.45)	(0.04)	(-0.74)	(0.00)	(-4.7, ***)
AirlinesIncr	0.0030	0.0016	-0.0012	0.0000	-0.0017	0.0005	0.0010
	(0.01)	(0.44)	(-0.95)	(0.11)	(-10.4, ***)	(0.00)	(1.58)
Gen_Decr	-0.0244	0.0013	0.0006	-0.0000	0.0046	0.0002	-0.0008
	(-0.08)	(0.98)	(0.74)	(-0.68)	(2.86, ***)	(0.00)	(-2.51, **)
FinlServDecr	-0.0308	-0.0017	0.0004	-0.0002	-0.0045	-0.0004	-0.0004
	(-0.10)	(-1.12)	(0.36)	(-17.68, ***)	(-39.90, ***)	(-0.00)	(-5.58, ***)
MassTransDecr	0.0106	-0.0006	0.0009	0.0001	-0.0005	-0.0000	-0.0011
	(0.03)	(-0.18)	(0.68)	(0.7800)	(-4.35, ***)	(-0.00)	(-1.73, *)
AirlinesDecr	0.0111	-0.0004	-0.0008	0.0001	0.0023	0.0013	0.0009
	(0.03)	(-0.10)	(-10.3, ***)	(0.84)	(19.6, ***)	(0.01)	(1.38)
δ_0	-0.0495	-21.7800	-0.2108	-18.1571	-0.0265	-0.0629	-1.0540
	(-0.16)	(-164, ***)	(-2.33, **)	(-49773, ***)	(-0.95)	(-0.53)	(-2.23, **)
$ln(h_{t-1})$	0.0041	-0.5890	0.1883	-0.7396	0.0940	0.1035	0.1572
	(0.01)	(-24.5, ***)	(6.32, ***)	(-13432, ***)	(4.31, ***)	(0.88)	(4.00, ***)
$g(z_{t-1})$	0.9938	-0.9424	0.9834	0.0147	0.9977	0.9952	0.9275
	(3.12, ***)	(-88.6, ***)	(139, ***)	(495, ***)	(409, ***)	(8.4, ***)	(28.5, ***)
z_t	-11.67	0.6888	-0.0687	0.2557	-0.1010	-0.0027	0.0726
	(-36.6, ***)	(23.9, ***)	(-0.97)	(4675, ***)	(-0.75)	(-0.02)	(0.49)
$ln(h_t)$	0.2024	0.0916	0.0996	-0.3339	0.0070	0.0128	0.2502
	(0.064)	(6.06, ***)	(0.74)	(-5980, ***)	(0.32)	(0.11)	(3.40, ***)
L	3071	5034	6094	9400	5160	6447	7091
SBC	-6014	-9940	-12060	-18763	-10192	-12766	-14055
AIC	-6106	-10032	-12152	-18764	-10283	-12858	-14146

Estimates of the potentially asymmetric effects of changes in the threat level are also presented in Table 5. For robustness, we include the Fama-French (1993) factors to control for market risk, as well as the effects related to firm size and the book-to-market equity ratio. The two Fama-French factors, the risk-free rate and the market return, were obtained from Kenneth French's web site.[13] Consistent with the univariate results presented earlier and the results of Rigobon and Sack (2005) related to war news announcements, the responses of index returns to changes in the perceived terror threat levels are mixed and, at times, have unexpected signs in a multivariate framework. For instance, general decreases in the threat level (as captured by the *Gen_Decr* dummy variable and the $\square_9$ parameter estimates) are negatively related to S&P 500 Index returns but positively related to Nasdaq Composite Index returns. However, the AMEX Airline Index, Bloomberg NYC Regional Stock Index, CRSP Equally Weighted Index and Value-Weighted Index, and Russell 2000 Index are not significantly associated with general decreases in the threat level. In addition, general increases in the threat level are unrelated to returns for all seven indexes.[14]

Variation in the relationship between threat level announcements and index returns might be driven by investors' perceptions that any change in the threat level (i.e., up or down) is "good news" for certain industries, such as the financial services industry, because it signals that the U.S. government is being proactive in its ability to prevent future attacks.

5.3. Effects on Implied Volatility

To further investigate the impact of changes in the perceived threat level on volatility expectations, we report multivariate tests using an implied volatility measure (the CBOE VIX) in Table 6. The event windows in this table extend from *X*-days prior (*Lead*) to an announcement of a new terror alert *increase* (*Incr*) to 10 trading days following the announcement. Similarly, the event windows surrounding announcements of *decreases* (*Decr*) in the terror threat level extend from *Y*-days prior to the relevant announcement to 10 trading days following the announcement. The particular time window is denoted by the number of days leading up to an announcement for terror alert increases and decreases, *Lead*(*X*,*Y*), respectively.[15]

Table 6: Models of the Effects of Terror Alert Announcements on Volatility Expectations

This table reports estimates of models of market expectations of near-term volatility measured by S&P 500 stock index options through the Chicago Board of Options Exchange (CBOE) Volatility Index (VIX). The variable *Incr* represents a time window surrounding the announcement of an increase in the terror alert status. Similarly, the variable *Decr* represents a time window surrounding an announcement of a decrease in the threat level. The time window for *Incr* and *Decr* extends from 10-days prior to an announcement to X-days preceding an increase announcement (Lead X), or Y-Days preceding a decrease announcement (Lead Y). Thus, Lead(X, Y) represents the number of days in the window preceding an announcement for increases and decreases, respectively. The remaining binary variables are: *Incr2003, Incr2004, Incr2005*, and *Incr2006* = 1 if an increase in the threat level occurs in 2003, 2004, 2005, or 2006, respectively, otherwise they equal zero. Similarly, the binaries *Decr2003, Decr2004, Decr2005,* and *Decr2006* = 1 if the threat level decreases during 2003, 2004, 2005, or 2006, respectively. The values beneath the parameter estimates represent the t-statistics and significance of the tests.

*, **, *** denote significance at the 10%, 5%, and 1% levels.

$$VIX_t = \mu + \beta_1 VIX_{t-1} + \beta_2 \left| \sum_{i=1}^{10} Incr_{t+i} + \sum_{j=1}^{X} Incr_{t-j} \right| + \beta_3 \left| \sum_{i=1}^{10} Decr_{t+i} + \sum_{j=1}^{Y} Decr_{t-j} \right| + \beta_4 Incr2003 + \beta_5 Incr2004 +$$
$$\beta_6 Incr2005 + \beta_7 Incr2006 + \beta_8 Decr2003 + \beta_9 Decr2004 + \beta_{10} Decr2005 + \beta_{11} Decr2006 + \varepsilon_t$$

Variable	Lead(3,0)	Lead(3,2)	Lead(3,3)	Lead(4,2)	Lead(5,2)	Lead(5,5)
Intercept	19.64	19.64	19.63	19.65	19.64	19.63
	(18.69, ***)	(18.71, ***)	(18.73, ***)	(18.63, ***)	(18.94, ***)	(18.94, ***)
VIX_{t-1}	0.9886	0.9886	0.9885	0.9887	0.9886	0.9886
	(236.30, ***)	(236.67, ***)	(235.34, ***)	(237.70, ***)	(237.02, ***)	(236.52, ***)
$Incr_{t+i,\, t-j}$	2.32	2.32	2.32	0.35	5.27	5.27
	(2.86, **)	(2.86, **)	(2.87, **)	(0.42)	(6.61, ***)	(6.61, ***)
$Decr_{t+i,\, t-j}$	-0.02	-0.77	0.65	-0.77	-0.77	0.11
	(-0.02)	(-1.35)	(1.13)	(-1.34)	(-1.37)	(0.19)
Incr2003	-2.13	-2.10	-2.13	-0.35	-4.66	-4.77
	(-2.34, **)	(-2.31, **)	(-2.35, **)	(-0.38)	(-5.19, ***)	(-5.31, ***)
Incr2004	-2.29	-2.28	-2.29	-0.45	-4.83	-4.66
	(-2.29, **)	(-2.29, **)	(-2.29, **)	(-0.45)	(-4.92, ***)	(-4.70, ***)
Incr2005	-2.42	-2.42	-2.42	0.00	-4.96	-4.96
	(-2.1, ***)	(-2.1, ***)	(-2.1, ***)	(0.00)	(-4.4, ***)	(-4.3, ***)
Incr2006	-1.84	-1.84	-1.84	-0.37	-5.17	-5.18
	(-1.60, *)	(-1.60, *)	(-1.60, *)	(-0.32)	(-4.59, ***)	(-4.58, ***)
Decr2003	-0.02	0.97	-0.05	0.93	1.04	0.00
	(-0.00)	(1.30)	(-0.00)	(1.25)	(1.41)	(-0.00)
Decr2004	-0.05	0.24	-1.09	0.24	0.24	-0.91
	(-0.00)	(0.29)	(-1.30)	(0.29)	(0.29)	(-1.10)
Decr2005	0.27	0.86	-0.96	0.86	0.86	-0.03
	(0.27)	(0.86)	(-0.90)	(0.86)	(0.87)	(-0.00)
Decr2006	-0.06	0.35	-0.72	0.35	0.35	0.28
	(-0.00)	(0.34)	(-0.70)	(0.34)	(0.35)	(0.28)
AIC	4221	4218	4217	4226	4180	4182
SBC	4283	4280	4280	4289	4243	4244
L	-2098	-2097	-2097	-2101	-2078	-2079

Of the models tested, the *Lead*(5,2) model performs the best with the lowest Akaike's information criterion (*AIC)* score (4,180). The *Incr* coefficient (β_2) of +5.27 for the *Lead*(5,2) model is statistically significant at the 1% level and shows that increases in the perceived threat of a terrorist attack coincide with heightened expected volatility. However, the *Decr* coefficient (β_3) of (-0.77) is not significant, suggesting that either announcements of decreases are not considered informative or they are partially anticipated and not reflected in the short lead time of this model. The former rationale of asymmetric responses to alert increases and decreases is more likely because the longer lead model, such as *Lead*(5,5), also finds decreases to be insignificantly positive, while increases are significantly positively related to implied volatility.

The marginal effects of increased threat level announcements are potentially consistent with the "cry wolf" hypothesis.[16] For example, the coefficients for the annual *Incr* dummy variables (*Incr2003-Incr2006*) are (-4.66), (-4.83), (-4.96), and (-5.17), respectively, and are all significant at the 1% level. These findings show that responses to increased threat level announcements are monotonically declining. That is, an increase in the terror threat actually leads to lower implied volatility levels over the period 2003 to 2006. This, in turn, provides support for the notion that investors are becoming less concerned about more-recent terror alerts (either due to the cry wolf hypothesis or because these later alerts do not contain as much new information about terror risk).

5.4. Changes in Informed Traders' Activity

We test the null hypothesis that terror alert announcements do not affect the level of informed trading. If the government is effective in assessing terrorism risks and disseminating valuable information to the public, then we should see informed trading increase during periods of heightened threat levels, as these traders might take advantage of the greater volatility associated with these announcements by executing trades with relatively uninformed investors.

Table 7 presents estimates of PIN based on Easley et al. (1996). We compute the PIN daily for the S&P 500 SPDR ETF (SPY) using intraday trades and quotes sampled every minute from 9:20a.m. to 4:00p.m. The daily estimates are averaged over the calendar date window associated with each threat level (i.e., green, blue, yellow, orange, and red) from the inception of the Homeland Security Advisory System on March 12, 2002.

Table 7: The Probability of Informed Trading (PIN) by Threat Level

The probability of informed trading (PIN) is computed daily for the S&P 500 Spider (SPY) using intraday trades and quotes sampled every minute from 9:20 a.m. to 4:00 p.m., creating 400 daily observations. The daily estimates are averaged over the calendar date window associated with each threat level since the inception of the Homeland Security Advisory System on March 12, 2002. The t-stat and Prob > t columns indicate whether the PIN estimates are significantly different from zero.

PIN = $\alpha\mu$ / $\alpha\mu$ + 2ε

Date	N-Days	SPY (%)	t-stat	Prob > t	Threat Level
3/12/02 – 9/9/02	106	15.64	13.30	(<.0001)	Yellow
9/10/02 – 9/23/02	10	17.91	3.98	(0.0032)	Orange
9/24/02 – 2/6/03	85	18.69	12.33	(<.0001)	Yellow
2/7/03 – 2/26/03	11	13.16	6.69	(<.0001)	Orange
2/27/03 – 3/16/03	8	19.51	4.25	(0.0038)	Yellow
3/17/03 – 4/15/03	18	24.79	6.96	(<.0001)	Orange
4/16/03 – 5/19/03	18	18.48	7.36	(<.0001)	Yellow
5/20/03 – 5/29/03	6	21.45	4.51	(0.0063)	Orange
5/30/03 – 12/20/03	123	17.12	16.46	(<.0001)	Yellow
12/21/03 – 1/8/04	10	25.98	5.94	(0.0002)	Orange
1/9/04 – 7/31/04	124	13.47	17.40	(<.0001)	Yellow
8/1/04 – 11/9/04	66	17.39	17.53	(<.0001)	Orange
11/10/04 – 7/6/05	150	15.07	25.16	(<.0001)	Yellow
7/7/05 – 8/11/05	24	13.49	8.43	(<.0001)	Orange
8/12/05 - 8/9/06	232	15.24	26.24	(<.0001)	Yellow
8/10/06 – 8/12/06	2	14.55	1.52	(0.3711)	Red/Orange
8/13/06 – 12/31/06	95	13.44	12.21	(<.0001)	Orange/Orange
Average	64	17.38			
Median	24	17.12			

Average probabilities of informed trading range from 13.16% for the 11-day period from February 7, 2003 to February 26, 2003, when the threat level was orange, to 25.98% from December 21, 2003 to January 8, 2004 (also a period when the threat level was orange). For the entire sample period, the average and median PIN are 17.38% and 17.12%, respectively. Table 8 presents t-tests for differences in the PIN levels between different threat levels and across various sub-periods. The sub-periods 2002-2004 and 2005-2006 are chosen to account for the structural change to the system described previously, as well as possible drop-offs in informed trading, consistent with declining responses by equity markets documented earlier. Panels A, B, and C compare PIN across two alert levels for the full period (panel A), as well as for the 2002-2004 and 2005-2006 sub-periods (panels B and C, respectively.) Panels D-F contrast PIN computed for the 5-days following all threat-level changes to all other days in the sample; they also provide results for the full period and subperiods 2002-2004 and 2005-2006. Panels G-I and J-L further break down the comparisons to the 5-days following threat level increases and the 5-days following threat level decreases matched against all other days over the full period and sub-periods.

While panel A shows that for 2002–2006, informed trading is not more likely during high or severe (orange or red) threat levels than during elevated levels, panel B confirms that the likelihood of informed trading is greater when threat levels are heightened during the 2002-2004 sub-period. Further, the results presented in panel C suggest that informed trading is lower when threat levels are elevated between during the 2005-2006 sub-period. When only 5-days following an announced change in the threat level are considered in panel D, informed trading appears to be higher for the full period. However, panels E and F show the results are driven by PIN estimates between 2002 and 2004. Panels G-I demonstrate a similar pattern when only threat level increases are evaluated; that is, higher probabilities of informed trading are present during the five trading days following heightened threat level announcements over the 2002-2004 period, but they disappear during 2005 and 2006. Lastly, panels J-L display no significant differences exist between mean PIN values for 5-day windows following threat level decreases and all other days. We interpret this evidence as a rejection of the hypothesis that threat level announcements contain no new information (H12), and that threat level increases soon after the system's inception (2002-2004) were the most salient.

Table 8: T-Tests of the Probability of Informed Trading

The probability of informed trading (PIN) is computed daily for the S&P 500 Spider (SPY) using intraday trades and quotes sampled every minute from 9:20 a.m. until 4:00 p.m., yielding 400 daily observations. Daily estimates are then averaged over calendar date windows associated with each threat level since the inception of the Homeland Security Advisory System on March 12, 2002. T-tests for differences between mean PIN values are computed by alert level, time period, and 5-day announcement windows.

Panel A: T-test between PIN Means for Yellow (Y) and Orange/Red (O) Alert (2002-2006)

N	PIN	Method	*t*-	Prob > *t*
846	0.1577 (Y)	Pooled (equal variances)	-0.65	0.5129
242	0.1627 (O)	Satterthwaite (unequal)	-0.63	0.5289
	-0.0050			

Panel B: T-test between PIN Means for Yellow (Y) and Orange (O) Alerts (2002-2004)

N	PIN	Method	*t*-	Prob > *t*
496	0.1610 (Y)	Pooled	-2.58	0.0101
121	0.1906 (O)	Satterthwaite	-2.64	0.0089
	-0.0296			

Panel C: T-test between PIN Means for Yellow (Y) and Orange/Red (O) Alerts (2005-2006)

N	PIN	Method	*t*-	Prob > *t*
350	0.1530 (Y)	Pooled	1.98	0.0481
121	0.1347 (O)	Satterthwaite	1.79	0.0748
	0.0184			

Panel D: T-test between PIN Means for All days vs. 5-days Post Announcement (2002-2006)

	N	PIN	Method	*t*-	Prob > *t*
All days (excl. 5-days)	1006	0.1563	Pooled	-2.75	0.0061
5-day Window	82	0.1890	Satterthwaite	-2.20	0.0304
		-0.0268			

Panel E: T-test between PIN Means for All days vs. 5-days Post Announcement (2002-2004)

	N	PIN	Method	*t*-	Prob > *t*
All days (excl. 5-days)	552	0.1627	Pooled	-2.62	0.0091
5-days Announcement	65	0.2016	Satterthwaite	-2.16	0.0340
		-0.0389			

Panel F: T-test between PIN Means for All days vs. 5-days Post Announcement (2005-2006)

	N	PIN	Method	*t*-	Prob > *t*
All days (excl. 5-days)	454	0.1486	Pooled	0.35	0.7245
5-days Announcement	17	0.1409	Satterthwaite	0.41	0.6877
		0.0077			

Table 8 Continued

Panel G: T-test between PIN Means for All days vs. 5-days Post Announcement for Alert Increases (2002-2006)					
	N	PIN Average	Method	*t*-stat	Prob > *t*
All days (excl. 5-days)	1046	0.1567	Pooled	-3.37	0.0008
5-days Announcement	42	0.2115	Satterthwaite	-2.52	0.0157
		-0.0548			
Panel H: T-test between PIN Means for All days vs. 5-days Post Announcement for Alert Increases (2002-2004)					
	N	PIN Average	Method	*t*-stat	Prob > *t*
All days (excl. 5-days)	582	0.1637	Pooled	-2.79	0.0055
5-days Announcement	35	0.2186	Satterthwaite	-2.16	0.0375
		-0.0550			
Panel I: T-test between PIN Means for All days vs. 5-days Post Announcement for Alert Increases (2005-2006)					
	N	PIN Average	Method	*t*-stat	Prob > *t*
All days (excl.	464	0.1479	Pooled	-0.84	0.4062
5-days	7	0.1758	Satterthwaite	-0.85	0.4263
		-0.0279			

Panel J: T-test between PIN Means for All days vs. 5-days Post Announcement for Alert Decreases (2002-2006)					
	N	PIN Average	Method	*t*-stat	Prob > *t*
All days (excl. 5-days)	1048	0.1585	Pooled	-0.41	0.6822
5-days Announcement	40	0.1654	Satterthwaite	-0.36	0.7218
		-0.0069			
Panel K: T-test between PIN Means for All days vs. 5-days Post Announcement for Alert Decreases (2002-2004)					
	N	PIN Average	Method	*t*-stat	Prob > *t*
All days (excl. 5-days)	587	0.1660	Pooled	-0.7353	0.4625
5-days Announcement	30	0.1817	Satterthwaite	-0.6482	0.5216
		-0.0157			
Panel L: T-test between PIN Means for All days vs. 5-days Post Announcement for Alert Decreases (2005-2006)					
	N	PIN Average	Method	*t*-stat	Prob > *t*
All days (excl. 5-days)	461	0.1490	Pooled	0.1553	0.2486
5-days Announcement	10	0.1165	Satterthwaite	0.6646	0.1270
		0.0325			

Taken together, the above results lead us to reject the null hypotheses described in Section 4 for H3-H4, and H6-H12. Thus, the rejection of these null hypotheses indicates that changes in terror threat levels: (a) positively affect conditional and implied volatility, (b) have monotonically lower effects on volatility over the sample period, (c) coincide with greater informed trading activity, and (d) have mixed/weak effects on the level of daily equity returns.

6. Policy and Portfolio Management Implications

The declining responses in volatility to increases in the perceived threat of terrorist attacks noted in the previous section have important policy implications. Why are conditional and implied volatility of equity returns responding less to the more recent DHS announcements of perceived increases in the threat of terrorist attacks? Consider the following options: (1) Were the large initial responses during 2002 the result of a permanent pricing of terrorism risks, causing later announcements to reflect only marginal increases in risk? The overall decline in volatility levels from 2003 through 2006 is not consistent with this idea, but does not preclude it. (2) Does the market perceive there to be less information in the later threat level announcements? If this were the case, the probability of informed trading should decline monotonically; however, it does not. (3) Are the declining responses reflecting the move to industry-specific announcements, thereby reflecting the lower value of specific assets perceived to be at risk of attack? For this to be true, we should see changes in conditional volatility move from the broad market indexes to the industry-specific indexes upon the move to industry-focused announcements. The greater number of significant effects of industry-specific threat announcements on the AMEX Airline Index and Bloomberg NYC Regional Stock Index (albeit with mixed signs) provides some support for this concept. (4) In view of the fact that no severe terrorist attacks occurred in the continental U.S. after any threat level increase announcement, is it a shortsighted “cry wolf” effect? (5) Alternatively, perhaps investors are simply not able to value or understand the information the DHS is trying to convey to the public, consistent with Knightian uncertainty. If the public cannot properly assess the risk of a terrorist attack, the DHS needs to alter the Homeland Security Advisory System to increase transparency or the quality and quantity of the information it disseminates (as it has recently done in 2011). We will probably not know why systematic and nonsystematic risks have become less responsive until there is a severe attack following an increased threat announcement (thus allowing analysts to estimate the probabilities of major attacks given DHS information and enabling investors to calculate expected losses).

Based on the current information contained in daily equity returns during the period 2001–2006, our results show that the increased volatility lasts about 10 trading days following the announcement. Thus, investors may want to eliminate some of the increased risk, Knightian uncertainty or not, using index put options or other hedging techniques following changes in threat levels. This hedging activity may cost several basis points in returns during most years, but it might be well worth it in the unfortunate situation in which the DHS raises the alert level and a macro-terrorism attack occurs soon thereafter.

7. Conclusions and Future Research

A key question investors face is how financial markets respond to sudden, large increases in uncertainty caused by factors such as the threat of terrorist activity on a global scale (also referred to as macro-terrorism). We find the conditional and implied volatility of daily U.S. equity returns to be positively and significantly related to increases in the threat of terrorist attacks. Although returns on broader stock market indexes do not always react to changes in threat levels as expected, PIN (the probability of informed trading) is consistently higher during periods of heightened threat alerts, reflecting the market’s assimilation of new information from informed traders. These findings are consistent with the hypothesis that the threat of terrorism might be a form of Knightian uncertainty, which ultimately affects both systematic and nonsystematic risks within a financial market. Although an investor may not be able to diversify away these risks fully, one can alter portfolio asset allocations or manage this increased risk via hedging techniques.

Responses to increased threat levels have also declined monotonically over the period of 2003–2006. Whether it is a case of "crying wolf" or the difficulty of assessing the financial impact of highly uncertain events such as terrorist attacks, one must consider whether these risks are underpriced. However, an alternative argument suggests that the muted reactions to these announcements might be due to the alerts becoming less informative in later periods. This view is consistent with the notion that more recent terror alerts are relatively uninformative because investors have already adjusted their expectations to reflect a more risky world in which terrorism risk remains heightened.

Identifying whether this decreased responsiveness to terror alerts is due to lack of credibility, possible mis-pricing, or a rational adjustment to new risks is an avenue for future research. Another topic for additional research is the identification of instruments that can forecast increases and/or decreases in the threat level, which, in turn, would enable investors to alter asset allocations or use risk management techniques, including shifting to U.S. Treasury securities as in flight-to-quality episodes.

Endnotes

[1] Important examples of Knightian uncertainty can be found in Keynes' (1921, 1936) rationale for "animal spirits" in financial markets (i.e., the effect of non-fundamental, psychological factors on asset prices) and the "Ellsberg Paradox" (1961). In particular, Ellsberg (1961) shows that people typically violate the basic properties of Savage-type (1954) expected utility functions. Ellsberg's experiment demonstrated that people are "uncertainty averse" because they prefer to play games of chance in which there are known probabilities and avoid games in which the probabilities are not known. See Epstein and Wang (1994) and Basili (2006) for further examples of the effects of Knightian uncertainty on asset prices, market "crashes," violations of put-call parity, the thinness of markets, and the bid-ask spread.

[2] These findings are consistent with Rigobon and Sack (2005), who show that war-related news affects the volatility but not the overall level of returns on various financial assets.

[3] For more details see http://www.dhs.gov/xnews/releases/press_release_0471.shtm. Secretary Ridge reported that the detail in intelligence reports enabled DHS to report that al Qaeda was targeting specific buildings, including the World Bank in Washington, D.C., the New York Stock Exchange and Citigroup buildings in New York, as well as the Prudential Financial building in northern New Jersey.

[4] On January 27, 2011, Janet Napolitano, Homeland Security Secretary, discussed the end of the color-coded alert system and introduced a new two-tiered threat alert system named the National Terrorism Advisory System (NTAS). For information on the NTAS, see the public guide at http://www.dhs.gov/xlibrary/assets/ntas/ntas-public-guide.pdf.

[5] See Abadie and Gardeazabal (2003), Brück and Wickström (2004), and Lenain et al. (2002) for more details on these types of studies.

[6] The EGARCH-M model is more relevant than the conventional GARCH approach, in our case, because EGARCH-M does not impose parameter constraints, although it adds the conditional volatility factor to the equation in order to describe the level of security returns.

[7] It should be noted that a weakness of the employed technique is it estimates long-run volatility and returns, ignoring possible regime shifts. However, because we use daily data, the wide range of threat

level durations causes properly specifying the appropriate number of regime shifts for non-linear models to be problematic. Further, efficiency gains are likely to be small or non-existent as the autoregressive model employed already captures some information of possible regimes. Thus, we leave this empirical question for future researchers.

[8] We thank an anonymous reviewer for suggesting this possible explanation.

[9] The *t*-tests of differences between the mean returns of non-event days across all seven stock indexes and returns on days of general increases and decreases in the perceived threat level, assuming unequal variances, were found to be insignificantly different. To conserve space, we do not report these results here but are available upon request.

[10] We also check for partial anticipation in the means by using event windows, such as (t-5, t-1), but do not find consistent results. Hence, the results are not reported here but are available upon request.

[11] Although not nearly as dramatic, the average level of volatility increases over 16% on days when the general threat level is lowered. Interestingly, the standard deviation of returns decreases significantly for the Nasdaq Composite Index on days when general threat levels are lowered.

[12] In particular, the conditional volatility of the Bloomberg NYC Regional Stock Index and the S&P 500 are positively related to returns in excess of the risk-free rate, while excess returns of the CRSP Value-Weighted Index is negatively related to conditional volatility. Thus, the evidence on the relationship between conditional volatility and daily returns is mixed. These findings are similar to prior studies investigating the relationship between conditional volatility and returns.\

[13] http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/

[14] Overall, five of the possible 28 responses to perceived threat level increases are significant (seven indexes times four categories of threat increases), including three negative responses and two positive responses. Out of the 28 possible responses to decreases in perceived threat levels, nine are significant with seven (2) shown to be negative (positive).

[15] For example, the model in the second-to-last column, *Lead*(5,2), represents time windows for increased threat level announcements during the five trading days prior to (and the 10 trading days following) these increased threat level alerts, while the time windows for decreased threat level announcements include the two trading days prior to (as well as the 10 days following) the announcement of the decreased threat alerts.

[16] This hypothesis predicts that market responses to terror alerts will decrease over time, as investors grow skeptical of the DHS's warnings (much like the shepherd boy's warnings in Aesop's classic fable)

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