The Effects of Recent Terrorist Attacks on Risk and Return in Commodity Markets

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Abstract

The event study methodology of Brown and Warner (1985) is adopted and augmented to evaluate the effect of the recent terrorist attacks on risk and returns in commodity markets. The methodology is supplemented with various techniques, such as the non-parametric ranking test and kernel regression, to identify if 20 terrorist attacks (including in Paris, Nice, Brussels, Stockholm, Manchester, Jakarta, London and Melbourne) generate abnormal returns. Asset pricing models are fitted with interaction variables while GARCH, TARCH, EGARCH and PARCH models are used to determine changes in systematic risk. Our results show abnormal returns and delayed reactions of up to 120 days in the commodity markets—evidence which defies the efficient market hypothesis. In addition, we identify sector and commodity effects in risk analysis.

JEL Classification: G12, G14, H56

Keywords: Terrorist Attack, Abnormal Returns, Systematic Risk, Commodity Market

1. Introduction

Terrorist activities or related matters make headlines on a daily basis with the most recent, at the time of writing, being the London tube bombing that injured 30 people on 15 September 2017. Terrorist activities are proclaimed to be disruptive as they are expected to promote fear in the populace, not just in the immediate area of the attack, but also in the wider community. In addition to increasing the risk of conducting business, these events affect the demand for a variety of products, as evidenced by sectoral abnormal returns in the equity markets. For instance, Cam (2008) shows that the September 11 terrorist attacks resulted in both positive (water, defence and telecommunications) and negative (airline, hotel and leisure industries) reactions on industry equity index returns.

Poteshman (2006) provides evidence of conspiracy theories surrounding the September 11 terrorist attacks whereby he shows an unusually high level of option trading activities in terms of put option buying. We extend this line of thought to the commodity markets, which tend to have delayed reactions due to seasonal aspects of certain commodities. Furthermore, while the findings of the equity markets are generally known, the effects of terrorism on commodity markets is relatively undocumented. Hence, the objective of this paper is to document how the recent terrorist attacks affect the risk and return of commodity markets.

From an economic perspective, volatility or large commodity price fluctuations following terrorist activities have considerable economic consequences. For instance, large price movements in oil prices are beneficial for oil producing countries and corporations, but economically detrimental for countries and corporations that have a heavy reliance on oil

importation. In turn, the difference between importers and exporters of oil affects individuals both positively (through higher standard of living) and negatively (inflationary tendency). Hence, terrorism has indirect economic consequences. Similarly, terrorism has the potential to (1) fetter investment and economic growth due to uncertainty, (2) increase cost of international trade, and (3) increase cost of production following an increase in security costs.

The efficient market hypothesis dictates that prices reflect all available information, including all terrorist activities. Market participants assess how terrorist activities affect prices, risks, returns and profitability, through anticipated (*ex-ante*) effects on costs and revenues. Immediately after an attack, analysts attempt to determine which equity stocks will be affected but they must wait for a longer period, (due to market processing time and new discoveries), to determine how the commodity market is affected. For example, following the September 11 attacks, insurance companies in the US waited a few weeks before they announced they were reinsured in Europe, and European insurance companies, in turn, revealed their re-insurance policies in the Asia-Pacific region after a longer period. In that example, we observe a delayed reaction, with a 'discovery effect', whereby the discovery is in terms of Australian insurance companies having an exposure around the September 11 terrorist attacks. We argue for a similar information 'discovery' process flow into the commodity markets as our goal is to show that commodity markets take a longer time to digest the effects of terrorist attacks. In addition, we should not forget the seasonal aspects of certain commodities, the time of production and derivative contracts on these products which may cause a delayed market reaction.

We consider the global commodity market and 20 terrorist events: September 11 attacks, Madrid bombings, London bombings, Delhi bombings, Mumbai- train bombings, Moscow Metro bombings, Charlie Hebdo shooting, Paris attacks, Jakarta attacks, Brussels bombings, Nice attacks, Pukhrayan train derailment, Istanbul bombings, Istanbul nightclub shooting, Mali bombing, Quebec City mosque shooting, Westminster attack, Stockholm attack, Manchester Arena bombing and London Bridge attack (see Table 1 for details). These provide an ideal testing ground for our arguments.

Given these increasingly frequent uncertain times, investors, traders, commodity-exporting/importing countries and monetary authorities will be interested in the findings of our study. Our contributions are as follows. First, we identify how the global commodity market was affected in terms of both risk and return. Second, we provide batteries of robustness tests including the Corrado (1989) non-parametric and Chesney et al. (2011) conditional probability robustness tests. Third, we look at how subsequent/recent attacks affected the various sectors within the commodity market. Fourth, we provide evidence that challenges the efficient market hypothesis.

To the best of our knowledge, there is no current study that investigates the effects of the recent terrorist attacks on the commodity market as a whole and addresses economic implications of the attacks. In Section 2, we provide a brief literature review. Section 3 presents the data and methods used in this paper. Section 4 presents the empirical findings, and Section 5 provides some concluding remarks.

2. A brief look at the literature

The effects of terrorism on the return of equity markets have been well documented in the literature, with event study methodology at its core. For instance, Chen and Siems (2004) study the effects of 14 terror attacks to conclude that capital markets in the US, UK, France, Belgium, Sweden, Australia and Indonesia are sensitive to these events. More specifically within the European context, we find a mixed reaction—for instance Baros and Gil-Alana (2009) show that stock markets react negatively, while Apergis and Apergis (2016) argue otherwise. Ramiah, et al. (2010), Ramiah (2012), Graham and Ramiah (2012), Ramiah and Graham (2013) and Ramiah and Hui (2015) contribute to this debate by showing that the September 11, Bali, Madrid, London and Mumbai terrorist attacks affected various sectors within the Asia-Pacific markets, and particularly Australia, Malaysia, Japan, Indonesia and Singapore respectively. Chen and Siems (2004) and Richman et al. (2005) conclude that the global equity markets are affected.

We notice a burgeoning series of papers in the area of the risk of terrorism on equity markets, with examples of these papers being Aslam and Kang (2015), Apergis and Apergis (2016) and Veron et al. (2017). Researchers in this area have a tendency to either (1) fit interaction variables to asset pricing models such as the CAPM or (2) use GARCH, TARCH, EGARCH and PARCH to determine changes in systematic risk. While most studies show an increase in risk in the domestic market following a terrorist event, Graham and Ramiah (2012) argue that international markets do not react as traders have already incorporated terrorist risk in their risk analysis post the September 11 attacks.

Chesney et al. (2011) proclaim to be the first study that looks at how terrorism affects the bond and commodity markets. They analyze how 25 terrorist events affect financial markets using event-study methodology, a non-parametric conditional distribution approach and a filtered GARCH–EVT model. Similar to the equity markets, their analysis shows both significant positive and negative reactions of commodity and gold market returns following terrorist attacks. Contrary to the notion that gold is a 'safe-haven'[1] investment during crisis periods, Chesney et al. (2011) show that the gold market behaves in an unexpected manner in that it did not react to the London bombings and even reacted negatively to other events. They argue that using commodity and gold markets as a hedging strategy against terrorism may not always work.

In a similar vein, Guidolin and La Ferrara (2010) investigate the impact of 101 internal and international military related conflicts on stock market indices, exchange rates, oil and commodity prices for the period 1974 to 2004. Their findings indicate the onset of military conflict result in mixed reactions. For instance, while the onset of an international conflict results in appreciation of the US dollar as a safe haven there was no discernible difference in the gold futures price. Additionally, international conflicts, on average, cause a decrease in the returns of oil futures, but no difference is observed for internal conflicts. In the same vein, for agricultural commodities, international conflicts are observed to decrease the value, while internal conflicts cause an opposite effect. While broadly similar to our objective, this study, through its analysis

[1] From past experiences, we have observed a significant increase in price of gold during conflict times such the Soviet Union's invasion of Afghanistan in 1979 (price increased from US$300 per oz in July 1979 to over US$500 per oz in December 1979) and Iraq's invasion of Kuwait in August 1990 (day of invasion price increased from US370.60 per oz to over US380.70 per oz).

of conflicts, provides a good rationale for analysing the effects of terrorism on commodity prices as the literature is unresolved.

As for the risk analysis, Choi and Hammoudeh (2010) study the effects of financial and geopolitical crises on commodity prices, such as Brent oil, WTI oil, copper, gold and silver, and show different volatility persistence responses. They examine the volatility persistence in the multi-variate DCC GARCH model after controlling for two structural breaks, namely the 1997 Asian crisis and the September 11 terrorist attacks. Choi and Hammoudeh (2010) conclude that Brent and WTI crudes have more volatility persistence over time in response to September 11 terrorist attacks, while copper is more sensitive to the Asian financial crisis.

The asymmetry of research in the area of terrorism and financial markets is quite significant, as we have seen a large number of papers in the equity markets but a relatively low number in the commodity markets. Furthermore, the literature fails to provide an answer as to how the commodity market reacted to the recent terrorist events. Combined, these two observations provide motivation for our research.

3. Methodology

The empirical work is based on the event study methodology, as we seek to find out what happens to abnormal and cumulative abnormal returns following the events listed in Table 1 as described briefly in the previous section. Following the early research by Brown and Warner (1985), MacKinley (1997) reiterates the importance of this event study methodology by arguing that the results generated by financial data series provide leading indicators as opposed to

lagging indicators provided by models that use economic variables. This is due to the data collection/availability which usually takes longer for economic variables. Furthermore, this is the preferred and highly recommended method when it comes to measure the effects of a particular event (Rau and Vermaelen, 1998; Giroud and Mueller, 2010; Chen and Siems, 2004).

The starting point is the calculation of daily returns, which are represented by the first natural logarithmic differences of the underlying stock prices. Following Brown and Warner (1985) and Ramiah et al. (2013), daily returns are adjusted to obtain *ex-post* abnormal returns where adjustments are approximated by the CAPM and other asset pricing models such as the rolling average model, the market model, the Fama-French three-factor model and the Carhart four-factor model. Commodity abnormal returns (AR) are then grouped into sectors to obtain the average sector (S) abnormal returns at time t, $(AR)_{st}$. The standard t-statistic for a sector's abnormal return is computed to find out if it is significantly different from zero. This gives rise to three possible outcomes: no abnormal returns, positive abnormal returns and negative abnormal returns.

The implicit assumption is that the abnormal return of a commodity sector is a function of demand and supply of each of the commodities in the sector. The first outcome of zero abnormal return materializes when demand or supply do not change following the terrorist attack. Under this scenario, the sector is not affected by the event. The second possible outcome of positive abnormal returns, typically associated with the metals sector, is as a result of an increase in the demand for products to be used in rebuilding (or hoarding of the commodity) and leads, in turn, to higher prices. The third outcome of negative abnormal returns will materialize if demand for

commodities within the sector decreases through a higher probability that subsequent attacks will disrupt the supply chain.

According to the efficient market hypothesis (EMH), the stock market reacts instantly to new information arrival as prices reflect the information content of the event instantly. However, when the EMH does not hold, the effect may take the form of over-reaction and under-reaction. To that end, we estimate the cumulative abnormal return (CAR) over the following five to 120 trading days to find out whether the market reverts to its mean process or continues to deviate from the mean price. We use the t-test to determine the statistical significance of cumulative returns.

3.1 Robustness Check

Additional tests are undertaken to check the robustness of the results. According to Corrado (1989), one of the criticisms of the Brown and Warner (1985) approach is that abnormal returns are not normally distributed, which leads to bias in the parametric t-statistics. To circumvent this problem, we adopt the Corrado (1989) non-parametric ranking procedure as the first robustness test. This test requires the transformation of abnormal returns into ranks over a combined period of 260 days. The period is broken up into 244 days before the event and 15 days afterwards. The ranks are then compared with the expected average ranks under the null hypothesis of no abnormal returns. A non-parametric t-statistic is accordingly calculated.

The non-parametric conditional distribution approach proposed by Chesney et al. (2011) is also used as an alternative robustness test, given that kernel estimation does not require the

specification of a regression equation or the distribution of the error term. Chesney et al. (2011) and Graham and Ramiah (2012) highlight the need to control for synchronicity, stock market integration, and spillover effects in event study. To that end, abnormal returns are calculated by augmenting the asset pricing models with three market risk premia representing Asia ($\tilde{r}_{mt}^{Asia} - \tilde{r}_{ft}^{Asia}$), Europe $\left(\tilde{r}_{mt}^{Europe} - \tilde{r}_{ft}^{Europe}\right)$ and the US ($\tilde{r}_{mt}^{US} - \tilde{r}_{ft}^{US}$).

Bilson et al. (2012) justify the augmentation process with reference to the factor model of Bekaert et al. (2005), which they use to estimate cross-market linkages. This model is specified on the assumption that markets are integrated, either internationally or regionally. Hence the model contains a term that represents the world market factor, implying that under global market integration, expected returns should be a linear function of the excess return on the world market. The model also contains a regional factor, calculated as the market return on a portfolio of geographically proximate countries.

Another problem that may be encountered is the influence of sector-specific information on abnormal returns. For instance, if sector-specific information becomes available on the day when an attack occurs, the results reflect a combination of sector-specific information and terrorist attack related fear or sentiment. Due to the confounding nature of these two events, it is not accurate to reason that an observed abnormal return is a result of the terrorist attack—at worst, we cannot determine how much of the abnormal return is related to the attack. Consequently, a third robustness test is conducted by excluding commodities with commodity-specific

information from the sector 15 days on either side of the attack day. The 15-day window[2] is consistent with the literature in the equity market. Commodity-specific information is defined as an announcement made, in any public forum, related to the commodity.

The effects of terrorist attacks affect our commodity sectors through different channels. For instance, an attack may represent increased uncertainty in the ability to deliver a commodity, while the same attack can be viewed, by another commodity sector, as an increase in future price. The environment of commodities in financial markets changes significantly with the impact of a terrorist attack whose effects on systematic risk are unknown. To test for changes in systematic risk, asset pricing models are modified to incorporate interaction variables. The first risk model captures the average change in risk as a consequence of terrorist attacks. Following Ramiah, Martin and Moosa (2013), we use an aggregate dummy variable (*AD*) to represent the events, which takes the value of one on the event date and zero otherwise. *AD* is also multiplied by the market risk premium to form the first interaction variable. The model takes the form of

$$\tilde{r}_{St} - \tilde{r}_{ft} = \beta_S^0 + \beta_S^1\left[\tilde{r}_{mt} - \tilde{r}_{ft}\right] + \beta_S^2\left[\tilde{r}_{mt} - \tilde{r}_{ft}\right] * AD_t + \beta_S^3 AD_t + \tilde{\varepsilon}_{it} \quad (1)$$

where, $\tilde{r}_{St} - \tilde{r}_{ft}$ is sector *s'* risk premium at time *t.* The first independent variable is $\tilde{r}_{mt} - \tilde{r}_{ft}$ and represents the market risk premium at time *t.* The second and third independent variables are the multiplicative and additive dummy variables respectively. $\tilde{\varepsilon}_{it}$ is the error term, β_S^0 is the intercept of the regression equation ($E(\beta_S^0) = 0$), β_S^1 is the average short-term systematic risk of the sector (beta), β_S^2 captures the change in sector risk (change in beta), and β_S^3 measures the

[2] Although we apply a 15-day window around the announcement for the robustness test of removing firm specific information, for each CAR 120 we checked for any major news arrival over that 120-day period. When we have news (including natural disasters) that is related to the commodity, we exclude the commodity.

change in the intercept of Equation (1). The equation is estimated to calculate the aggregate effect of the attack on the market. We also note that β_s^3 is included for completeness purposes and does not have any empirical meaning in an excess return model such as Equation (1).

To address the problem in the aggregate model whereby the effects of opposite outcomes from different terrorist attacks may cancel each other out, we use an individual dummy variable (ID) for each attack, which takes a value of one on the attack date and zero otherwise. This alternative model allows us to identify the exact contribution of each attack. Each dummy variable is then multiplied by the market risk premium to obtain interaction variables whose coefficients capture short-term changes in systematic risk following the terrorist attack. The model is written as follows:

$$\tilde{r}_{St} - \tilde{r}_{ft} = \beta_S^0 + \beta_S^1\left[\tilde{r}_{mt} - \tilde{r}_{ft}\right] + \sum_{g=1}^{N} \beta_{S,n}^2 \left[\tilde{r}_{mt} - \tilde{r}_{ft}\right] * ID_{gt} + \tilde{\varepsilon}_{it} \quad (2)$$

To study the long-term effects on systematic risk, Equations (1) and (2) are re-estimated such that the aggregate dummy variable (*AD*) assumes the value of zero prior to the attack date and one thereafter, while the individual dummy variables (*ID*) take the value of zero prior to the attack and one for subsequent periods. The additive dummy variable is dropped in Equation (2) as it is highly correlated with the multiplicative dummy variable.

Since the empirical results of this study are obtained by using the event study methodology, it may be worthwhile saying something about recent developments in this field. The most recent development is the method, suggested by Borochin and Golec (2016), to measure the full value effect of an event for firms with traded options. This is in light of the argument that event studies typically provide a measure of only a fraction of the full value effect because they do not adjust

for market anticipation of the event. This method is a generalization of earlier work by Subramanian (2004), Barraclough et al. (2013), and Borochin (2014) to disentangle the value effects caused by a merger announcement (the expected synergy value and the signals about the stand-alone values of the bidder and target). In this respect, the unique information extracted from option prices is used to identify the synergy and stand-alone values, along with the ex-ante probability that the merger will be completed.

The proposition that good estimates of event probabilities could be useful can be traced back to Brennan (1990) who suggests that stock price changes, due to partly anticipated events, must be adjusted to obtain a proper measure of the full value effect of an event. Malatesta and Thompson (1985), Acharya (1993), Chaplinsky and Hansen (1993), Prabhala (1997), Song and Walkling (2000), Bhagat et al. (2005) and Cai et al. (2011), suggest that firm-specific attributes can be used to estimate the *ex ante* event probability. The potential problem with this approach is that data on relevant firm-specific attributes may be scarce. Furthermore, we take into account sector-specific information in one of the robustness tests.

According to Graham and Ramiah (2012), the September 11 terrorist attacks had a major influence on the equity markets, but subsequent attacks failed to affect the stock market as market participants use adaptive expectations. From an econometrics point of view, September 11 represents a structural break in the data and, following Narayan and Popp (2010), Narayan and Popp (2013), Narayan and Liu (2015) and Narayan et al. (2016), we conduct structural break tests on all of our regressions. The multiplicative and additive dummy variables were excluded from the models to perform the structural tests. Our results show strong structural breaks for all

terrorist attacks from September 11 terrorist attack through to the Jakarta attacks (Events 1 to 9) for most commodities. Only three terrorist events (Events 16, 17 and 18) caused significant structural breaks in the chemicals sector following the Jakarta attacks. These results are available from the authors upon request.

4. Data and empirical results

These terrorist attacks are chosen based on (1) a global consensus of what is regarded as a terrorist attack and (2) one that has been reported in the global news as a terrorist attack. Based on the equity market literature, September 11 was the first major terrorist attack that surprised the financial market system and as a result our first terrorist attack is September 11. At the time of conducting this analysis, the last terrorist activity was carried out on the London Bridge. Table 1 shows the 20 terrorist attacks that we study in this analysis and each event is numbered from 1 to 20. The first event is the September 11 attacks which occurred on 11 September 2001 at 8.46 am, and the last event is the London Bridge attack which occurred on 3 June 2017 at 22.06. It should be noted that 3 June 2017 was a Saturday and the commodity market was not open, which implies that we assess the impact of this attack on the next available day of trading, Monday 5 June 2017. Several of these attacks occurred around times that the market was closed and hence, we resort to the first day of trading following the attack.

To investigate the effect of these terrorist attacks on commodity markets we download daily commodity price indices, the risk-free rate, regional indices and world indices from DataStream. Our initial sample consisted of 96 different commodities but we exclude 20 commodities that were not denominated in US dollars as they were denominated in Euros. To isolate the influence

of the exchange rate between Euro and US on the commodities, we exclude these 20 commodities from our sample. Our final sample consists of daily data on the 76 individual commodity prices, the MSCI World Index as a proxy for the market and the US three-month interbank rate as a proxy for the risk-free rate. The DataStream classification standards are utilized to construct five sectoral portfolios, namely the agricultural, chemicals, energy, metals and precious metals sectors and Table 2 reports the descriptive statistics for each of the sectoral portfolios. Over the period January 1990 to July 2017, we have 7195 daily risk adjusted returns for each sector. The mean, median, maximum, minimum and standard deviation for the agriculture sector are -0.0020%, -0.0073%, 7.3908%, -7.2508% and 1.1298%, respectively. Table 3 shows the constituents of each sector and we can see that agricultural products are confined to commodities such as cocoa, corn, cotton, coffee, soya beans, soya meal, soya oil, raw sugar, wheat and a few others. As we have different grades and variety of the commodities, we show 58 of the 76 commodities in Table 3.

4.1 Return analysis

Table 4 reports the parametric empirical results for eight events where we observe statistically significant abnormal returns for the agriculture sector. We report the abnormal return on the first day of trading, the five-day cumulative abnormal return (CAR5), the ten-day cumulative abnormal return (CAR10), the fifteen-day cumulative abnormal return (CAR15), CAR30, CAR60, CAR90, CAR120[3] as well as their respective *t*-statistics. With regards to the September 11 attacks, unlike the equity market (which opened six days after the attack), we are assessing the performance of the commodity market on 11 September 2001. The results reported in Table 4

[3] Note CAR120 represents six months as we have 20 trading days on average per month.

show a consistent positive effect. Each column of Table 4 reports a terrorist attack's abnormal returns and the parametric *t*-statistics for the various windows. For instance, the last two rows of column 5 shows the CAR120 is 19.13% after the Moscow Metro bombings, with a *t*-statistic of 2.30, indicating that this value is statistically different from zero. Similarly, we find a sensitive (positive) agricultural sector reaction after six months following the Paris attacks and Jakarta attacks. This result indicates that, in the aftermath of these attacks, investors tend to prefer commodities that would safeguard against shortages of raw necessities such as food. As the demand for these commodities increase over the days following the attack, and with limited ability of producers to increase supply (inelastic supply), the prices for these types of commodities increase. To the extent that investors herd towards commodities that provide the basic necessities for life—our results are consistent with the prior literature of Cam (2008).

On the other hand, our results defy the efficient market hypothesis in that it takes up to 120 days to react. Most studies cited in the literature review section suggest that cumulative abnormal returns in equity markets following a terrorist event are short-lived, but the evidence provided in our paper suggests otherwise as we detect cumulative abnormal returns after 120 days. We provide three possible explanations for this occurrence. The first explanation is economic in nature whereby the commodity market is influenced by both the demand side (price, income, tastes and preferences, competition and fashion) and the supply side (cost of production, natural conditions, technology, government policies and shocks). Following a terrorist attack, demand of certain product will change and due to interconnectedness, there is a delayed effect in the commodity market. For instance, first the demand for tourism around the location of the attack will decrease. Next the demand for airline travelling to this location will drop and, in turn, the

airline company will reduce the supply by cancelling any plan of ordering new planes. As the airline cancels the new plane order, the manufacturer will eventually cancel any order of raw materials to manufacture the plane and this is when the commodity market is affected. The supply chain management literature document such interconnectedness after shocks (see Gunasekaran et al., 2001; Kilian, 2009) and our results suggest that interconnectedness takes around 120 days to reach the commodity market. The second explanation revolves around conspiracy theory. Our argument is that certain speculators are aware of these delayed reactions in the commodity market and take advantage of these positions. To the best of our knowledge no study has linked commodities market manipulations that occur up to 120 days later. Third, we argue that there is a potential demand and supply discovery process[4] that takes place over time.

In line with the discussion on delayed reactions to the terrorist attacks, Table 5 shows the other four commodity sectors where we find similar effects whereby (1) while the chemical sector did not react significantly over 120 days, we do find significant effects for four terrorist attacks at the 60 and 90 day horizon (September 11 attacks, Pukhrayan train derailment, Istanbul bombings and Quebec mosque shooting); (2) the energy sector reacted to one event (Jakarta attacks); (3) the metal sector reacted to four terrorist attacks (London bombings, Delhi bombings, Jakarta

[4] Cam (2008) identified several sectors that were affected around September 11 terrorist attacks. One of the sectors that had an unusually long delayed reaction was the insurance sector. This was because it took a long time to uncover that American insurance companies have re-insured in the UK. It took additional time for UK insurance companies to look into their re-insurance policies. They found out that they hedged their positions in the Asian capital markets who in turn found out that they re-insured in Australia. Ramiah et al. (2010) eventually documented the effects of the insurance companies in Australia. Within the equity market literature, this is no longer a surprise and it is now expected. We believe the same discovery process is occurring in the commodity market.

attacks and Brussels bombings); and (4) precious metals reacted to two terrorist attacks (Delhi bombings and Paris attacks).

As indicated, terrorist attacks have different effects on each of the sectors; therefore, it is safe to assume that an attack will have different effects on individual commodities within the sector. As our five sectors are constructed from 76 individual commodities, it is possible that sector cumulative abnormal return results will be driven by only a few commodities. Tables 6 to 9 show which commodity, in each sector, contributes most to the cumulative abnormal return around 120 days. The results presented in Tables 6 to 9 are consistent with our expectations that some commodities drive the cumulative abnormal return for their sector. For instance, when looking at the metals sector (Table 8), columns 2 and 3 show that the cumulative abnormal return for aluminium[5] and zinc contributed the most CAR120 for event 3 (London bombings) of 13.62%. In relation to this terrorist attack, this result may indicate that these commodities are materials associated with rebuilding following the attack. In a similar vein we show, via columns 4 and 5, for the precious metals sector (Table 9), an increase in the value of gold, silver and platinum which contributes the most to the precious metals CAR120 of 21.46% for event 8 (Paris attacks). These returns may be evidence of a 'flight to safety' by investors, and is observed over a long window as investors re-evaluate the risk inherent in the market and the possibility of future attacks.

Analysing the prior results, we observe a disproportionate number of commodities affected by the Jakarta attacks (event 9) relative to the other terrorist attacks. Table 10 shows a total of 27

[5] LME-NASAAC is an abbreviation of London Metals Exchange – North American Special Aluminium Alloy Contract.

commodities including agricultural foodstuffs, many energy commodities and metals which are affected by this terrorist attack. The significant (positive) returns observed for agricultural commodities range from a CAR120 of 16.14% to 39.11% for Brazilian coffee and soymeal, respectively.

Looking at the results in aggregate, a plausible explanation for these high abnormal returns is as a result of investors considering possible future attacks that might limit the ability to source basic necessities which, in turn, increases the aggregate demand for the commodities. Jakarta, the location of this particular attack, is not geographically distant from one of the world's most busy shipping lanes—the Malacca Strait. This strait is also a choke point for shipping through South East Asia.

Disaggregating the results into individual commodities, we observe many of the energy commodities are affected by the Jakarta attack with the majority of the abnormal returns being large, positive and significant. Looking at the commodities within this sector, there is a distinct separation between domestic (civilian) and military types of energy sources. The commodities that are generally used in domestic energy production are crude oil, fuel oil, gasoil, propane, butane and ethanol. We associate these positive returns with concerns on future availability of the commodities such that the supply route into major global markets may be attacked again, which would have the effect of decreasing the supply of energy-producing commodities. An associated, or complementary, explanation may be that, as the timing of the Jakarta attack occurred in the middle of the northern hemisphere winter, these countries were likely to be

concerned with the supply of energy resources that could hinder their ability to produce heating, which drove up the demand for these commodities.

On the other hand, there are some commodities that are used extensively in military applications (but not exclusively). For instance, crude oil, jet kerosene and naphtha are typically associated with the production and use of domestic and military aircraft fuels. Some of the abnormal returns could be explained through the perceived lack of supply of commodities to support domestic aviation industries. However, given that the returns are obtained after the Jakarta terrorist attacks, intuition would suggest that the returns may also be driven by military purchasing to ensure the supply of mission-critical materials to support future terror related (or unrelated) conflicts around the globe. In conjunction with the proximity of the attacks to the key supply route through the Malacca strait, the high abnormal returns in these commodities are not surprising given the reliance on planes for transportation and operations by global air forces.

In terms of the effect of the terrorist attack on metals, there are positive results for tin and copper, which may be associated with demand for building materials. We believe the large abnormal return for molybdenum (51.51%) is a result of two distinct channels. First, molybdenum is used widely as a catalyst in the refining of petroleum and is also used in the nuclear power generating industry which ties in with our argument regarding the ability to produce basic necessities such as fuel and heat. Secondly, molybdenum is also used to make missile and aircraft parts, which, in light of a terrorist attack, may indicate an increase in the risk observed by governments around the world.

The Jakarta attacks also highlight the lack of significant results for precious metals, which is in stark contrast to the many significant results for other commodities. The location of this particular attack, as indicated, is not distant to the Malacca Strait, however the attack is significantly far from other major financial centres such as London or New York. This leads us to believe that the instability in the supply chain for agricultural and metal commodities is a larger concern to market participants than a contagious event that spreads to major financial centres resulting in a 'flight to safety', which is why we do not find significant results for gold, silver or other precious metals.

Additional robustness tests for the Jakarta attack, which correspond to the abnormal return estimates from columns 2 and 3 of Table 10, are reported in columns 4 and 5 of Table 10. Using higher significance cut-offs, we observe that at least one of the two robustness tests we perform supports 21 of the 27 cases of significant cumulative abnormal returns. Our argument indicating that terrorist events affect the commodities markets over a long period is further supported by a statistical significance in the Corrado (1989) ranking test or the conditional probability test. In simple terms, both tests provide evidence indicating a long-term influence of the Jakarta terrorist attacks. Following Chesney et al. (2011) and Graham and Ramiah (2012) we also control for synchronicity, stock market integration, and spillover effects in event study studies and the results of these robustness tests confirm our argument.[6]

[6] For brevity purposes, we have not reported these results but are available from the authors on request.

The commodities affected by terrorist attacks are shown in Table 11 (excluding the Jakarta attacks). We find a smaller quantity of commodities affected over the longer term by these attacks. For instance, only two commodities were affected by the Moscow Metro bombing, namely yellow corn and South Central No. 2 corn, whereby both commodities experienced positive abnormal returns of about 38%. We speculate that the abnormal returns for corn are due to hoarding of food in anticipation of shortages. When we look closer at the effect of the London bombings, we notice a large influence on the metals sector, with aluminium and zinc being the two affected commodities. Aluminium is not generally associated with structural materials related to the rebuilding process, as opposed to zinc. However, aluminium is one of the main resources used in the construction of fighter planes and other military assets. Therefore, we believe that the abnormal demand is driven by the expectation (or buying pressure) that governments will be expanding their military operations following this attack.

The Brussels bombings had a limited outcome on the commodities market with only two commodities, namely aluminium alloy and steel billets, with abnormal returns of 5.28% and 133.52%, respectively. Steel billets could be used in military operations, but it is much more likely that the large abnormal return for this commodity is representative of an increase in demand for raw steel, presumably for a rebuilding or for stockpiling in the event of subsequent terrorist attacks.

The effect of the Delhi bombings on the commodities suggest a mixed reaction. We observe a number of scenarios that could be plausible. For instance, there may be a slight flight to safety based on the silver, palladium and ruthenium returns, but it may also be that as a country that

purchases a large amount of precious metals, the bombing may have influenced the future supply of these commodities. We also observe positive abnormal returns for aluminium, copper, tin and zinc which, as indicated above, could be in expectation of rebuilding, military demand or supply concerns.

The results from these attacks also show differences in the reactions through the long-term abnormal returns of the commodities. For instance, the affected commodities following the Delhi bombings show us that there are mixed results that could be attributable to a 'flight to safety' response (silver, palladium and ruthenium) a rebuilding response (copper, tin and zinc) and a military response (aluminium). The London and Brussels bombings indicate a rebuilding effort and military demand (aluminium and zinc) while the Moscow Metro bombings indicate a stockpiling of basic necessities (corn) and the Paris attacks point to a 'flight to safety' response (gold, silver and platinum).

4.2 Risk analysis

From the literature, we can hypothesise that following the September 11 attacks, an increase in systematic risk is to be expected. Our next objective is to test if the commodity sectors and their constituents experienced a general increase in their systematic risk. The regression analysis of Equation (1) attempts to test this hypothesis immediately after each of the 20 terrorist attacks have occurred and provides the results in an aggregate manner. Table 12 reports the results from the estimation of Equation (2) and, of specific interest, the multiplicative dummy variable model (β_S^2) which captures the change in the sector's systematic risk (column 6). A positive coefficient of the multiplicative dummy variable reflects an increase in systematic risk caused by the 20

terrorist activities. When the coefficient of the multiplicative dummy variable is statistically different from zero, it implies a significant statistical change in the systematic risk of the industry and is called the aggregate terrorist risk. Our results from Table 12 show no statistically significant results at the 5% confidence level, despite using several GARCH models (GARCH, TARCH, EGARCH and PARCH). This suggests that we do not find any aggregate terrorist risk and, to a certain degree, is consistent with Graham and Ramiah (2012) who argue markets do not react to terrorist events post the September 11 attacks.

The previously documented limitations inherent with Equation (1), that limit our ability to measure the effects of the terrorist attacks on our commodity portfolios, are corrected with Equation (2). As such, Equation (2) is estimated to capture the change in the short-term systematic risk where the short-term change is over a period of one day. The results show various mixed results as we find evidence of both increases and decreases in systematic risk. The result of estimating Equation (2) for each of the sectors is represented graphically in Figure 1. For example, following event 9 the systematic risks (note beta is negative) for the agricultural and energy sectors increased which corresponds to the Jakarta attack. On the other hand, the risks decrease after event 10, leading to a V-shape risk structure. Event 10 coincides with the physical delivery of crude oil whereby the uncertainty in the price of oil disappears as the futures and spot price converge around the delivery date. The removal of uncertainty results in a large negative beta value. As spillovers that originate in the oil market and flow to other commodities have been found to occur (Mensi et al, 2017), this reduction in risk in energy markets is observed to spillover to other markets. We also notice one diamond risk shape (see Ramiah, Martin and

Moosa, 2013) between events 12 and 14 whereby some sectors have increases in beta while others have a decline in beta.

There are a number of conclusions that can be drawn from Figure 1. First, the terrorist attacks following the September 11 attack had little effect on the risk structure of the commodity sectors, however the increased frequency of terrorist attacks following the Paris attacks are associated with greater changes in the risk structure, indicating greater uncertainty of outcomes. Secondly, there are a number of commodity specific effects whereby the impact of a terrorist attack varies from one commodity to another within a commodity sector. Thirdly, significant differences in the change in systematic risk from one terrorist attack to another are encountered (the short-term change in risk can be either positive or negative). Lastly, the time series representation of terrorist attacks tends to lead to V-shape and diamond shape risks.

5. Conclusion

The objective of terrorists is to propagate fear and discord in global populations through various methods, including financial damage to equity markets. In this paper our objective is to document the effects of terrorist activities on the commodities markets. Our study shows that terrorist attacks do not have their intended effect on commodity markets, in that there is little evidence to indicate a short-term effect immediately after an attack (only one abnormal return was observed). However, we do observe the effect of terrorist attacks within a longer time frame, with these effects materialising after 120 days. Not only is there a delayed reaction, but the abnormal returns are positive, indicating that the terrorist activities have an opposite effect to the effect they intended.

We propose that the activities of terrorists, contrary to their objective of spreading chaos, result in an increase in demand for commodities through basic human needs and emotions and the desire to rebuild. That is, an attack may have the effect of (1) hoarding of food and basic necessities (foodstuffs and energy), (2) a 'flight to safety' response (gold, silver and precious metals) or (3) an increased demand for building equipment (aluminium, zinc and copper). While these terrorist attacks do not cause negative returns over the longer term they do achieve their desired return of upsetting the equilibrium in commodity markets, pushing prices to artificial levels. Furthermore, terrorist attacks do appear to create uncertainty in the commodity markets through V-shape and diamond risks. In general, the effect of terrorist attacks on systematic risk in commodities markets is mixed, although the evidence shows volatility as terrorist activities become more frequent.

The evidence shown in the equity markets suggests that markets react instantly to terrorist activities, but our paper shows delayed reactions in commodity markets. We believe it is important for future research to study the reasons why commodity markets may take up to 120 days to react to the terrorist attacks (discovery effect, seasonality, production time and derivative contracts).

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Table 1: Details of the terrorist attacks

This table reports the details of the 20 terrorist attacks used in this study, where each of them is represented by a number. A brief description, the event date, the local time and the day of the attacks are also shown.

Event	Description	Event date	Event time	Day of attack
1	September 11 attacks	11/09/01	08:46	Tuesday
2	Madrid train bombings	11/03/04	07:36	Thursday
3	London bombings	07/07/05	08:49	Thursday
4	Delhi bombings	29/10/05	17:38	Saturday
5	Mumbai train bombings	11/07/06	18:24	Tuesday
6	Moscow Metro bombings	29/03/10	07:56	Monday
7	Charlie Hebdo shooting	07/01/15	11:30	Wednesday
8	Paris attacks	13/11/15	21:16	Friday
9	Jakarta attacks	14/01/16	10:40	Thursday
10	Brussels bombings	22/03/16	07:58	Tuesday
11	Nice attack	14/07/16	22:30	Thursday
12	Pukhrayan train derailment	20/11/16	03:10	Sunday
13	Istanbul bombings	10/12/16	22:30	Saturday
14	Istanbul nightclub attack	01/01/17	01:15	Sunday
15	Gao bombing	18/01/17	09:00	Wednesday
16	Quebec mosque shooting	29/01/17	07:55	Sunday
17	Westminster attack	22/03/17	14:40	Wednesday
18	Stockholm truck attack	07/04/17	14:53	Friday
19	Manchester Arena attack	22/05/17	22:31	Monday
20	London Bridge attack	03/06/17	22:06	Saturday

Table 2: Descriptive statistics

This table shows the descriptive statistics for the five sectoral portfolios for the period January 1990 to July 2017.

	Mean	Median	Maximum	Minimum	Std. Dev.	Observations
Agricultural	-0.0020%	-0.0073%	7.3908%	-7.2508%	1.1298%	7195
Chemicals	-0.0023%	-0.0105%	11.8230%	-12.3308%	1.3323%	7195
Energy	0.0002%	0.0002%	14.2603%	-34.9021%	2.2957%	7195
Metals	-0.0015%	-0.0082%	9.1340%	-9.1438%	1.1551%	7195
Precious Metals	0.0053%	-0.0002%	12.0246%	-11.6098%	1.2043%	7195

Table 3: Example commodities within the sectors

This table shows the generic commodities investigated. They are classified in their respective sectors.

Agricultural	*Energy*
Average Cotton	0.2% Sulphur Gasoil
Brazilian Coffee	Base Rate Electricity
Cocoa	Butane
Colombian Coffee	Crude Oil
Cotton,1 1/16 Str Low-Mid	Ethanol
Hard Red Spring Wheat	Fuel Oil
Raw Sugar	Gasoline
Soya Oil	
Soft Red Wheat	Jet Kerosene
Soyameal	Naphtha
Soymeal	Natural Gas
South Central Corn	Peak Rate Electricity
Swine (pork)	Propane
US Yellow Soybean	Tapis Crude Oil
Yellow Corn	*Metals*
Chemicals	Aluminium Alloy
Acrylonitrile	Aluminium, 99.7%
Butadiene	Cobalt
Copolymer Polypropylene	Grade A Copper
Ethylene	Lead
High-density Polyethylene	Molybdenum
Low-density Polyethylene	Nickel
Naphtha	High Grade Zinc 99.995%
Paraxylenes	Steel Billet
Polyvinyl Chloride (PVC) Suspension	Tin 99.85%
Purified Terephthalic Acid	*Precious Metals*
Solvent Xylene	Gold Bullion
Styrene	London Platinum
Toluene	Palladium
Vinyl Chloride Monomer (VCM)	Rhodium
	Ruthenium
	Silver

Table 4: Abnormal and cumulative abnormal returns following the terrorist attacks for the agricultural sector

This table identifies the abnormal returns at various windows (0 to 120 days) from the event date. We show the terrorist events that generated statistically significant abnormal or cumulative abnormal returns.

Event	1	2	5	6	8	9	10	11
AR (%)	0.17	1.54	0.61	0.70	-0.56	0.16	0.51	0.03
t-stat	*0.24*	*2.02*	*0.86*	*0.72*	*-0.69*	*0.20*	*0.77*	*0.04*
CAR5 (%)	1.23	4.47	-1.29	-1.32	-0.29	0.92	0.02	-3.00
t-stat	*0.77*	*2.27*	*-0.77*	*-0.57*	*-0.17*	*0.56*	*0.01*	*-1.88*
CAR10 (%)	-0.36	5.67	-2.92	-1.18	0.82	1.40	-1.33	-5.16
t-stat	*-0.17*	*2.16*	*-1.20*	*-0.38*	*0.33*	*0.62*	*-0.56*	*-2.19*
CAR15 (%)	-4.37	2.67	-4.48	0.97	2.93	2.69	-1.00	-6.19
t-stat	*-1.67*	*0.89*	*-1.59*	*0.26*	*0.97*	*0.98*	*-0.34*	*-2.11*
CAR30 (%)	-8.38	-0.95	-8.60	5.01	0.92	1.29	6.69	-7.08
t-stat	*-2.44*	*-0.24*	*-2.26*	*0.98*	*0.22*	*0.36*	*1.71*	*-1.60*
CAR60 (%)	0.09	-2.95	-5.79	10.22	4.18	3.27	13.86	-9.53
t-stat	*0.02*	*-0.47*	*-1.36*	*1.43*	*0.80*	*0.72*	*2.58*	*-1.41*
CAR90 (%)	1.75	-12.34	3.19	17.05	6.63	13.92	5.20	-8.85
t-stat	*0.52*	*-1.29*	*0.78*	*1.98*	*1.28*	*2.53*	*0.93*	*-1.13*
CAR120 (%)	0.08	-20.93	3.79	19.13	12.39	16.00	0.60	-11.31
t-stat	*0.02*	*-1.60*	*0.99*	*2.30*	*2.50*	*2.76*	*0.10*	*-1.30*

Table 5: 120-day cumulative abnormal returns for other commodity sectors

This table reports the 120-day cumulative abnormal returns (CAR120) for four sectors.

	Chemicals		Energy		Metals		Precious Metals	
Event	%	t-stat	%	t-stat	%	t-stat	%	t-stat
1	-6.38	*-1.14*	-11.36	*-0.96*	9.93	*1.32*	3.93	*0.43*
2	-1.48	*-0.18*	-42.92	*-1.65*	-9.87	*-0.96*	-13.26	*-1.01*
3	0.17	*0.03*	-14.30	*-1.39*	13.62	*2.06*	12.34	*1.17*
4	-4.07	*-0.79*	-10.50	*-0.66*	25.94	*2.10*	20.43	*2.60*
5	-10.85	*-1.52*	-17.62	*-1.21*	-14.15	*-0.90*	-6.29	*-0.35*
6	-16.99	*-0.95*	-0.70	*-0.05*	0.26	*0.02*	-9.61	*-0.54*
7	35.06	*1.63*	44.18	*1.79*	-11.39	*-1.33*	-5.64	*-0.87*
8	12.76	*0.78*	15.67	*1.01*	13.98	*1.54*	21.46	*2.15*
9	16.27	*1.29*	42.69	*2.87*	20.87	*2.39*	22.04	*1.87*
10	12.03	*1.00*	14.09	*0.93*	15.78	*2.19*	9.09	*0.90*
11	15.21	*1.81*	16.73	*1.23*	-1.30	*-0.25*	-11.05	*-1.14*
12	-11.41	*-1.11*	-13.85	*-0.88*	-9.31	*-0.98*	5.89	*0.61*
13	-14.55	*-1.15*	-19.79	*-1.18*	-10.74	*-1.04*	7.91	*0.85*
14	-24.15	*-1.54*	-29.16	*-1.73*	-8.82	*-0.86*	11.08	*1.34*
15	-32.97	*-1.83*	-20.91	*-1.29*	-7.82	*-0.76*	3.43	*0.47*
16	-37.66	*-1.94*	-16.57	*-1.05*	-7.55	*-0.74*	5.47	*0.79*
17	-30.69	*-1.36*	0.75	*0.06*	-7.75	*-0.84*	3.26	*0.56*
18	-24.62	*-1.09*	-3.63	*-0.29*	-6.34	*-0.75*	-1.81	*-0.31*
19	-13.55	*-0.62*	1.72	*0.14*	-0.53	*-0.09*	-0.27	*-0.05*
20	-8.98	*-0.42*	7.19	*0.57*	1.78	*0.33*	-1.57	*-0.27*

Table 6: Contribution of individual commodities within the agricultural sector to cumulative abnormal returns (CAR120)

This table reports the 120-day cumulative abnormal returns for each commodity within the agricultural sector.

	%	*t*-stat	%	*t*-stat	%	*t*-stat
Event	6		8		9	
Cocoa-ICCO, Daily Price	-14.41	*-0.84*	-8.72	*-0.83*	1.06	*0.11*
Corn, No.2 Yellow	38.30	*2.71*	4.19	*0.57*	-2.30	*-0.32*
Cotton,1 1/16Str Low -Mid, Memphis	6.28	*0.86*	2.38	*0.28*	4.28	*0.66*
Coffee, Brazilian (NY)	20.65	*1.83*	11.05	*0.85*	16.14	*2.10*
Soybean, No.1 Yellow	19.76	*1.11*	19.69	*2.44*	22.88	*2.47*
Soybean meal, USA 48% Protein	27.38	*1.13*	22.21	*1.56*	38.21	*2.21*
Soya Oil, Crude Decatur US	9.72	*1.54*	21.43	*1.84*	1.02	*0.09*
Raw Sugar-ISA, Daily Price	31.37	*1.08*	6.60	*0.48*	29.47	*2.78*
Wheat No.2, Soft Red	54.01	*1.72*	17.92	*1.49*	3.78	*0.31*
Colombian Coffee, ARAB Ex DC NY	17.88	*1.05*	13.33	*1.09*	21.63	*2.54*
Cotton, NY Average	-2.53	*-0.21*	2.49	*0.27*	8.49	*1.34*
Yellow Soybean, US NO.1 Sth Dvprt	18.24	*1.02*	18.92	*1.69*	20.19	*1.68*
Soymeal, 48% FOB K.City	24.61	*1.04*	25.04	*1.75*	39.11	*2.06*
HOG, 51-52% US 3 AREA Ntnl MR	0.09	*0.01*	24.70	*1.14*	44.91	*1.86*
Wheat, US HRS 14% Del Minneapolis/Duluth	15.92	*1.34*	12.10	*1.08*	8.49	*0.70*
Corn, US No.2 South Central IL	38.77	*2.64*	5.01	*0.66*	-1.28	*-0.18*

Table 7: Contribution of individual commodities within the energy sector to cumulative abnormal returns (CAR120) for Event 9 (Jakarta Attack)

This table reports the 120-day cumulative abnormal returns for each commodity within the energy sector.

	%	t-stat
Event	9	
Crude Oil, BFO M1 Europe FOB	55.48	*3.10*
Gasoline, Premium Unleaded FOB NYH	35.38	*1.45*
Gasoline, Regular Unleaded FOB NYH	32.18	*1.81*
Naphtha, CIF NEW	40.85	*3.38*
Jet Kerosene, CIF NEW	53.92	*3.00*
Crude Oil, North Sea BFO FOB	57.64	*3.02*
Crude Oil, WTI Cushing	49.37	*2.86*
Crude Oil, Tapis FOB Malaysia	53.15	*2.97*
Fuel Oil, No. 2, Spot NY Harbour	56.18	*2.35*
Gasoil, 0.2% Sulphur FOB ARA	57.92	*2.58*
Gasoline, Regular Unleaded 10ppm NEW	44.89	*1.87*
Gasoline, RBOB LA	45.09	*1.58*
Ethanol, Spot NY Harbour	17.34	*2.02*
Jet Kerosene, FOB US Gulf?	60.58	*2.71*
Jet Kerosene, FOB Singapore	54.40	*2.77*
Butane, Mont Belvieu Del. Pipe	34.17	*2.00*
Propane, Mont Belvieu Del. Pipe	45.17	*2.95*
Naphtha, FOB Singapore	33.16	*2.79*
Natural Gas, Henry Hub	36.96	*1.89*
Electricity, PJM Base Rate	-2.11	*-0.05*
Electricity, PJM Peak Rate	21.00	*0.50*
Crude Oil, WTI FOB Cushing	49.37	*2.86*
Crude Oil, WTI Spot Cushing	49.79	*2.91*

Table 8: Contribution of individual commodities within the metal sector to cumulative abnormal returns (CAR120)
This table reports the 120-day cumulative abnormal returns for each commodity within the metal sector following events 3, 4, 9 and 10 (London bombings, Delhi bombings, Jakarta attacks and Brussels bombings).

	%	*t*-stat	%	*t*-stat	%	*t*-stat	%	*t*-stat
Event	3		4		9		10	
LME-Aluminium, 99.7% Cash	20.53	*2.10*	14.63	*1.20*	13.63	*1.43*	5.09	*0.65*
LME-Aluminium, 99.7% 3 Month	19.16	*2.20*	15.38	*1.37*	14.89	*1.61*	4.89	*0.62*
LME-Aluminium Alloy, Cash	18.56	*2.32*	26.65	*1.67*	2.53	*1.06*	5.28	*2.09*
LME-Aluminium Alloy, 3 Month	19.12	*2.38*	26.56	*1.73*	2.76	*1.00*	4.70	*1.81*
LME-NASAAC, Cash	19.72	*2.32*	21.36	*2.05*	3.07	*0.45*	1.47	*0.35*
LME-NASAAC, 3 Month	19.93	*2.31*	21.33	*2.03*	3.21	*0.50*	1.31	*0.33*
LME-Cobalt, 3 Month	N/A		N/A		10.29	*0.89*	19.13	*1.24*
LME-Copper, Grade A Cash	10.47	*1.25*	23.64	*3.41*	15.20	*2.06*	-5.83	*-0.79*
LME-Copper, Grade A 3 Month	14.07	*1.58*	24.25	*3.22*	15.28	*2.04*	-4.94	*-0.66*
LME-Lead, Cash	21.67	*1.80*	0.27	*0.02*	9.40	*1.26*	6.47	*0.86*
LME-Lead, 3 Month	18.90	*1.78*	6.07	*0.39*	9.36	*1.30*	6.38	*0.88*
LME-Molybdenum, 3 Month	N/A		N/A		51.51	*2.20*	33.35	*1.54*
LME-Nickel, Cash	-13.42	*-0.78*	37.56	*1.73*	24.22	*1.88*	19.30	*1.53*
LME-Nickel, 3 Month	-11.03	*-0.73*	37.11	*1.86*	24.34	*1.89*	19.37	*1.53*
LME-Steel Billet, 3 Month	N/A		N/A		76.41	*1.26*	133.52	*2.27*
LME-Tin, 99.85% Cash	5.37	*0.45*	39.21	*2.25*	23.35	*3.32*	5.65	*0.79*
LME-Tin, 99.85% 3 Month	3.96	*0.35*	39.64	*2.21*	23.22	*3.19*	5.99	*0.86*
LME-SHG Zinc, 99.995% Cash	25.87	*1.97*	41.10	*2.11*	37.23	*1.79*	19.38	*0.97*
LME-SHG Zinc, 99.995% 3 Month	25.11	*1.97*	40.26	*2.11*	36.68	*1.81*	19.30	*0.99*

Table 9: Contribution of individual commodities within the precious metals sector to cumulative abnormal returns (120 day)

This table reports the 120-day cumulative abnormal returns for each commodity within the precious metals sector. We report the statistically significant results which occur following terrorist events 4 and 8 (Delhi bombings and Paris attacks).

	%	*t*-stat	%	*t*-stat
Event	4		8	
Gold, Bullion LBM	11.42	*1.52*	19.27	*2.36*
Gold, Handy & Harman Base	11.80	*1.52*	18.18	*2.22*
Silver, Handy & Harman (NY)	31.41	*2.56*	26.47	*3.09*
London Platinum, Free Market	3.88	*1.45*	29.12	*2.50*
Palladium	23.98	*2.00*	23.60	*1.87*
Rhodium, CIF NEW	15.31	*0.96*	20.38	*1.09*
Ruthenium, CIF NEW	45.19	*2.07*	13.20	*1.35*

Table 10: Commodities most affected by the Jakarta attack

This table reports the 120-day cumulative abnormal returns for each commodity significantly affected by the Jakarta attacks. The Corrado and conditional probability test robustness results are also reported.

Commodity	CAR120	*t*-stat	Corrado	CP
Soymeal, 48% FOB K. City	39.11	*2.06*	1.35	0.024
Soybean meal, USA 48% Protein	38.21	*2.21*	1.37	0.022
Raw Sugar-ISA	29.47	*2.78*	1.38	0.007
Soybeans, No. 1 Yellow	22.88	*2.47*	1.42	0.022
Colombian Coffee ARAB Ex DC NY	21.63	*2.54*	1.43	0.009
Coffee-Brazilian (NY)	16.14	*2.10*	0.93	0.017
Jet Kerosene, FOB US Gulf	60.58	*2.71*	1.67	0.030
Gasoil, 0.2% Sulphur FOB ARA	57.92	*2.58*	1.71	0.037
Crude Oil, North Sea BFO FOB	57.64	*3.02*	1.73	0.044
Fuel Oil, No. 2 Spot NY Harbour	56.18	*2.35*	1.49	0.027
Crude Oil, BFO M1 Europe FOB	55.48	*3.10*	1.71	0.062
Jet Kerosene, FOB Singapore	54.40	*2.77*	1.61	0.028
Jet Kerosene, CIF NEW	53.92	*3.00*	1.71	0.067
Crude Oil, Tapis FOB Malaysia	53.15	*2.97*	1.73	0.060
Crude Oil, WTI Spot Cushing	49.79	*2.91*	1.71	0.040
Crude Oil, WTI Cushing	49.37	*2.86*	1.70	0.055
Crude Oil, WTI FOB Cushing	49.37	*2.86*	1.70	0.052
Propane, Mont Belvieu Del. Pipe	45.17	*2.95*	1.35	0.009
Naphtha, CIF NEW	40.85	*3.38*	1.73	0.031
Butane, Mont Belvieu Del. Pipe	34.17	*2.00*	0.87	0.404
Naphtha, FOB Singapore	33.16	*2.79*	1.61	0.029
Ethanol, Spot NY Harbour	17.34	*2.02*	0.97	0.035

LME-Molybdenum, 3 Month	51.51	*2.20*	1.55	0.024
LME-Tin, 99.85% Cash	23.35	*3.32*	1.26	0.021
LME-Tin, 99.85% 3 Month	23.22	*3.19*	1.27	0.019
LME-Copper, Grade A 3 Month	15.28	*2.04*	1.62	0.023
LME-Copper, Grade A Cash	15.20	*2.06*	1.62	0.023

Table 11: Commodities most affected by terrorist attacks (excluding Jakarta)

This table reports the 120-day cumulative abnormal returns for each commodity significantly affected by terrorist attacks excluding the Jakarta attack. We show the statistically significant results which occur following terrorist events 3, 4, 6, 8 and 10 (London bombings, Delhi bombings, Moscow Metro bombings, Paris attacks and Brussels bombings).

	CAR120 (%)	t-stat		CAR120 (%)	t-stat
London bombings			*Moscow Metro bombings*		
LME-Aluminium, 99.7% Cash	20.53	*2.10*	Corn, No. 2 Yellow	38.30	*2.71*
LME-Aluminium, 99.7% 3 Month	19.16	*2.20*	Corn, US No. 2 South Central IL	38.77	*2.64*
LME-Aluminium Alloy, Cash	18.56	*2.32*			
LME-Aluminium Alloy, 3 Month	19.12	*2.38*	*Paris attacks*		
LME-NASAAC, Cash	19.72	*2.32*	Soybeans, No. 1 Yellow	19.69	*2.44*
LME-NASAAC, 3 Month	19.93	*2.31*	Gold Bullion, LBM	19.27	*2.36*
LME-SHG Zinc, 99.995% Cash	25.87	*1.97*	Gold, Handy & Harman Base	18.18	*2.22*
LME-SHG Zinc, 99.995% 3 Month	25.11	*1.97*	Silver, Handy & Harman (NY)	26.47	*3.09*
			London Platinum, Free Market	29.12	*2.50*
Delhi bombings					
LME-NASAAC, Cash	21.36	*2.05*	*Brussels bombings*		
LME-NASAAC, 3 Month	21.33	*2.03*	LME-Aluminium Alloy, Cash	5.28	*2.09*
LME-Copper, Grade A Cash	23.64	*3.41*	LME-Steel Billet, 3 Month	133.52	*2.27*
LME-Copper, Grade A 3 Month	24.25	*3.22*			
LME-Tin, 99.85% Cash	39.21	*2.25*			
LME-Tin, 99.85% 3 Month	39.64	*2.21*			
LME-SHG Zinc, 99.995% Cash	41.10	*2.11*			
LME-SHG Zinc, 99.995% 3 Month	40.26	*2.11*			
Silver, Handy & Harman (NY)	31.41	*2.56*			
Palladium	23.98	*2.00*			
Ruthenium, CIF NEW	45.19	*2.07*			

Table 12: Change in systematic risk of commodity sectors

This table shows the change in systematic risk for each of our five commodity sectors in an aggregate manner, using various models. A positive change in beta represents an increase in the systematic risk relative to its original risk factor (beta) as a result of the 20 terrorist attacks. The *t*-stat indicates whether the change in beta variable is statistically different from zero.

	GARCH							
Sector	Intercept	t-stat	Beta	t-stat	Change in beta	t-stat	Intercept change	t-stat
Agricultural	0.00	-0.17	-0.87	-88.33	0.10	0.41	0.00	0.16
Chemicals	0.00	0.54	-0.98	-85.87	0.28	0.43	0.00	0.50
Energy	0.00	0.43	-0.87	-51.44	-0.52	-1.42	0.00	-0.37
Metals	0.00	-0.65	-0.75	-71.83	-0.35	-1.81	0.00	1.55
Precious Metals	0.00	0.88	-0.90	-94.70	0.06	0.14	0.00	0.72
			EGARCH					
Agricultural	0.00	-0.06	-0.87	-91.40	0.12	0.51	0.00	0.15
Chemicals	0.00	12.73	-1.02	-122.05	0.54	1.15	0.00	2.01
Energy	0.00	1.79	-0.87	-48.47	-0.37	-0.97	0.00	-0.42
Metals	0.00	-0.28	-0.75	-72.13	-0.32	-1.64	0.00	1.55
Precious Metals	0.00	1.03	-0.90	-96.06	0.04	0.10	0.00	0.89
			TARCH					
Agricultural	0.00	0.06	-0.87	-88.63	0.10	0.42	0.00	0.18
Chemicals	0.00	0.60	-0.98	-84.75	0.27	0.43	0.00	0.50
Energy	0.00	1.36	-0.87	-50.49	-0.43	-1.27	0.00	-0.64
Metals	0.00	-0.40	-0.75	-72.14	-0.35	-1.82	0.00	1.53
Precious Metals	0.00	1.03	-0.90	-93.76	0.07	0.15	0.00	0.71
			PARCH					

Agricultural	0.00	0.06	-0.87	-88.72	0.10	0.43	0.00	0.17
Chemicals	0.00	-0.93	-0.96	-117.63	0.48	1.07	0.00	2.55
Energy	0.00	1.44	-0.87	-49.08	-0.39	-1.11	0.00	-0.54
Metals	0.00	-0.36	-0.75	-72.17	-0.35	-1.80	0.00	1.50
Precious Metals	0.00	1.04	-0.90	-94.29	0.04	0.11	0.00	0.87

Figure 1: Short-term changes in systematic risk (measured after one day)
This figure shows the changes in systematic risk as a result of the 20 terrorist attacks. The results are displayed as an aggregate effect on the risk for the five commodity sectors.