

Garvey, John; Mullins, Martin

Working Paper

An Examination of "New" and "Old" Terrorism Using High-Frequency Data

Economics of Security Working Paper, No. 18

Provided in Cooperation with:

German Institute for Economic Research (DIW Berlin)

Suggested Citation: Garvey, John; Mullins, Martin (2009) : An Examination of "New" and "Old" Terrorism Using High-Frequency Data, Economics of Security Working Paper, No. 18, Deutsches Institut für Wirtschaftsforschung (DIW), Berlin

This Version is available at:

<https://hdl.handle.net/10419/119343>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

John Garvey and Martin Mullins

An Examination of “New” and “Old” Terrorism Using High-Frequency Data

September 2009

Economics of Security Working Paper 18



Economics of Security Working Paper Series

Correct citation: Garvey, J. and Mullins, M. (2009). "An Examination of 'New' and 'Old' Terrorism Using High-Frequency Data". Economics of Security Working Paper 18, Berlin: Economics of Security.

First published in 2009

© John Garvey and Martin Mullins 2009

ISSN: 1868-0488

For further information, please contact:

Economics of Security, c/o Department of International Economics, German Institute for Economic Research (DIW Berlin), Mohrenstr. 58, 10117 Berlin, Germany.

Tel: +49 (0)30 89 789-277

Email: neat@diw.de

Website: www.economics-of-security.eu

Economics of Security is an initiative managed by DIW Berlin

An Examination of “New” and “Old” Terrorism Using High-Frequency Data.

Keywords: Political risk, terrorist risk, financial markets, realized volatility.

Abstract

The impact of large-scale terrorist attacks has clear implications for financial market participants and corporate risk management. In this paper, that impact is measured in the intraday trading patterns of participants in the London stock market. A two-scale realized volatility (TSRV) estimator is used to provide an insight into market activity in a number of FTSE-100 companies in the days around the Madrid (11M) bombing. Furthermore, empirical trading patterns, reflected in trade volumes and five-minute realized volatility, are used to identify changes in risk perceptions in the immediate aftermath of the 11M attack. Intraday tick data illustrates the distinct perceptions of risk associated with “old” terrorism and “new” terrorism as represented by Al-Qaeda.

Introduction

This paper uses quantitative finance techniques and insights from political science to provide a precise examination of the effects of terrorism on the financial markets. The reaction and media commentary immediately following the Madrid (11M) bombings were marked by conflicting information regarding the attribution of responsibility. Evidence supporting the involvement of Islamic radicals emerged gradually in the hours after the event. Using high-frequency data (HFD) we observe the impact of this weight of evidence as it entered into the mainstream media and the financial markets. The lag time between the attack itself and the significant part of the market reaction appears counterintuitive to the notion of a highly liquid and efficient market. We present a strong rationale for the apparent delayed reaction. The effective use of the entire information set available in HFD distinguishes this paper from previous attempts at capturing the dynamic reaction to terrorist activity.

Terrorist events affect those in the proximity of an attack most acutely. In the context of international business operations, terrorism presents a series of risks both directly in terms of business interruption and property damage, and indirectly through declines in consumer confidence. The ability of terrorist groups to influence risk perceptions and subsequent trading patterns in financial markets is also worthy of serious consideration for many stakeholders. Terrorist groups have come to be feared not only for the immediate casualties and damage they cause but also for the long-term impact on business confidence. Al-Qaeda use media, particularly, the internet and television to amplify the emotional reaction to their attacks. The strategy reinforces the sense of dread associated with the human and physical cost of terrorist attacks in the US and Europe.

Background

On the morning of the 11th of March 2004, a series of bombs exploded on commuter trains in the Spanish capital resulting in an immediate death toll of 192 with some 1,247 people injured. This attack was

quickly recognised as one of the worst ever terrorist attacks to take place in Europe and left the city of Madrid traumatised. The timing of the attacks had profound long-term consequences on the Spanish *body politic* and on that country's foreign policy (Financial Times, 2004). The presence of Spanish troops in Iraq and the Spanish Prime Minister, José María Aznar's strong support for the "war on terror" were seen as the primary motivating factors for the bombings. Furthermore, the manner in which the crisis was handled by the Aznar government certainly contributed to its defeat in the general election later that month. The election brought the Socialist Party to power and Spanish troops were quickly withdrawn from Iraq.

There is a long history of terrorist groups striking at economic targets in Spain. Over the past twenty years the Basque separatist group, Euskadi Ta Askatasuna (ETA) have attacked Spanish economic infrastructure. In particular, they have attempted to cause disruption to Spain's vast tourist sector (Enders and Sandler, 1991). In a study of terrorism's impact on tourism in the Eastern Mediterranean, Drakos and Kutan (2003) show a strong causal relationship between terrorist violence and tourist flows. More recently, there has been an increased awareness of the impact of terrorism on financial markets. Barros and Gil Alana (2008) show the impact of ETA violence on Spanish/Basque stocks and a decrease in ETA attacks is shown to positively influence the share price of those companies based in the Basque Country. In the aftermath of the World Trade Centre (WTC) attacks, financial markets exhibited an increased vulnerability to terrorist risk. The events that day demonstrated that there was a new brand of terrorist organisation at work for which there were no limits on the scale of damage they would inflict on their enemies.

The WTC attacks produced a paradigm shift in political thought and policy. Garvey and Mullins (2008) show how trading activity in out-of-the-money put options on the FTSE-100 Index in the post-9/11 environment became extremely sensitive to terrorist attacks from Islamic extremist groups. A clear distinction is to be made between "new" terrorism and "old" terrorism. The term "old" terrorism refers to those groups such as ETA and the Provisional Irish Republic Army (PIRA) whose dispute with State

authorities is territorial. Support for these groups largely consists of a single ethnic group concentrated in one geographical area. These groups are highly dependent upon local support and this above all else limits their actions. As a result, we see a discourse emanating from these groups that seeks to maintain the legitimacy of their struggle and the justifiable nature of their actions. The use of such terms as “legitimate targets” and the adoption of military-style language e.g. “Active Service Units” or the “Madrid Commando” is commonplace.¹ Al-Qaeda and its affiliates are much less formal groupings in this regard and this has meant that their actions are much more unpredictable. This is the main characteristic of the “new” terrorism. The growing prominence of Islamic inspired violence with non-discrete goals and greater flexibility in terms of targets has changed the landscape of political risk. The ability of Al-Qaeda to strike in one part of the world and affect business interests elsewhere on the globe is now proven. There has been a realisation within terrorist groups, including Al-Qaeda of the importance of economic targets (Lutz and Lutz, 2006; Post, Ruby and Shaw, 2002). The involvement of such groups amplifies the “signal value” of individual attacks and now, where there are doubts, markets are eager to establish the authorship of any attack.² The reaction to the 11M bombings from both the political elite in Spain and market participants around the world demonstrate the salience of authorship with regard to terrorist attack. The gradual realisation that these bombings were the work of Islamic militants had a profound impact.

This attack is the singular example of the co-presence of “old” and “new” terrorism. For the first 48 hours or so after the bomb blasts there was an intense debate around the authorship of the attacks. Figures in the governing party, the Partido Popular (PP), made it clear from the outset that they believed ETA was responsible. The political atmosphere of the time was especially highly charged with a general election pending and a deeply unpopular war in Iraq.³ In the hours after the bombs, government sources attempted to establish a clear link between the bombing and ETA. According to government communications the explosive used in the attack was consistent with that used the Basque group. The links made by government became increasingly tenuous as the day progressed as it emerged that certain characteristics of the attacks pointed to Al-Qaeda. More substantial was the denial on the part of Batasuna that ETA was

involved. Batasuna, banned by the Spanish for its linkages to ETA, had never before rejected ETA attacks and was an authoritative voice with regard to the actions of ETA. Certainly, the attacks would have marked a radical shift in ETA military tactics.

The 11M bombings were carried out without warning and were designed to inflict mass civilian casualties. This tactic was virtually unprecedented for the ETA group and did not tie with the dual track military and political strategy that the organisation had been pursuing for many years. A statement by Arnaldo Otegi, the Batasuna leader, suggested the attacks could have been an operation by “sectors of the Arab resistance”. This raised fear that the bombs were the work of Al-Qaeda. By the early afternoon on the day of the bombing there were reports that a vehicle linked to the bombers had been found and that it contained tapes of Koranic verse.

The financial markets’ response to the 11M bombings was initially negative and virtually all European bourses declined on the news of the explosions. It is clear that as the day progressed the issue of the authorship of the attacks was seen as important by market participants and that doubts over whether or not ETA carried out the attack weighed heavily on the market. On the 11th of March, Cema Marti, a fund manager at Ata Investment was quoted by Reuters, “Sales came with the fall in European bourses because of fears Al-Qaeda is behind the blasts in Madrid...” (Reuters, 2004b). A second trader noted the perception that, “ETA is possibly not behind these attacks is putting additional strain on the markets” (Reuters, 2004c)⁴, while Jeremy Batstone of the brokers Fyshe Group said the market’s greatest fear was the Al-Qaeda network was responding the US led invasion of Iraq (Reuters, 2004d). The realisation within the financial community that this was the work of Islamic extremists was not immediate. As stronger information arrived to the market, share prices exhibited greater volatility both in Europe and the US. Commentary and market reaction show that ETA was perceived as being engaged in a discrete and local struggle against the Spanish State. The consequences of a long conflict with Islamic militants were seen as much more far-reaching. Despite the fact that the bombing took place in the euro-zone, trading on

that Thursday afternoon, the 11th of March saw the Euro rise against the dollar. Marc Kasumovich, currency analyst at Merrill Lynch explained these movements in the Forex market;

“The fact that the bombing in Spain might be linked to Al-Qaeda ...is behind the Euro's rise....It begs the question as to why this is negative for the dollar, but I think the rationale....is that the United States is believed to be more susceptible to terrorists than the euro-zone.” (Reuters 2004a)

It would appear that as the US is seen (and sees itself) as the main protagonist in the “war on terror” then attacks by their enemies reverberate strongly in US assets. In this instance it effectively devalued their currency and this implies that any “new” terrorist attack is perceived as heightening the risk to the United States. For international business this underlines the interconnectivity of world polity and the global economy.

Literature Review

Terrorism has its roots in power asymmetries and the consequences of terrorist conflict are highly uncertain. This is, in part due to an essential characteristic of terrorism, namely it is an attempt to strike at the psyche of the target population. In the case of Al-Qaeda this asymmetry is all the more striking and given the absence of a standing military-style structure (as in the case of PIRA), engaging in highly symbolic acts of violence becomes a key aspect of their strategy. The WTC attacks were extremely successful in this regard, indeed Slovic (2002) argues that 9/11 changed the manner in which we perceive terrorist risk. The impact of terrorist attacks are not temporally bounded and their impact may linger and continue to cause economic loss for some time after the initial event. In the social sciences and philosophy there is a widely held consensus that decision-making within the social realm is inevitably influenced by the past (Heidegger, 1962; Geertz, 1983; Ricouer 1981). The implications of this are quite profound in that decisions taken in the present are necessarily framed by past events and moreover any plausible explanation of current behaviour must factor in past experiences. Behavioural changes in the aftermath of the WTC attacks by the US population are well established and demonstrate this relationship

(Gigerenzer, 2006; Lerner, Gonzalez, Small and Fischhoff, 2003). The degree of unfamiliarity with the cause and outcomes from an event contributes to its resonance or “signal value” and herein lies the key to understanding the impact of terrorism (Slovic, 2002; Beck, 2002). Although many terrorist groups are unable to sustain themselves militarily over time and attacks may be infrequent, these attacks linger in the collective memory of the target population. In effect, they are constantly available to be recalled and the spectre of these events hangs over the present. Frequently cited, and valuable in this context is Thomas Nagel’s (1986) contention that we cannot achieve a “view from nowhere” and that our reactions are framed by our experiences.

In the case of terrorism, we are not only discussing the reaction of individual members of society but also the manner in which these events are communicated within any society. The role of both the State and the media in communicating risk are crucial in this regard, hence the concepts of intersubjectivity and power relations are indispensable tools in explaining reactions to terrorist events. The manner in which risks are communicated within financial markets determine the reaction of market participants. Thus, these concepts allow us to explain more fully reactions of individuals and groups of individuals in the aftermath of terrorist attacks.

Much of conventional financial theory relies on the assumption that individuals react to new information in a rational manner. The notion of rational behaviour among market participants is most strongly reflected in empirical tests of the efficient market hypothesis (EMH). Fama (1970, 1991), Jensen (1978) and Lo (1997) have provided empirical evidence that broadly shows strong-form market efficiency holds in the pricing of liquid stocks traded on major indices. The implication of this research is that all publicly available information is reflected in the stock price. Decision-making in an uncertain environment is influenced by a number of factors and certain characteristics of market participants do not fit neatly with traditional theories on rationality. In particular, studies in behavioral finance have demonstrated departures from rational decision-making. Individuals’ decisions are closely linked to reference points (Kahnemann and Tversky, 1974, 1979) and very often market participants are motivated by their

emotional states as well as the perception of control (Fenton-O'Creevey, Nicholson, Sloane and Willman, 2003).

Hogarth (2005) notes that decisions made by market participants are not based simply on discount rates and probabilities but are highly context-dependant. In many cases investors demonstrate an impulse to herd.⁵ This has been observed by Prechter and Parker (2007) in the buying behaviour of individuals during uptrends and their tendency to sell in downtrends. Prechter and Parker show that this behaviour “induces feelings of safety and well-being” (2007: 97) as investors succumb to the illusion that by following the general trend, they are somehow reducing their own risk exposure. DeBondt notes that as “investor behaviour likely affects what happens in markets” (1998: 841), it would be “unsound to model market behaviour based on the assumption of common knowledge of rationality” (1988: 842).

Research by Ellsberg (1961) and Fox and Tversky (1995) explores people's willingness to act in the presence of uncertainty. Their experimental work shows that the ambiguity or “vagueness” of a situation has important implications. When faced with the financial outcomes and costs associated with terrorist activity, investors find the risks to be highly vague or ambiguous. As the level of ambiguity regarding outcomes increases, investor's willingness to be exposed to these risks declines.

In this paper, we propose that Al-Qaeda presents a threat to the stability of the financial markets. This threat is likely to be more acute than that of terrorist groups that fall within the broad category of “old” terrorism. By examining both daily and intraday volatility patterns in highly liquid financial assets, we show the perceptions of the risk associated with “old” terrorism and “new” terrorism are markedly different.

Measuring Volatility

Asset price volatility is a key input in investment and risk management decisions and the volatility of an asset over a particular holding period is considered a starting point in assessing the risk associated with that asset. The accurate measurement of asset price volatility presents a series of challenges. “True” or

integrated volatility is unobservable since we only observe the discrete price movements of an asset and not the continuous dynamic that drives this movement. Issues associated with approximating “true” volatility relate to the optimal use of available data and the application of the best estimation method. A useful review of the literature of volatility modelling is provided by Poon and Granger (2003). In the context of this paper, a sophisticated measure of volatility is essential if we are to capture subtle market movements related to the arrival of new information.

Conventional attempts at measuring volatility were constrained by datasets that were often limited to daily intervals for even the most liquid of assets. Improvements in computational capacity have facilitated the recording of tick-by-tick price data. The increasing availability of high-frequency data (HFD) has allowed research into how this information can be optimally used to provide accurate estimates of “true” integrated volatility $\int_0^T \sigma_t^2 dt$ (Andersen, Bollerslev and Meddahi, 2004). The most primitive application of HFD is realized volatility estimated by summing up the squared returns in $[0, T]$:

$$[Y, Y]^{(n,1)} = \sum_{t_{n,i} \in G_{n,i} \geq 1} (Y_{t_{n,i}} - Y_{t_{n,i-1}})^2$$

where Y is the observed log prices of a financial instrument and observations take place on a grid of time points $G_n = \{t_{n,i}, i=0,1,2,\dots,n\}$. This method of calculating volatility is problematic since it does not account for the irregular intervals between recorded tick prices. Brown (1990) and Zhou (1996) have shown that the use of HFD in this manner leads to an inconsistent and biased estimator of realized volatility. The bias in the volatility estimator has been attributed to a series of issues categorised broadly as market microstructure effects and these effects become more dominant in the measuring process where finer sampling intervals are used.

An effective solution to overcome these so-called microstructure effects is the selection of a subgrid, G_n and the calculation of the squared returns from this subgrid. These intraday squared returns are then summed to produce a daily estimate of *realized volatility* (Fung and Hsieh, 1991; Andersen and

Bollerslev, 1998). Andersen, Bollerslev, Diebold and Labys (2001) recommend this method of sparse sampling as an efficient estimator. It has become practice to select sampling intervals, such as five-minute or thirty-minute intervals, in an ad-hoc manner. This approach has an obvious weakness from a statistical point of view since it excludes a significant amount of the information that is available in any dataset. In the context of this paper, realized volatility estimated using sparse sampling is an unattractive estimator since it omits the trading behaviour observed in tick-by-tick trade patterns.

In this paper, we avoid the issues associated with sparse sampling by using an estimator that includes all available tick data and adjusts for the bias associated with microstructure noise effects. The two-scale realized volatility (TSRV) estimator developed by Zhang, Mykland and Ait-Sahalia (2005) overcomes the bias associated with microstructure effects and provides a sensitive measure of daily realized volatility.

Applying the methodology to the FTSE-100 market, we first measure five-minute returns starting at 8:30, using the intervals 8:30-8:35, 8:35-8:40,...,8:31-8:36, 8:36-8:41, and so on. The full grid $G_n =$

$\{t_{n,i}, i=0,1,2,\dots,n\}$ is partitioned into K non-overlapping subgrids $G_n^{(k)}$, $k=1,\dots,K$, such that

$$G_n = \bigcup G_n^{(k)}, \text{ where } G_n^{(k)} \cap G_n^{(j)} = \emptyset \text{ when } k \neq j.$$

Set $n_t^{(k)}$ as the number of observations in each subgrid, and realized volatility (RV) for grid k as,

$$RV_t^{(k)} = \sum_{i=1}^{n_t^{(k)}} r_{t,i}^2.$$

Zhang, Mykland and Ait-Sahalia (2005) propose the following daily realized volatility (RV) estimator that includes all trades in the estimation procedure,

$$RV_t^{(ZMA)} = \frac{1}{K} \sum_{k=1}^K RV_t^{(k)} - \frac{\bar{n}_t}{n_t} RV_t^{(all)},$$

where $RV_t^{(all)}$ is estimated by summing, squared returns estimated from the full grid (one second intervals). The HFD used in this paper is produced by the London Stock Exchange (LSE) where trading takes place between 08:00 and 16:30, so that n_t , that is, the number of one-second observations is 30,600 and

$$\bar{n}_t = \frac{1}{K} \sum_{k=1}^K n_t^{(k)} = \frac{n_t - K + 1}{K}.$$

$RV_t^{(all)}$ measures the variance of microstructure noise and is used to correct the realized volatility bias observed in earlier studies. The approach used in this paper estimates across 5 minute subgrids, that is, $K=300$, so that in the first subgrid, $k=1$, returns are calculated from prices at the 08:00:00, 08:05:00, 08:10:00,...,16:25:00, 16:30:00 time marks; the second subgrid, $k=2$ consists of returns from prices at 08:00:01, 08:05:01, 08:10:01,...,16:25:01 and $k=300$, 08:04:59, 08:09:59, 08:14:59,...,16:29:59. Actual trade times occur at irregular intervals, so in order to calculate five-minute realized volatility a linear interpolation technique is applied to convert the prices recorded at irregular trade times a series of prices at regular intervals. Zhang, Mykland and Ait-Sahalia (2005) show that the TSRV estimator converges to integrated volatility at a faster rate than alternative estimators that use ‘sparse sampling’ techniques and its estimation is robust to the choice of interval.

Empirical Analysis

The volatility of equity prices for ten FTSE-100 companies is estimated using the TSRV measure. This is the first time that the risk implied in asset prices around a terrorist event has been measured in this way. The application of the TSRV estimator means that the entire sample of price observations contained in the HFD is fully and efficiently used. The sample period runs from the 5th March 2004 to the 14th March 2004 and the data used is the best price series recorded by the London Stock Exchange over that period. A preliminary filtering procedure removes outliers from the data set and considers transactions that take place within the London market’s trading hours (08:00 to 16:30).

Our empirical analysis estimates daily TSRV for ten FTSE-100 companies and explores the impact of the Madrid bombings on the share price of the cross-section of companies. The duration of the impact is assessed across a window of five trading days either side of the event. Furthermore, we carry out a preliminary examination of intraday share activity for two companies in the travel and leisure industry. The earnings of both British Airways and Hilton Group are strongly sensitive to increased terrorist activity in that it may impact on people's travel patterns. We focus on intraday volumes of shares traded and five minute realized volatility in the London stock market around the time of the attacks.

Two-Scale Realized Volatility (TSRV)

The daily TSRV estimator is calculated for the day of the 11M bombings and compared to the five previous trading days and the five subsequent trading days. The sample of ten companies is split into categories, defined as 'immune', that is, those whose earnings should not be affected by single terrorist attacks and the 'sensitive' group whose earnings are either directly or indirectly influenced by heightened terrorist activity. In the category of 'immune' companies, we include Barclays Bank (BARC), Cadburys (CBRY), Diageo (DGE), Marks and Spencers (MKS) and Tesco (TSCO). Movements in these companies is affected by stock-specific new information arriving to the market and a common sensitivity to mainstream economic factors including levels of consumer spending. Single one-off events should produce little effect on levels of uncertainty regarding the expected earnings. From Figure 1 we can observe a marginal increase in the TSRV estimates for the five companies. This increased level volatility on the 11th March can be attributed to broad-based asset allocation decisions relating to UK and European shares arising from the information flow from the 11M bombings.

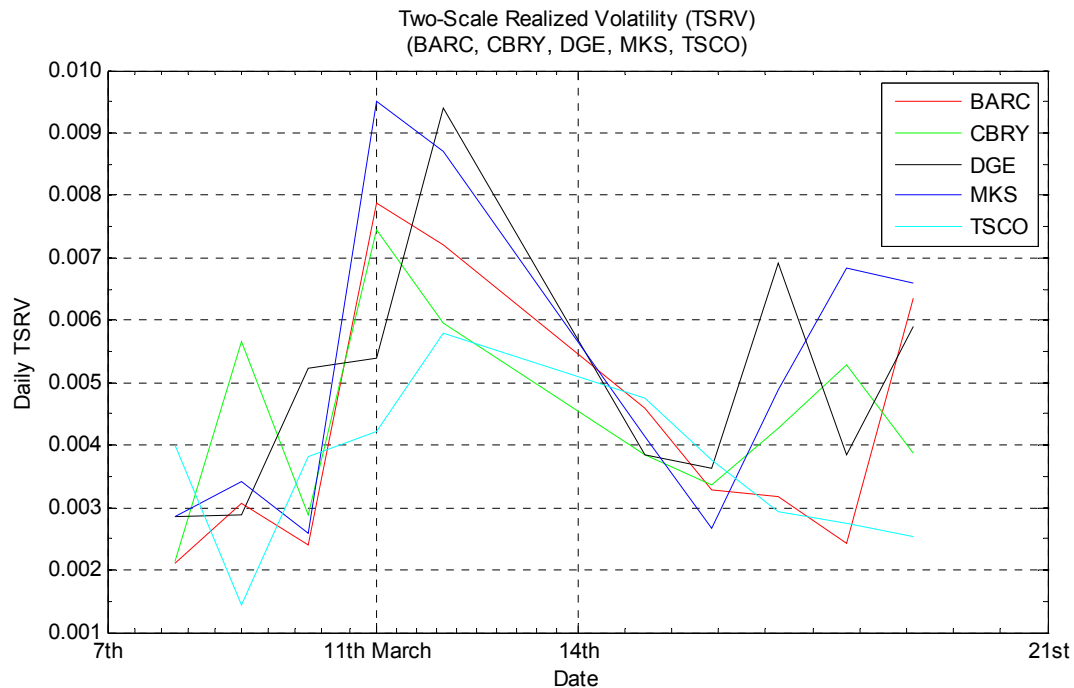


Figure 1 Daily TSRV Estimates for 'Immune' Companies

The five companies identified as 'sensitive' are those whose earnings are directly influence by changes in travel and leisure patterns, namely, British Airways (BAY), Hilton Group (HG) and International Hotel Group (IHG). For the purposes of comparison, we include in this category companies that we would expect to exhibit at least a mild reaction to heightened Islamic terrorism. The link between Islamic terrorism and the oil-rich Middle East is well established and for this reason we include British Petroleum (BP) and Imperial Chemical Industries (ICI) as representatives of oil-sensitive industries. Figure 2 shows that share price volatility for both British Airways and Intercontinental Hotel Group spike on the 11th March. The Intercontinental Hotel Group includes the Crowne Plaza and Holiday Inn chains and it operates eight hotel properties in Madrid. The TSRV estimator is significantly higher for IHG on the day of the attack, spiking by more the six times compared to the previous day. Hilton Group exhibits a minor reaction to the attack. The more ambiguous relationship between Middle Eastern terrorism and the stock

price of oil-sensitive stocks is not recognized in the market price reaction in the immediate aftermath of the attacks. The TSRV estimator for both British Petroleum (BP) and Imperial Chemical Industries (ICI) does show a minor increase on the day following 11M.

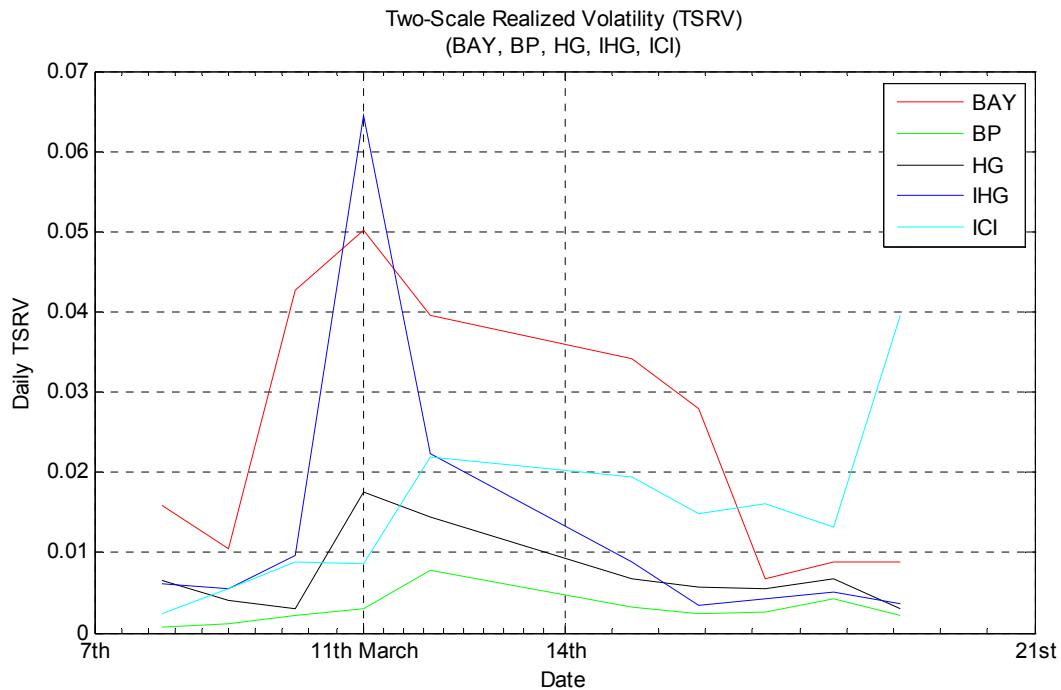


Figure 2 Daily TSRV Estimates for 'Sensitive' Companies

Intraday Trading Patterns

On the day prior to the attack, 790,283 shares were traded in Intercontinental Hotel Group (IHG) and the volume of British Airways (BAY) shares traded was higher at 1,873,055. The relatively high volumes of shares traded in both companies reflect the liquidity and the associated market efficiency in FTSE-100 companies. Based on end-of-day statistics, we can observe a dramatic increase in the volumes of shares traded in both companies. On the day of the bombing, the number of shares traded in IHG increased to 16,664,491 and the amount of BAY stock that changed hands also increased to 2,371,594. The increase in volumes on the 11th of March as compared with the previous day was 25% in the case of BAY and more than doubled among traders in IHG stock. On the 12th of March trade volumes remained high for both

companies BAY (2,025,639) and IHG (4,258,689). Ostensibly, the 11M attack appears to have increased uncertainty in the London Stock Market, particularly with respect to those companies with a sensitivity to travel and leisure. Observing the timing of intraday trading patterns for both companies tells us a lot more about how a highly efficient and liquid market in blue chip companies reacts to a terrorist event.

Intraday five-minute squared returns are calculated using five-minute intervals from the start of trade at 08:00 to 16:30 for the day of the bombing. The first step is to specify a grid of five-minute intervals across the trading day from 08:00, 08:35, 08:40,...,16:30 and estimate 'five-minute' prices using the interpolations method described earlier. Five-minute squared returns are estimated using the regular five-minute time series as;

$$RV_t = (P_t - P_{t-1})^2$$

Where P_t is the price at time t where t is 08:35, 08:40,...,16:30. Figures 3 and 4 show stock volume patterns and five-minute squared returns for IHG and BAY on the day of the Madrid bombings.

Comparison is provided by showing the trading days immediately before (10th March) and immediately after (12th March) the attacks.

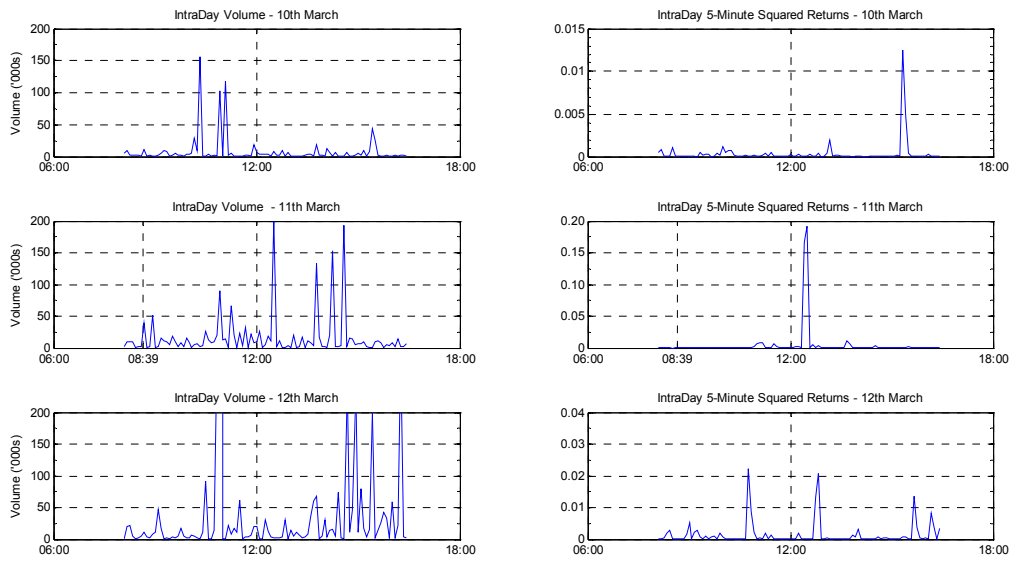


Figure 3 Intra Day Trade Patterns in IHG Stock

Given the heavy trade volumes in the stock of both companies, the speed of adjustment to new information should be rapid and relatively appropriate. In Figure 3 the heaviest trades in IHG stock traded on the day of the attack do not occur at the opening of the London market as we would expect, bearing in mind that the attacks took place at 06:39 GMT. In the aftermath of the attack the largest individual trades take place on the afternoon of the 11th and 12th of March. Intraday volatility, measured as five-minute squared returns, also spikes at these times. These trading patterns are clearly not a direct consequence of the physical damage arising out of the bombing. If that were the case, heavy volumes of trading activity should be observed at the market opening reflecting a speedy reaction to a terrorist event. The increasing level of activity in IHG stock is closely related to the news flow emerging throughout the day of the bombing. In particular, the timing crucial information linking the attacks to an Al-Qaeda affiliate can be directly associated with an acute rise in uncertainty and fear in the market.

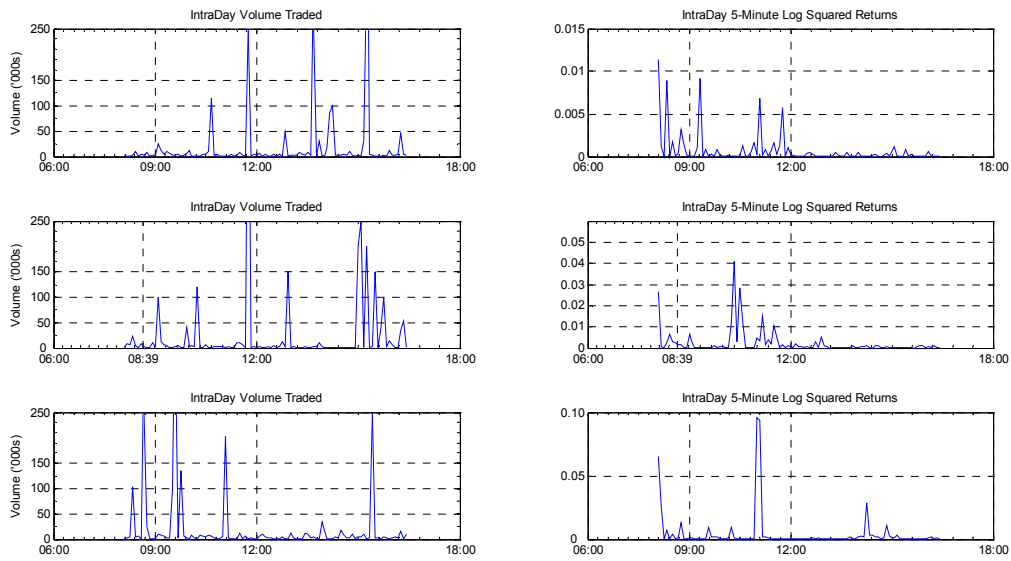


Figure 4 Intra Day Trade Patterns in BAY Stock

The trading pattern for British Airways stock also reflects the emerging reality that the attacks were not orchestrated by ETA. The initial low level reaction to the bombing gives way to heightened uncertainty reflected in greater activity in British Airways shares in the afternoon of the 11th of March and in the day following the attack.

Conclusions

The unique contribution of this paper is the application of HFD in measuring feelings of fear and uncertainty among market participants. This study is the first empirical analysis that extracts the complete information set available in HFD using the TSRV estimator. Our findings demonstrate a heightened negativity associated with outcomes from “new” terrorist events. The lack of an historical context for the 11M bombings depressed expectations and led to an increase in stock price volatility. We also illustrate the effects of risk communication on market sentiment in the intraday traded volume and five-minute squared returns of selected FTSE-100 companies. The results show that financial market participants are sensitive to the nuanced differences in the political and security issues arising from terrorist events that take place outside their national borders.

¹ Post, Ruby and Shaw, (2002) provide a discussion on the factors that restrain terrorist groups, including the attitudes of their political constituencies.

² The term “signal value” refers to the strength of a message(s) resulting from a hazardous event and the ability of these messages to alter perceptions of risk within populations. Where there is dread and uncertainty the signal is stronger. Useful also in this context are the notions of risk amplification and risk attenuation. For a full discussion of risk amplification see Pidgeon, Kasperson and Slovic, (2003). Kasperson and Kasperson (1996) are also instructive in this area.

³ One of the perceived strengths of the incumbent party was the hard line they had taken with ETA. The scale of the attacks was such that it would likely reaffirm the government strategy. However, given the high level of support by Aznar’s government for US activity in Iraq, the possibility that the attacks were Islamic inspired would have had serious implications for his party.

⁵ MacLean (1990) defines herding as unconscious and impulsive behaviour. It is considered to serve the function of increasing an individual’s chances of survival.

Bibliography

- Andersen, T.G., & Bollerslev, T, 1998. Answering the skeptics: Yes, Standard volatility models do provide accurate forecasts. *International Economic Review*, (39)4: 885-904.
- Andersen, T.G., Bollerslev, T., Diebold, F.X., & Labys, P. 2001. Modeling and forecasting realized volatility. *Econometrica*, 71(2): 579-625.
- Andersen, T.G., Bollerslev, T. & Meddahi, N. 2004, Correcting the Errors: Volatility Forecast Evaluation Using High-Frequency Data and Realized Volatilities, *NBER Working Paper*.
- Beck, U. 2002, The terrorist threat: world risk society revisited, *Theory, Culture and Society* 19: 29-55.
- Brown, S. 1990. Estimating Volatility. In S. Figlewski, W. Silber, and M. Subrahmanyam (eds), *Financial Options: From Theory to Practice*: 516-537. Homewood, IL: Business One-Irwin.
- DeBondt, W. 1998. A portrait of the individual investor. *European Economic Review*, 42: 831-844.
- Drakos, K. & Kutun A.M. 2003. Regional Effects of Terrorism on Tourism in Three Mediterranean Countries *Journal of Conflict Resolution*, 47 (5): 621-641.
- Ellsberg, D. 1961, Risk Ambiguity and Savage Axioms, *Quarterly Journal of Economics*, 75(4): 643-669.
- Enders W. & Sandler W., 2003. Causality Between Transnational Terrorism and Tourism: The Case of Spain *Terrorism* 14 (1): 301-316.
- Fenton-O'Creevey, M., Nicholson, N., Sloane, E. & Willman, P. 2003, Trading on Illusions: Unrealistic perceptions of control and trading performance, *Journal of Occupational and Organizational Psychology*. 76: 53-68.
- Fox, C. & Tversky, A. 1995. Ambiguity Aversion and Comparative Ignorance, *The Quarterly Journal of Economics*, 110 (3): 585-603.
- Financial Times 2004 After the Madrid bombings. Triumph of terrorism or victory for democracy? Spain's stunning election results asks tough question of Europe. *Financial Times* March 16, 2004: p. 11.
- Fung, W. & Hsieh, D. 1991. Empirical analysis of implied volatility: Stocks, Bonds and Currencies, *Working Paper, Department of Finance*, Fuqua School of Business.
- Garvey J. & Mullins, M. 2007 Contemporary Terrorism: Risk Perception in the London Options Market *Risk Analysis* 28 (1): 151-160.
- Geertz, C. 1983. Local Knowledge, Further Essays in Interpretative Anthropology. New York: Basic Books.
- Gigerenzer, G. 2006. Out of the Frying Pan into the Fire: Behavioral Reactions to Terrorist Attacks. *Risk Analysis*, 26 (2): 347-351.
- Heidegger, M. 1962. Being and Time. Oxford: Basil Blackwell.
- Hogarth, R. M., 2005. The Challenge of Representative Design in Psychology and Economics. *Journal of Economic Methodology*, 12(2): 253-263.

-
- Kahneman, D. & Tversky, A. 1974, Judgment under Uncertainty: Heuristics and Biases, *Science*. 185 (4157): 1124-1131.
- Kahneman, D. & Tversky, A. 1979, Prospect Theory: An Analysis of Decision under Risk, *Econometrica*. 47(2): 263-292.
- Kasperson R E., Kasperson J X. 1996, The Social Amplification and Attenuation of Risk. *Annals of the American Academy of Political and Social Science*. 545: 95-105.
- Lenain P. & Bonturi, M. & Koen, V. 2002 The Economic Consequences of Terrorism. OECD Economics Department Working Papers 334, Paris: OECD Economics Department.
- Lerner, J. S., Gonzalez, R. M., Small, D. A., & Fischhoff, B. 2003 Effects of fear and anger on perceived risks of terrorism: A national field experiment. *Psychological Science*, 14: 144-150.
- Lutz, J. M. and Lutz B. J. 2006. Terrorism as Economic Warfare *Global Economy Journal* 6 (2): 1-20.
- MacLean, P. D. 1990 *The Tribune Brain in Evolution: Role in Paleocerebral Functions*. New York: Plenum Press.
- Maillet B, & Michel T. L. 2005 The Impact of the 9/11 Events on the American and French Stock Markets. 13(3): 567-611.
- Nagel, T. 1986. The View from Nowhere. New York: Oxford: Oxford University Press. Pidgeon, N, Kasperson, R.E. and Slovic, P. (eds), 2003. *The Social Amplification of Risk*. Cambridge, UK: Cambridge University Press.
- Poon, S-H. & Granger C.W.J. 2003, Forecasting Volatility in Financial Markets: A Review, *Journal of Economic Literature* 41: 478-539.
- Post J. Ruby K. G. and Shaw E. D. 2002 The Radical Group in Context: 1. An Integrated Framework for the Analysis of Group Risk for Terrorism *Studies in Conflict & Terrorism*, 25: 73-100.
- Prechter, R. R. and Parker, W. D. 2007. The financial/economic dichotomy in social behavioral dynamics: The socioeconomic perspective. *The Journal of Behavioral Finance*, 8(2): 84-108.
- Reuters (11/03/2004)a, Forex-Dollar extends fall on purported Qaeda Madrid Link.
<https://portal.hpd.global.reuters.com>
- Reuters (11/03/2004)b, Turkey's shares slip after Madrid blasts. <https://portal.hpd.global.reuters.com>
- Reuters (11/03/2004)c, Eurostock sink 3 pct on Madrid blasts, NY outlook.
<https://portal.hpd.global.reuters.com>
- Reuter (11/03/2004)d Sector de Viajes Europa afectado por atentados en Madrid.
<https://portal.hpd.global.reuters.com>
- Ricoeur, P. (ed. & translated by Thompson, John. B) 1981. *Hermeneutics and the Human Sciences*. Cambridge: Cambridge University Press.

Shefrin, H. 2000. *Beyond Greed and Fear: Understanding Behavioral Finance and the Psychology of Investing*. Boston: Harvard Business School Press.

Shleifer, A. 2000. *Inefficient Markets: an Introduction to Behavioral Finance*. Oxford: Oxford University Press.

Slovic, P. 2002 Terrorism as Hazard: A New Species of Trouble *Risk Analysis* 22 (3): 425-426.

Thaler, R.H. 1993. *Advances in Behavioral Finance*, New York: Russell Sage Foundation.

Zhang, L., Mykland, P.A. & Ait-Sahalia, Y. 2005. A tale of two time scales: Determining integrated volatility with noisy high-frequency data. *Journal of the American Statistical Association*, 100(472): 1394-1411.

Zhou, B. 1996. High-frequency data and volatility in foreign-exchange rates, *Journal of Business & Economic Statistics*, 14: 45-52.