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Identifying Irrationality and Fear-Driven Reactions to Financial Market Shocks & Terrorism

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Identifying Irrationality and Fear-Driven Reactions to Financial Market Shocks & Terrorism

Observed Through the Volatility Index (VIX) and the Duration of the Fixed-Income Market Response

Kimberly Roland

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ABSTRACT

Economic research on post 9-11 terrorism lacks a distinction between fear-based reactions and rational financial market behavior in its analysis surrounding terror strikes. The purpose of this paper is to expose and interpret the fear triggered by terrorism in financial markets, and to separate rational market responses from irrational, fear-driven investor reactions. A rational market response follows the efficient market theory (Wang 1993) in which investors alter their behavior based on changes in fundamental values. Becker and Rubinstein (2011) define terror-triggered fear as the magnitude with which subjective beliefs about danger hinder objective risk assessment. I apply this definition to the De Long et al (1990) discussion of noise trading to define irrational investor reactions as a response to subjective beliefs about danger and disregard for fundamental risk that causes volatility and a divergence from fundamental valuations. I observe the Volatility Index (VIX) and change in 10-year Treasury yield surrounding terror events to identify irrationality, and differentiate from rational market behavior through a comparison to the two gauges surrounding foreign and domestic central bank action. I analyze market behavior surrounding 9-11 and recent 2013 and 2015 terror events and find consistently heightened post-event volatility. I observe responses in the 10-year Treasury yield, and find that response duration is dependent on the implications for Federal Reserve policy and expectations of demand for safe-haven assets (Krishnamurthy & Vissing-Jorgensen 2012). I also find a decrease in magnitude of financial market response from 2001 to 2015, which could be due to prior experience with terrorism (Becker & Rubinstein 2011) or the Federal Reserve's recent consideration of global instability in domestic monetary policy.

Table of Contents

1. INTRODUCTION.....	3
2. METHODOLOGY.....	8
3. DOMESTIC ECONOMIC NEWS & MARKET REACTION	10
3.1. 2013	11
3.2. 2015	12
3.3 Conclusion	15
4. FOREIGN ECONOMIC NEWS & MARKET REACTION	16
4.1. 2013	17
4.2. 2015	18
4.2. Conclusion	20
5. TERROR STRIKES & MARKET REACTION	21
5.1. 9/11/2001	21
5.2. Boston Marathon	23
5.3. Paris Attacks	26
5.4. Conclusion	29
6. CONCLUSION.....	30
7. REFERENCES.....	33

1. Introduction

Several years ago I came across an article written from the perspective of a Wall Street trader as he recounted his experience on September 11th. Most accounts of the event serve as chilling reminders of terror and loss; however, this unique report offered the opportunity to understand a trader's response to tragedy. As he reviewed his thoughts from the day, he was alarmed to have realized that the first thing on his mind was not his family or his colleagues and friends in surrounding buildings, but on the market's response. While the individuals evacuating beside him were processing the news and calling their wives, he was internally projecting the effect of the terror on the spot rate of gold futures.

Market speculation had replaced grief and emotion as this trader's first instinct to this traumatic event. He knew that investors would react by pouring money into safe haven assets while the stock market plummeted; he was quantifying investor fear.

The purpose of this paper is to expose and interpret the fear triggered by terrorism in financial markets, and to separate rational market responses from irrational, fear-driven investor reactions. In the wake of 9-11, many economists have focused on the immediate economic and sector specific equity responses to the terror event (Chen *et al* 2008, Obi 2007). Lenain, Bonturi, and Koen (2007) attempt instead to observe the long-lasting macroeconomic effects of the subsequent increase of risk-aversion through an observation of insurance coverage, changes in trading costs, and increases in security spending, and conclude that unless a new large-scale threat emerges, these effects are tangible but limited. Many look at the magnitude of reactions by closely related stock prices, and have concluded that although fundamentals remained strong for each, airline and insurance sectors suffered significantly following the attack, indicating

contagion and panic-selling in response to the tragedy (Chen *et al* 2008). Obi (2007) closely observes stock market behavior surrounding the event, concluding that pre-event volatility is suggestive of trading on knowledge of an impending market shock. Evidence exists of a lasting post-event increase in risk premium by market participants (Obi 2007), a permanent retreat to safety indicative of a widely inexperienced investor base with terror shocks (Becker & Rubinstein 2011).

Economic research on post 9-11 terrorism lacks a distinction between fear-based reactions and rational financial market behavior in its analysis surrounding terror strikes. In their observation of the effects of terrorism on the use of terror-targeted services, Becker and Rubinstein (2011) define terror-triggered fear as the magnitude with which subjective beliefs about danger hinder objective risk assessment. As applied to my thesis, this definition (Becker and Rubinstein 2011) can be broken down as follows. First, an individual's "subjective belief" describes one's inflated conviction in the likelihood of personal affliction. "Danger" in Becker and Rubenstein refers to the actual threat of being a victim of terror, and here will be as well, with the extension to financial market uncertainty. The hindering of "objective risk" describes the restriction of an ability to employ an unbiased assessment of fundamental riskiness. And finally, "magnitude" can be equated to the severity of the post-event response, measured through the volatility and fixed income gauges detailed below.

A specific discussion of the definition of "risk" is also necessary. Gigerenzer (2006) describes "dread risk" as a low-probability, high-damage event in which many people are killed at one point of time, causing direct damage at the time of the event, and indirect damage through its lasting effects on citizens. Similar to the effect noted by Becker and Rubinstein (2011), Gigerenzer details "avoidance-behavior" in which citizens irrationally alter their behavior by

avoiding the terror-targeted activity. Girgerenzer finds that this behavior, not only unproductive, is sometimes harmful in the inappropriate alternatives that individuals engage in to avoid such risk. Michel-Kerjan (2008) focuses on methodology in measuring the perceived risk of terrorism. He points to the misconception that risks are mainly local, routine, and predictable through past experience, which he counters through a discussion almost identical to Girgerenzer's of dread risk (2006). Michel-Kerjan (2008) finds that current catastrophe risk calculus is unreliable in evaluating terror risk due to the uniquely unpredictable nature of terrorism. The inability to accurately quantify risk of terror has led to observable panic in the market following a terrorist attack. I define perceived risk as financial market volatility in the wake of a terror event. The timeline of the surrounding volatility suggests the extent of the market's anticipation, indicating the accuracy of investor risk perception. If a risk is accurately priced-in to the market, volatility occurs prior to the event's fruition. If a risk is unforeseen, markets respond with higher levels of volatility following the event as investor fear leads to a bout of panic selling (Bernanke & Kuttner 2005). The extent of this investor fear, captured through market volatility (Durand, Lim, & Zumwalt 2011), will be evident through its magnitude and duration.

I differ from Rubinstein and Becker (2011) in the mode of my assignment and observation of fear. Instead of the use of goods and services affected by terrorism, I will observe financial market reactions through volatility in the stock market with the widely referenced "investor fear gauge" Volatility Index (VIX) (Durand *et al* 2011). I will observe the validity of the market's response through the 10-year Treasury bond's change in yield surrounding the event. Following a release of new information, the duration of the 10-year Treasury's response indicates if the information has altered economic fundamentals (Fleming & Remolona 1999).

Taken in aggregate, these two indicators create a quantifiable measure of “magnitude” as referenced in Rubinstein and Becker’s (2011) definition of fear above.

De Long *et al* (1990) identify “noise traders” as irrational market participants that respond to “noise” in the market and disregard fundamentals in risk assessment, causing significant price divergence from fundamental values. Brown (1999) interprets the noisy signal to be any event causing an undue shift in investor sentiment, causing systematic risk and increasing volatility. Because noise-trader theory describes cohesive action in response to a noisy signal (Brown 1999, De Long *et al* 1990), I interpret the aggregate reaction to a noisy signal as a fearful response to a market shock. Paired with Becker and Rubinstein’s (2011) definition of terror-triggered fear, this depicts the irrational, fear-driven market illustrated in depth in Section 5. Reacting to subjective beliefs about danger and disregarding fundamental risk, the irrational investor responds in fear to a terror threat, observable through relatively high VIX readings and a concurrent lack of fundamental economic change. The market considers United States Treasuries to be virtually riskless (Krishnamurthy & Vissing-Jorgensen 2012), so it follows naturally that 10-year yields respond to terror through an observed tightening as uncertainty mounts and investors flee to safety.

In order to first present examples of rational market behavior, I will observe policy actions and economic data releases out of both the United States and other relevant foreign ministries. Consistent with efficient market theory (Wang 1993), markets operate rationally while appropriately adjusting investment strategy based on expectations of security fundamentals. Economic data releases and central bank behavior alter expectations of the federal funds target interest rate, which alters the market discount rate, a determinant in financial security valuation via the capital asset pricing model (Litzenberger & Tuttle 1972). Thus, I am

able to illustrate rational market activity through observation of the VIX and movements in 10-year yields surrounding economic data releases and central bank activity. Scheduled announcements regarding the state of the economy, FOMC statement releases, or any indication of future changes to monetary policy will observe a pre-event surge in VIX, indicative of investor speculation (Obi 2007). Post-event volatility declines, as the opportunity for speculation has concluded (Bernanke & Kuttner 2005). Foreign central banks do not all have the same responsibility of transparency as the Federal Reserve, making their activity harder for U.S. investors to predict relative to the Fed, observable through large swings in VIX following surprise announcements (Kausik & Koo 2001). Foreign central bank action is significant to the Federal Reserve's policy decisions because global monetary policy changes the value of the domestic financial securities. In turn, relative attractiveness of U.S. securities is altered.

Once I establish instances of rational market behavior, I evaluate the effect of the market's risk environment surrounding terror events. Based on the exponential increase to the threat of terrorism since 9-11, investors have gained meaningful exposure to terrorism. Becker and Rubinstein (2011) observe that following a terror attack on public transportation, occasional riders almost entirely stop their use of the service, despite the risk of an additional attack being negligible. Frequent users observe less of a decline in use. Over a period of increasing terror threats, riders reestablish their former frequency of public transportation use. Becker and Rubinstein conclude that additional exposure teaches market participants to combat their fear of terror that initially hindered objective risk assessment. Similarly, my observations expose irrational financial market behavior as an initial response to terrorism that, after a rapid increase in reports of global terror instances (START 2013), observes a reduction in duration as investors learn to respond appropriately. I first outline the initial shock to the US financial marketplace

after 9-11, and then observe how markets have adapted in the more recent attacks of 2013 and 2015.

I narrow my remaining analysis to the years 2013 and 2015 for two specific reasons. First, each was host to a largely publicized act of terror on a first-world country (Brinkley 2013, Brisard 2015). The Boston Marathon bombing in April of 2013 and the coordinated strikes on Paris in November of 2015 shattered the developed world's perceptions of security, and will provide an interesting comparison as the threat of terror continues to grow. Second, 2013 and 2015 observed very different volatility trends. In 2013, the maximum VIX reading barely scraped over 20, while in 2015 it reached levels above 50. In selecting these very different years, I will analyze the significance of investor risk aversion prior to each event in determining the magnitude of reaction to a market shock (Durand *et al* 2011).

2. Methodology

I will illustrate fear in the market through the intraday VIX maximum reading and then, observing the 10-year Treasury's activity, determine how long the market took to correct back to pre-shock levels. My purpose in selecting these two indicators is to express both the short-term and long-term responses to each market shock. An event that corresponds to a spike in VIX will indicate the panic in the market (Kausik & Koo 2001), while the reaction time in the yield on the 10-year Treasury will signify the validity of the initial panic. If the 10-year corrects back to previous levels quickly, this indicates that the market has discounted the event as insignificant, acknowledging an overreaction (Fleming & Remolona 1999, Bernanke & Kuttner 2005).

The VIX is comprised of a weighted measure of the implied volatility of a wide range of S&P 500 call and put options on the Chicago Board of Options Exchange (CBOE), and is widely referred to as the “investor fear gauge” by market speculators (Durand *et al* 2011). Durand *et al* (2011) refer to a reading of 20 or higher as representative of a highly uncertain and risk-averse market, and a number below 20 as indicative of more bullish investor pool. In terms of its actual mathematical derivation, the CBOE offers this formula on their website:

$$\sigma^2 = \frac{2}{T} \sum_i \frac{\Delta K_i}{K_i^2} e^{RT} Q(K_i) - \frac{1}{T} \left[\frac{F}{K_0} - 1 \right]^2$$

WHERE...

σ is $VIX/100 \Rightarrow VIX = \sigma \times 100$

T Time to expiration

F Forward index level derived from index option prices

K_0 First strike below the forward index level, F

K_i Strike price of i^{th} out-of-the-money option; a call if $K_i > K_0$ and a put if $K_i < K_0$; both put and call if $K_i = K_0$.

ΔK_i Interval between strike prices – half the difference between the strike on either side of K_i :

$$\Delta K_i = \frac{K_{i+1} - K_{i-1}}{2}$$

(Note: ΔK for the lowest strike is simply the difference between the lowest strike and the next higher strike. Likewise, ΔK for the highest strike is the difference between the highest strike and the next lower strike.)

R Risk-free interest rate to expiration

$Q(K_i)$ The midpoint of the bid-ask spread for each option with strike K_i .

Source: Chicago Board of Options Exchange (March 2016)

More simply put, the VIX represents any +/- percentage point movement by the S&P 500 index, annualized for one standard deviation (Deuker 1997). For example, when the VIX is at 20, the

S&P is expected to stay within a +/- 20% range over one year 68% of the time (or within the first standard deviation). It then becomes obvious why high VIX levels are representative of volatility—an increase in VIX signifies an increase in future uncertainty.

Coupling this indicator with the 10-year Treasury yield allows for a complete understanding of the market's reception of a shock, as well as the preceding risk environment (Fleming & Remolona 1999; Kausik & Koo 2001). According to historical data from the FOMC, the 10-year Treasury saw average daily moves of 4 basis points ("bps" here on) in both 2013 and 2015, but 2013 reached wider a wider maximum shift of 21 bps, while 2015's intraday ceiling was +/- 16 bps. Over the year, 2015 saw a minimum yield of 1.68% and a maximum yield of 2.5%. 2013 hit nearby lows of 1.66%, but reached its widest level at 3.04% over the year, ranging a total of 138 bps. This summarizes a more responsive bond market in 2013, while VIX readings point to a more responsive stock market in 2015. In observing both the VIX and the 10-year's response to market shocks over each of these years, I will interpret this difference in responsiveness as it affects the way investors react to market-shocks.

I will differentiate between fear and rationality using these gauges. An analysis of the VIX reading preceding each event and its relative change following will expose the "magnitude" of fear, as outlined in Becker and Rubinstein (2011). An event with legitimate consequences for financial security fundamentals will observe lasting effects on the 10yr yields (Lange, Sack, & Whitesell 2003; Fleming & Remolona 1999).

3. Domestic Economic News & Market Reaction

First, I will observe the market's reaction to domestic economic data releases and FOMC announcements. The Federal Reserve Open Market Committee (FOMC) is the governing body

tasked with establishing U.S. monetary policy that aims to achieve the dual mandate of stable inflation and low unemployment. The release of data related to the Fed's dual mandate can significantly disrupt markets through a change in expectations of FOMC action (Bernanke & Kuttner 2005; Lange *et al* 2003).

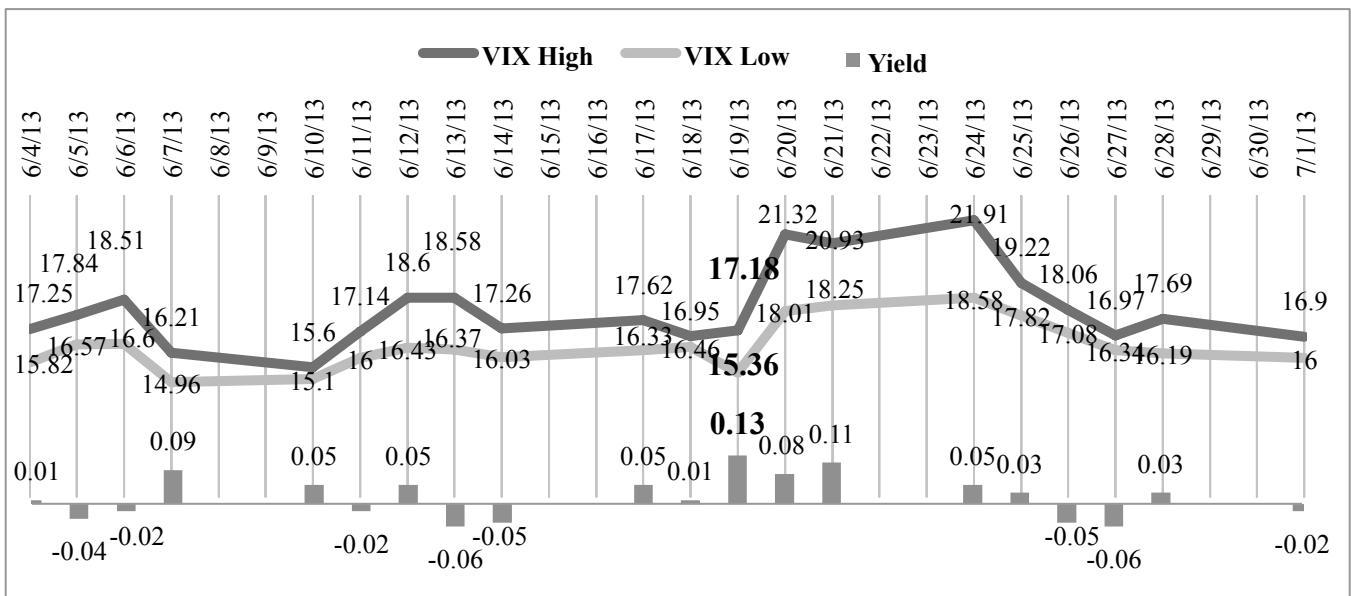
A 2005 study by previous Federal Reserve Chairman Ben Bernanke concludes that unanticipated changes in the federal funds rate target are significant in their correlation to an immediate stock market reaction (Bernanke & Kuttner 2005). Using federal funds futures contracts to distinguish the level of expectation of a rate change by investors, the Kuttner and Bernanke are able to regress the coefficient for expected rate changes and the variable for unexpected rate changes on the corresponding stock market return. They find that an unanticipated cut of 25 bps is associated with a 1% increase in broad stock indexes. Their study focuses on the difference in market reaction once the Federal Reserve increased transparency and began signaling a rate change in advance of any action, beginning in 1994.

Since 2005, the transparency provided by the FOMC has significantly increased (Ihrig *et al* 2015). The market typically has any federal funds target changes priced-in weeks ahead of the announcement, leaving the immediate reactions to FOMC action limited (Bernanke & Kuttner 2005). Therefore, instead of focusing on FOMC action, I will focus on domestic releases that alter expectations of future action, as well as broader economic data releases that have potential to alter the projected course of Fed action.

3.1. Domestic Economic News & Market Reaction: 2013

In the wake of the 2008-2009 financial crisis the Federal Reserve engaged in an expansionary monetary policy that brought the federal funds target to extremely low levels.

Money was pumped into the economy through multiple rounds of quantitative easing to ensure a liquid marketplace and a greater accessibility to credit for investors and consumers (Ihrig, Meade, & Weinbach 2015). Monetary policy stimulus is consistently very supportive of the stock market, as low yielding fixed-income securities leads yield-seeking investors to riskier equities (Thorbecke 1997). On 6/19/13, Fed Chairman Ben Bernanke warned of a tapering of stimulus, and an eventual end to the stimulus that had inflated equity values since the crisis. The VIX and 10-year yield reaction following his announcement are pictured below:

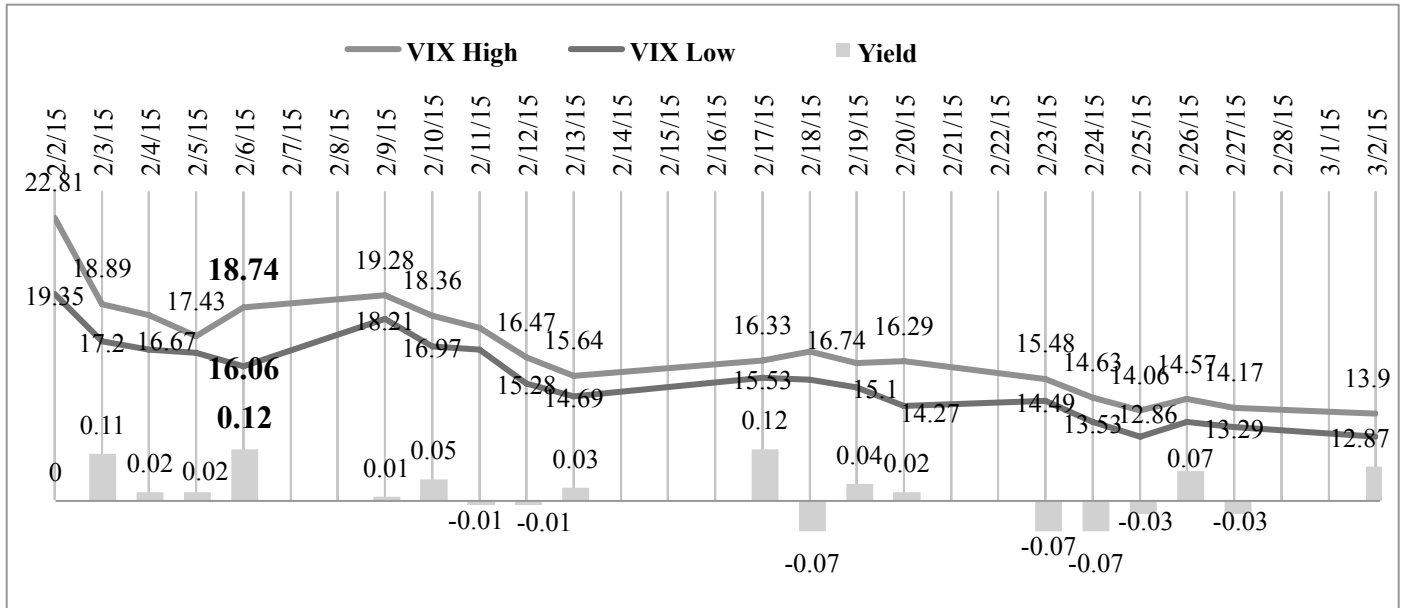


Each gauge experiences an initial surge in reaction to the Thursday news, and the VIX continues climbing through Monday, where it hits 2013 highs. The yield on the 10-year Treasury experiences an initial increase of 13 basis points, gaining a total of 32 basis points through the weekend as investors drive down Treasury prices due to the change in expectations of interest rates.

3.2. Domestic Economic News & Market Reaction: 2015

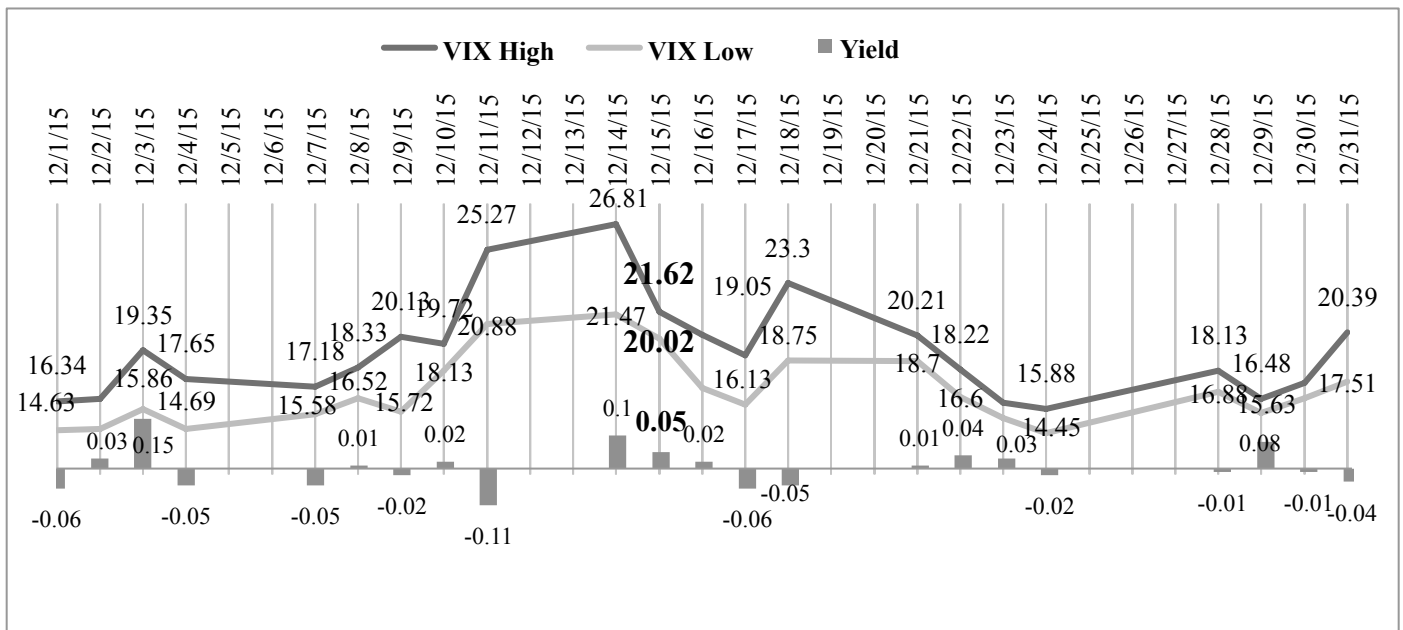
The rate discussion became even more prominent in 2015. The FOMC began tapering their purchases of government securities, and was searching for the right time to begin increasing the federal funds target rate. The Fed had communicated confidence in a rate hike by year-end, but a plunge in commodity prices and global uncertainty weighed on their dual mandate of stable inflation and low unemployment. Consequentially, any data-release regarding the state of the economy was read as indicative of the Fed's behavior (Bernanke & Kuttner 2005).

The Nonfarm Payroll report released by the Bureau of Labor Statistics (BLS) each month summarizes the amount of jobs added to the economy. Positive readings –recently in the ballpark of 150,000+ new jobs— signal a healthy job market. Analysts polled by Bloomberg, Reuters, and other market-based news sources form an aggregated prediction, widely referenced as the market's consensus expectation (Campbell & Sharpe 2009). The January Nonfarm Payroll report released on February 6th, 2015 came in above expectations of 230,000 at 257,000, and included large upward revisions to November and December numbers. Due to the importance of low unemployment to the Federal Reserve's main objectives, the report is considered indicative of future FOMC action (Bernanke & Kuttner 2005)—in this case, indicating a reduced timeline to rate-hike. Following the release, the stock market experienced a minor increase in volatility with intraday highs of 18.74, over prior day's highs of 17.38. The pre-event downward trend of VIX indicates the market's surprise, and the subsequent daily increase in volatility indicates uncertainty in processing the news. Pictured with the VIX below, the 10-year saw a much sharper decline in value with yields widening out 12 basis points:



A swing of 12 bps is substantial, and indicative of a change in investor expectations of interest rates. Here, the positive data released by the BLS illustrates a healthy economy, which is supportive of a near-term rate hike (Bernanke & Kuttner 2005).

The FOMC increased their target rate from 0-25 basis points to 25-50 basis points at the December 15, 2015 meeting. After 11 months of signaling an increase before year-end, investors had largely priced-in the hike. Pictured below is the market's reaction:



Because of the FOMC's transparency (Ihrig *et al* 2015), investors had begun speculating before the weekend, four days prior to the 12/15/15 rate hike. Consistent with rational behavior in markets prior to a scheduled event (Lange *et al* 2003), VIX stays above 25 in the two prior trading days, before beginning its decline at the announcement.

3.3. Domestic Economic News & Market Reaction: Conclusion

This section has served to define rational market behavior. Investors alter their expectations of FOMC action and confidence in equities based on economic data releases (Lange *et al* 2003; Bernanke & Kuttner 2005; Fleming & Remolona 1999). Positive releases signal a tightening of monetary policy, encouraging an exit from treasuries—sending yields higher, and prices lower- and an increase in equity volatility as investors reposition themselves, observed as an increase in VIX (Lange *et al* 2003). FOMC announcements provoke volatility in trading as the announcement approaches, until returning to normal levels at the time of the release (Lange *et al* 2003; Fleming & Remolona 1999; Bernanke & Kuttner 2005). I observe a sharper increase in volatility in 2013 following the surprise FOMC announcements, relative to each year's respective annual median. 2015, however, experienced higher overall levels of volatility, indicating a more risk-averse investing environment. This discussion is beneficial to my thesis in providing a framework for rational behavior in response to domestic shocks. Consistent with rational market behavior (Wang 1993), my observations provide a relevant framework for comparison to the market behavior in the wake of a terror event.

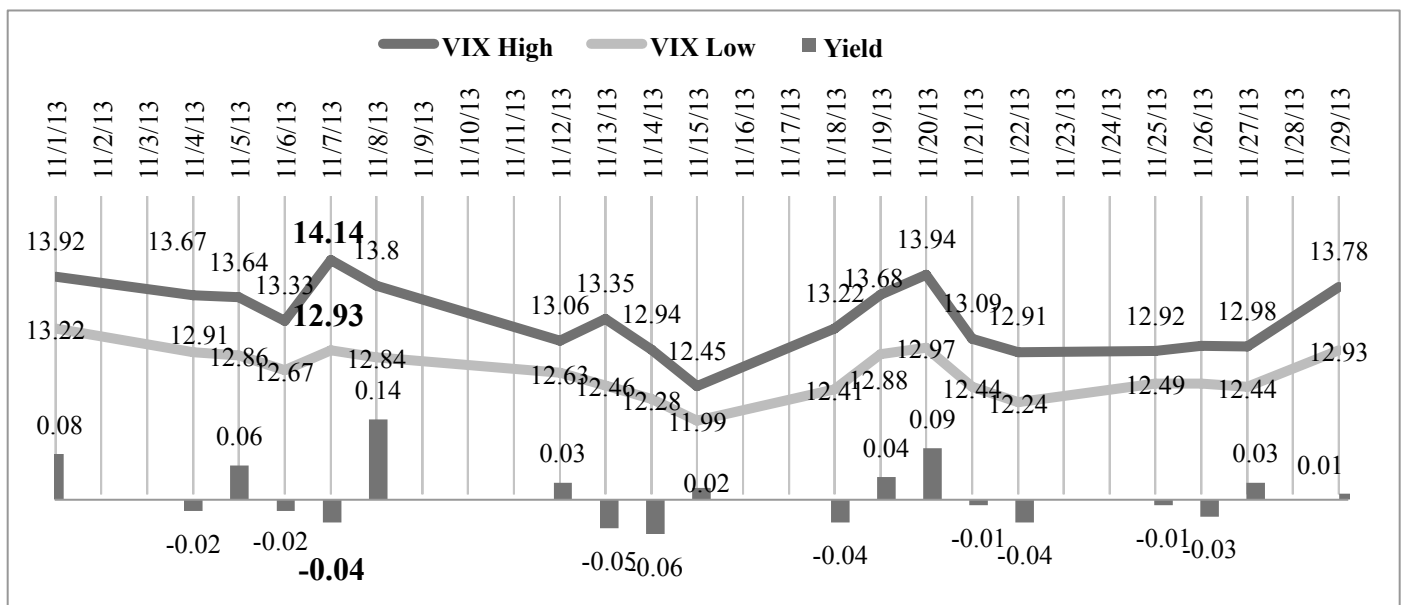
4. Foreign Economic News & Market Reaction

The Federal Reserve's policy of extreme transparency makes the actions of other major central banks appear brash by comparison. This creates the potential for foreign central bank behavior to rattle domestic financial markets, and has become increasingly relevant as global markets become further interdependent. 2013 and 2015 diverge in treatment of foreign monetary policy announcements as investors adjust to the FOMC's emphasis on global economic health in the 2015 rate hike decision (Federal Reserve Board 2015).

In the wake of the financial crisis, the United States was the first major economy to take extreme easing measures, significantly expanding the balance sheet and lowering the federal funds target to near zero levels (Mishkin 2010). The European Central Bank (ECB), the Bank of Japan (BOJ), and the People's Bank of China (PBOC) lagged the Fed in their stimulus, leaving central bank policy incongruent (Pill 2009). This divergence created a situation in which the United States became the first major economy to need to return to normalcy, strengthening the USD against all foreign currencies and thereby having extensive implications for foreign investment and international trade. In 2013, the Federal Reserve focused on domestic indicators of economic health in its decision to slow stimulus. Positive domestic data was supplemented in 2015 by global financial market uncertainty as the Fed considered the risks of policy divergence, evoking severe volatility in response to any central bank announcements (Federal Reserve Board 2015).

4.1. Foreign Economic News & Market Reaction: 2013

The ECB’s monetary policy was much less aggressive than the Federal Reserve in response to the financial crisis (Pill 2009). From July-October 2008, the ECB raised the main refinancing rate as opposed to lowering it. The central bank began cutting rates in October 2008, but did not announce near-zero levels until 2013, on November 7th, ahead of the BLS Nonfarm Payroll release on November 8th (European Central Bank 2013). The market reaction was muted, pictured below:



The announcement of near-zero rates on 11/07/13 appears to have spiked the VIX to its monthly high, but it is important to note the proximity of the jobs report on 11/08/13.

It is typical of rational market behavior for speculators to employ volatile trading tactics while anticipating a major economic report (Lange *et al* 2003; Bernanke & Kuttner 2005). In this instance, yields on the 10-year decline with the ECB news, as European stimulus weighs on inflation (because an increase in the European money supply strengthens the dollar against the

euro), but increased by 14 basis points on the positive employment data released Friday. The swift recovery in yields signals the insignificance of the ECB announcement to the market, and is suggestive of a stronger correlation between 11/07 behavior and 11/08 Nonfarm Payrolls data.

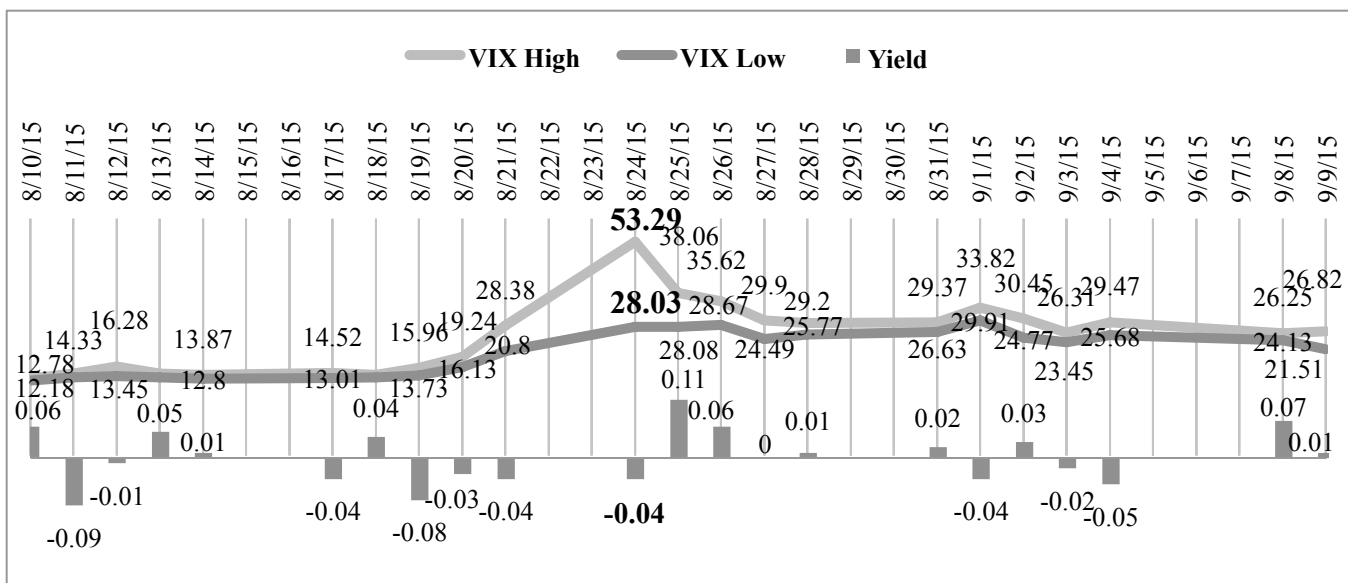
4.2. Foreign Economic News & Market Reaction: 2015

Due to consistent improvements to the domestic economy, 2015 saw a shift in the Federal Reserve's focus from domestic economic data releases to monetary policy changes abroad. A steep decline in commodity prices put deflationary pressures on the USD, and coupled with monetary easing abroad, was threatening the Federal Reserve's goal of 2% inflation (Federal Reserve Board 2015).

In particular, the market had been focusing on the slowing growth in the Chinese economy. A significant portion of global demand comes from Chinese consumers (Morrison 2013) ensuring that a slowdown in growth is felt across nations. For the first half of 2015, Chinese financial markets and economic data releases dominated market headlines (Federal Reserve Board of St. Louis 2015). Then, on August 11th, the PBOC shocked financial markets by announcing a devaluation of their currency, the Yuan (People's Bank of China 2015). This announcement left investors uneasy, but did not send markets into a spiral until HSBC released the Caixin China PMI Manufacturing numbers on August 21st.

The PMI (Purchasing Managers' Index) measures the performance of the manufacturing sector. A reading above 50 indicates an expansion of the manufacturing sector, a reading below 50 signals a contraction, and a reading of 50 indicates no change (Caixin Markit 2015). The August 21st numbers were expected to drop 0.1 to 47.7 from a prior month's reading of 47.8.

Instead, at 47.1, the index had hit 77-month lows. An initial 47.5% surge in VIX from 8/20/15 highs indicates the importance of China’s economic standpoint to American investors, and was reaffirmed after the weekend with 8/24/15 highs of 53.29 (marking the highest VIX reading since 2009). Investors who did not participate in the initial spike in VIX on the 21st processed the news over the weekend and entered the marketplace ready to act on the negative data, driving volatility levels beyond 2009 highs, bolded below:



The surge in the investor fear gauge of 25 points (that is, an increase in uncertainty of the direction of the market of 25%) signifies how relevant the global uncertainty story has become in recent years (Lange *et al* 2003; Durand *et al* 2011). The poor reading implies a need for further Chinese monetary easing, triggering a fear in the stability of global markets and in a strong US dollar’s implications for domestic inflation targets (Kaminsky & Lewis 1996), while threatening the recovery of the global economy.

4.3. Foreign Economic News & Market Reaction: Conclusion

Based on the above examples, there was a clear and increasing trend of importance in the anticipation of monetary policy actions abroad to the stock market's reaction domestically from 2013 to 2015. With commodity prices already muting domestic inflation levels, the relative increase in USD spending power against its peers created an additional obstacle in the Fed's fulfillment of its 2% inflation target (Kaminsky & Lewis 1996). The increased relevance of foreign monetary policy to domestic market behavior is observed in the comparison between VIX reactivity across the foreign events discussed in 2013 and 2015. This provides further insight into the divergence in behavior across each year, as well as an example of rational investor decision making in the face of a shock.

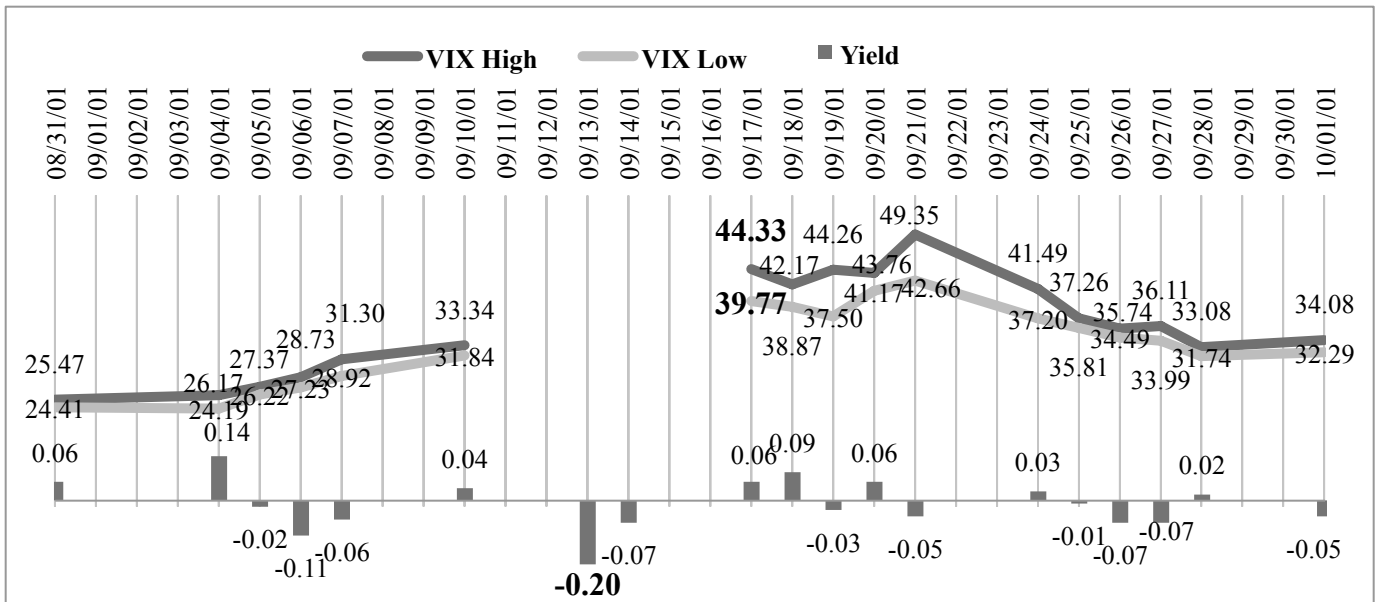
5. Terror Strikes & Market Reaction

Terrorism is unique in its effect on financial markets. While the likelihood of being directly affected by terrorism is negligible, it reserves the power to alter the behavior of entire populations by instilling a lasting fear of unlikely dangers (Becker & Rubinstein 2011), evoking an irrational necessity for average investors to exit all risky positions. Becker and Rubinstein consider the timeline of the impacts of terrorism on human behavior, acknowledging the influence of fear on beliefs and decision-making, "so that subjective and objective beliefs can diverge with concomitant effects on individual decisions" before individuals learn to control their emotions to align with their long-run interests (Becker & Rubinstein 2011, p. 3). Of the accounts examined in this paper, September 11, 2001 elicited the most extreme response from financial markets to terrorism. Since 2001, the threat of terrorism on the western world has exponentially increased, but investor reactions have diminished (START 2013). Consistent with

Becker and Rubinstein (2011), investors gained initial experience with 9-11, and have since learned to adequately control their fear-driven responses to terror.

5.1. Terror Strikes & Market Reaction: 9/11/2001

For the broader American population, 9-11 introduced a newfound feeling of danger, a more cautious perspective on safety and the power of evil. This broad-based fear erupted through American financial markets as soon as stock markets reopened on September 17th, seen as an initial 11-point surge in VIX and decline of 20 basis points in the 10-year Treasury yields when Over-the-Counter (OTC) securities resumed trading on September 13th:



For a much smaller population, like the commodities trader mentioned previously, it meant an opportunity to profit from common investor fear as it drove fundamentally strong equities to new lows, and inflated the price of safe-haven assets (De Long *et al* 1990). This fight between fear and greed kept volatility high above pre-event levels for multiple weeks.

According to efficient market theory, investors act rationally while responding to an economic event that alters their expectations of the fundamental value of a security (Wang 1993). Following 9-11, many economists studied the immediate effects on the value of airline, financial, and insurance equities (Chen *et al* 2008; Obi 2007). Airline stocks fell off significantly after the event, as investor's predicted a new fear of flight and the consequential decrease in demand for major airlines (Drakos 2004; Carter & Simkins 2002). Insurance companies were hit with massive payout claims, and the financial sector was expected to face reduced liquidity as investors withdrew assets (Chen *et al* 2008; Carter & Simkins 2002). Obi (2007) observes "significant negative excess returns...in the airlines and financial services sectors due to the incident," followed by a reversal of excess returns, indicative of an overreaction by the markets.

Because the reaction cannot be attributed to a rational belief in the fundamental valuation of the equity market, I will now argue that expectations of fundamental values across fixed income markets should not rationally been altered by the attack. The immediate decline in 10-year yields by 20 basis points exposes clear excitement in the bond market, despite the Federal Reserve remaining unchanged in its policy. In fact, the immediate response from the Federal Reserve came as a statement issued on the morning of 9/11, stating very simply, "The Federal Reserve system is open and operating. The discount window is available to meet liquidity needs" (Federal Reserve Board 2001). This statement should have had two main effects. First, all else equal, the market should have been reassured by the Fed's pledge of consistency, which does not necessarily warrant a change in yields. Second, the Fed plainly stated that they would support financial intermediaries by providing needed liquidity, which should have dismissed fears of a bank-run and instilled confidence in financial equity shareholders (Gorton & Metrick 2013). Instead of stability on both fronts, a fear-driven retreat from bank stocks tore through markets,

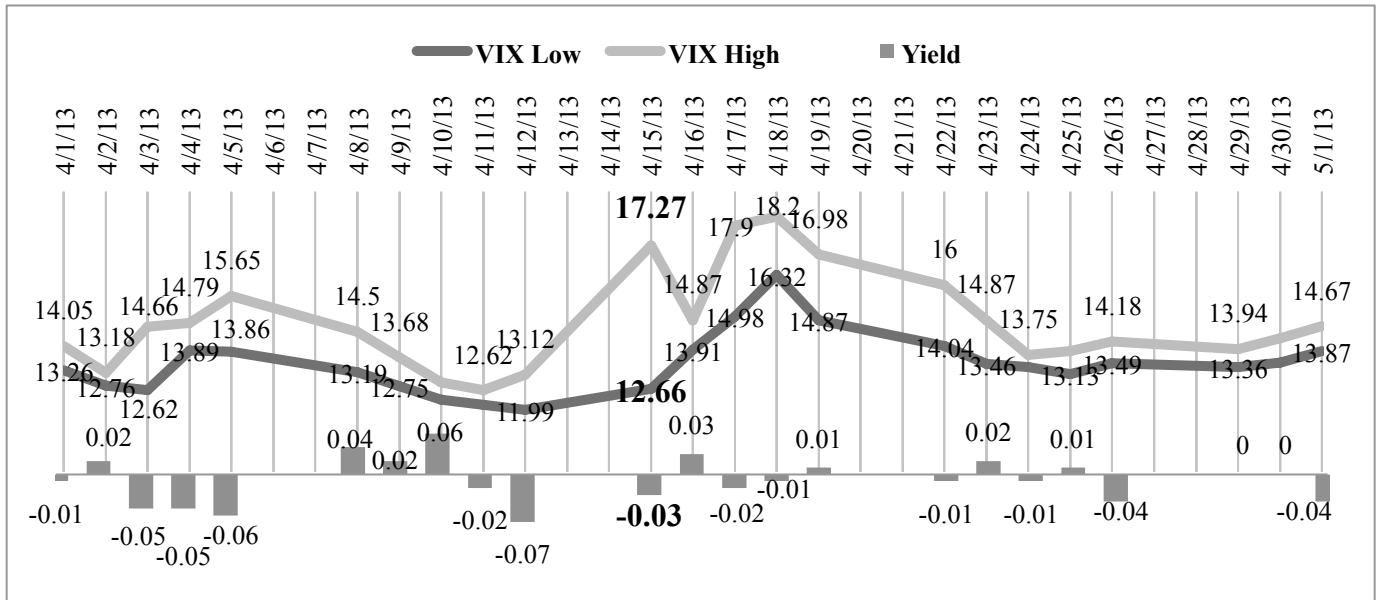
leaving financial intermediaries' share values to plummet and the price of the 10-year Treasury to skyrocket (Carter & Simkins 2002). In the wake of the terror, uncertainty in market stability drove investors away from equities and into Treasuries, the least risky alternative (Krishnamurthy & Vissing-Jorgensen 2012). This decrease in risk tolerance was observed by Obi (2007) who suggests that 9-11 instilled such uncertainty in financial markets that it permanently altered investor risk appetite.

I return now to Rubinstein and Becker's (2011) definition of fear, and evaluate the magnitude with which subjective beliefs about danger have hindered objective risk assessment. I want to distinguish between a fear of uncertain future value and a speculation that values are approaching a near-term change, the former indicative of irrational fear, and the latter of rational fear. Investor speculation surrounded the January 2015 Nonfarm Payrolls, as well as China's August 2015 PMI reading. Market speculation, or economic reasoning based on beliefs in future stream of endowments (Leoni 2009), requires a rational decision-making process—an ability to connect one catalyst event to a logical outcome, and react based on the severity of the potential outcome (Kausik & Koo 2001). While an overreaction to airline stocks is suggestive of this process, a volatile reaction across all sectors indicates an irrational investor fear, evident in the wake of 9-11 by the cross-sector panic selling. The fall-off in yields surrounding the terror can be attributed to a lasting decline in risk tolerance (Obi 2007).

5.2. Terror Strikes & Market Reaction: Boston Marathon

The attack at the April 2013 Boston Marathon was the first terrorist bombing on United States ground since September 2001. Three victims were killed by the blast, while several

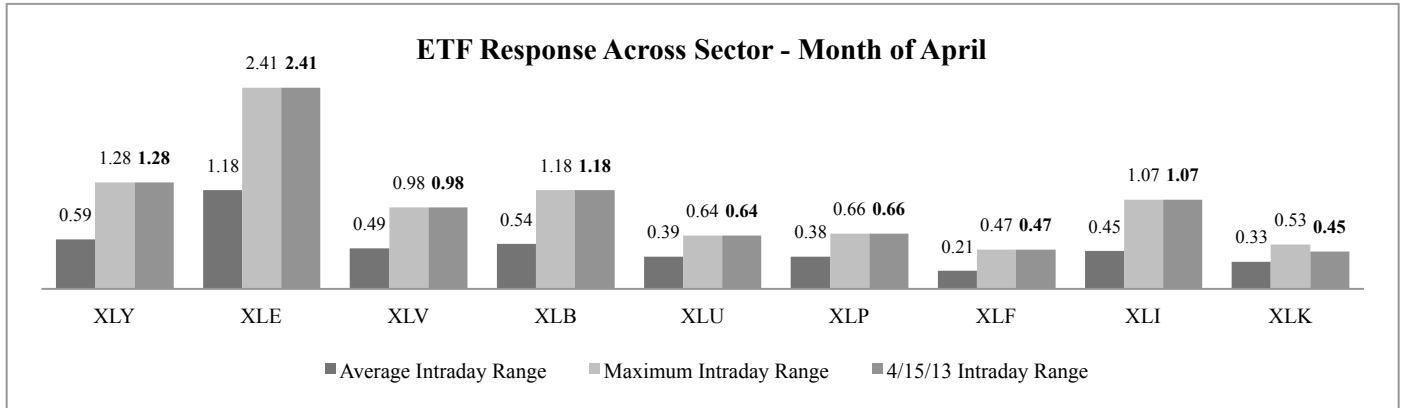
hundred were injured (Brinkley 2013). 4/13/13 intraday VIX highs reached just 13.12, making the 4/15 reading of 17.27 a 31.6% surge in volatility:



While a reading of 17.27 is below the accepted “normal” reading of 20, its premium over the annual average signals a meaningful increase in investor fear (Durand *et al* 2011).

Returning to the Wang (1993) theory of efficient markets, investors behave rationally by reacting to an economic event that alters their expectations of fundamental valuations. As mentioned in the prior discussion of the 9-11 attacks and airline stocks, a terror threat does not merit a response in equities unless a direct path of influence can be interpreted (Litzenberger & Tuttle 1972; Fleming & Remolona 1999). Insufficient research has been published on the effects of Boston Marathon attack on stock market sectors, so I will be using data on the prices of the SPDR sector ETFs (Exchange Traded Funds) that underlie the S&P 500 index to draw conclusions about the nature of the stock market’s reaction across sectors (Hasbrouck 2003). There are eleven broad-based sectors represented by the S&P 500: Consumer Discretionary

(XLY), Energy (XLE), Health Care (XLV), Materials (XLB), Utilities (XLU), Consumer Staples (XLP), Financials (XLF), Industrials (XLI), and Technology (XLK).



Observable through the chart above, the range in value in every underlying sector of the S&P 500 was above the monthly average. Further, 10 of the 11 sectors saw their largest monthly spreads the day of the attack. Thus, the response on 4/15/13 was not a change in investor expectations of fundamental valuation—investors were not solely targeting stock sectors with direct relationships to Boston’s economy.

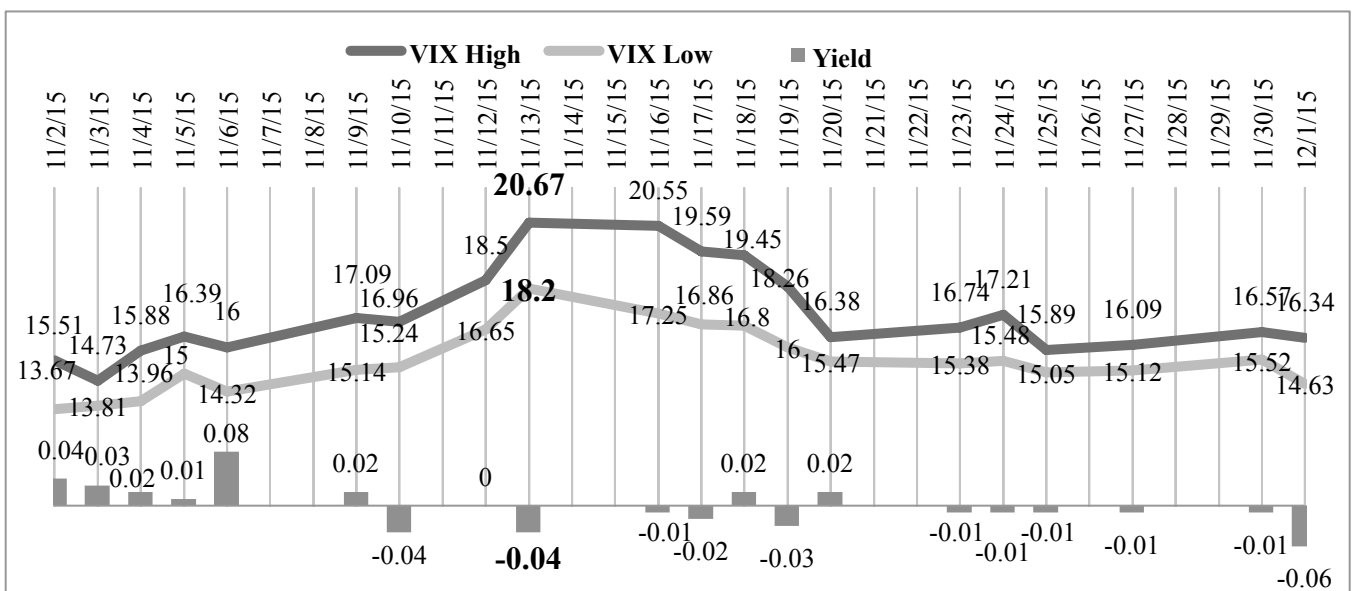
As I have established the similarities between investor behavior following 9-11 and the market’s reaction to the April 2013 attack, I will highlight the differences that suggest a declining fear of terrorism due to increased exposure (Becker & Rubinstein 2011). Defining fear as the magnitude with which a subjective belief about danger hinders objective risk assessment (Becker & Rubinstein 2011), following the attack, it appears that investors are able to alter their response. Unlike the September 11th reaction, VIX returns to annual averages within 10 days of the bombing. Similarly, after an initial 10-year tightening of 3 basis points, investors corrected their reaction in the fixed-income market by allowing yields to return to pre-event levels the following day. Initially, irrational panic selling caused the spike in volatility and the decline in 10-year Treasury yields (De Long *et al* 1990). Becker and Rubinstein (2011) observe the impact

of prior experience with terror on fear-driven market behavior, and conclude that previous experiences allow individuals to assess risk more objectively. Investors' swift return to rational decision-making following the Boston Marathon attack, evident in surrounding VIX and 10-year yields, is supportive of this phenomenon.

A possible alternative explanation is 2013's low volatility environment, implying a sense of bullishness in market participants. Mun, Fleak, and Morgan (2010) found that volatility prior to a negative shock adversely affects the market's speed of adjustment. This suggests that the swift correction back to normalcy (or settlement to a new normal following the event) observed post-4/15 might be the result of a less volatile investor base. While this theory appears logical, I provide the counterexample in my examination of the 2015 Paris attacks below, as the attacks on 11/13/15 were met by a similar response timeline despite higher pre-event volatility.

5.3. Terror Strikes & Market Reaction: Paris Attacks

The coordinated terror strikes in Paris, France of November 2015 marked the deadliest terror attack in Europe since the 2004 Madrid bombings (Brisard 2015). VIX spiked 11.72% day-over-day following the news, ranging 26.93% higher than median 2015 highs of 16.28:



Volatility returned to pre-event levels by 11/19/15. 10-year yields continued to fall through the end of the month, signaling a lasting effect felt by bond-markets (Krishnamurthy & Vissing-Jorgensen 2012; Fleming & Remolona 1999).

A rational reaction to a market event is triggered when expectations of fundamental valuations have been reasonably altered (Wang 1993). The November 2015 Paris attacks, consistent with the previous examples, did not cause any fundamental changes in equity valuations across sectors of the S&P 500. Due to insufficient research published surrounding the attacks, I observe the SPDR sector ETFs, and their intraday ranges in values. While every sector experiences a sell-off, only Consumer Discretionary (XLY), Materials (XLB), and Technology (XLK) sectors saw their maximum spread the day of the attack. The volatility range across each remaining sector was not far from their monthly averages. Paired with disappointing retail and commodities data releases the day of the attack (United States Census Bureau 2015), this behavior is suggestive of a primary sell-off in those three sectors based on unrelated fundamental changes (Kausik & Koo 2001), spreading throughout other sectors with the Paris attacks bringing geopolitical concerns to the forefront. The initial volatility spike is consistent with the market behavior following both the Boston Marathon attacks and 9-11. The indiscriminate sell-off emphasizes the degree of panic selling (Durand *et al* 1990; Kausik & Koo 2001; Mun *et al* 2010) as investors act in fear of the uncertainty that a terror threat of this magnitude evokes.

Intraday VIX highs dipped down to 18.26 nine days after the attack, just 0.24 shy of the 18.5 reading on 11/12/15. Following the 2013 attack on the Boston Marathon, intraday VIX highs returned to pre-event levels in ten days. In response to the attack on September 11th, it took intraday VIX highs seventeen days to reach 9/10/01 levels. It is important to note the declining

trend in return times, as the timeline of a return to normal levels following a spike indicates a greater degree of lasting uncertainty (Dueker 1997).

The yield on 10-year Treasuries tightened by 4 basis points. Again, a tightening in fixed income markets following the event is consistent with both the April 2013 Boston attack and 9-11. The recovery time, however, varies across all three events. This could be due to a number of different outside variables. Permanent decreases in risk tolerance were observed across U.S. financial markets post-September 11th (Obi 2007). Instead of returning to previous levels, 10-year yields settled to a new normal, reflective of the increase in demand for safe-haven assets (Litzenberger & Tuttle 1972). Similarities in stock market volatility following the 2013 Boston Marathon and the 2015 Paris attacks might lead to the assumption that fixed income markets would also be consistent. Comparing November 2015's continual decline in 10-year yields to Boston Marathon's rapid return to normalcy suggests either that, similar to 9-11, the Paris attack caused an increase in risk premium, or that an outside force was influencing fixed income markets surrounding one of the two events.

Returning to broad comparisons, 2015 experienced more financial market volatility than 2013. The Federal Reserve was signaling a rate hike before year-end, causing unease across both equity and fixed income markets. Lange *et al* (2003) examine the effects of anticipation of monetary policy change on financial markets, and observe that an expectation of a tightening in monetary policy is met by an *increase* in Treasury yields. The sustained decline in yields following the November 2015 Paris attacks does not signal the market's anticipation of the Fed's promised 2015 rate-hike, but is more suggestive of speculation that the Fed would *not* take rate action at the December meeting. Following the September 2015 FOMC meeting, a statement was issued that newly incorporated concerns of global instability weighing on the ability for a near-

term rate hike (Federal Reserve Board 2015). The extended decline in November 2015 yields following the Paris attacks suggests the market's belief that monetary policy would remain unchanged in the near-term, confirmed by a reversal of the downward trend following Janet Yellen's 12/03/15 announcement affirming plans to raise the federal funds rate target at the December meeting (Federal Reserve Board 2015).

5.4. Terror Strikes & Market Reaction: Conclusion

The threat of terror on North American or European soil consistently causes a surge in equity volatility, measured in VIX, as outlined in the above examples. Further, this surge in volatility is not attributed to a belief in fundamental equity valuations changing, as some reports surrounding 9-11 claim (Carter & Simkins 2002; Drakos 2004). Lacking a rational link to an expected change in fundamental value, the amount of time that VIX remains above pre-event levels is suggestive of the magnitude of fear in the market. The yield on the 10-year Treasury declines in each examined instance of terrorism, but the time period of the decline differs across each event. Because 9-11 serves as the first large-scale instance of terrorism in recent decades, market participants collectively decrease their risk tolerance and yields remain low, indicative of a risk-averse market (Litzenberger & Tuttle 1972). From 2001-2015, the frequency of terror attacks increases exponentially (START 2013), and the increased exposure allows investors to mute their reactions to terror shocks (Becker & Rubinstein 2011). Boston's April 2013 attack observes a one-day displacement of Treasury yields, consistent with this phenomenon. Paris' November 2015 attack, by contrast, contributes to a steady decline in yields through the end of the month. This can be attributed to the impending December FOMC Meeting, in which market behavior, prior to the Paris attack's reminder of global uncertainty, was consistent with an

anticipation of a Federal Reserve interest rate hike (Lange *et al* 2003). The terrorism's reminder of global uncertainty caused a reversal of expectations in fixed-income markets, explaining the sustained decline in yields.

Again, I will return to the Becker and Rubinstein (2011) definition of fear as the magnitude with which a subjective belief about danger is able to hinder objective risk assessment. Surges in VIX illustrate irrational market behavior when no evidence exists of a change in expectations of fundamental values (De Long *et al* 1990). Consistent across each observed instance of terror, the fear of uncertainty in domestic stock value spikes volatility across equity sectors, hindering investors' ability to objectively assess the risk that a single-name equity is exposed to. No change in the 10-year Treasury yield can be indicative of an overreaction in equities. Lasting changes in the 10-year Treasury yield indicate a change in expectations of monetary policy or a shift in demand for safe-haven assets as substitutes to riskier asset-classes (Krishnamurthy & Vissing-Jorgensen 2012). While inconsistent, each terror event's reaction in the 10-year Treasury yield is justifiably attributed to one of the three rational outcomes, allowing my inference that 10-year Treasury yields respond rationally to terrorism.

6. Conclusion

The purpose of this paper is to distinguish between rational market reactions to market shocks and irrational fear-driven behavior, with particular emphasis on the power of terrorism in provoking the latter (Becker & Rubinstein 2011). I observe market behavior in the wake of economic data released relative to the FOMC's dual mandate, and any surprise announcements in monetary policy, and find an inflation in VIX readings before scheduled FOMC announcements, remaining active after the announcement if the substance of the release was

unanticipated (Bernanke & Kuttner 2005). I expand my observation to foreign monetary policy action to incorporate impact of less transparent central bank behavior (relative to extremely high transparency from the Federal Reserve) on domestic asset-values and volatility (Lange *et al* 2003; Thorbecke 1997) and find that markets behave rationally, as investors speculate about the implications for domestic monetary policy and investment demand.

Rational market behavior, outlined by efficient market theory, involves a shift in security value due to a change in expectations of economic fundamentals (Wang 1993). Yields on government bonds (and at their inverse: prices) change in the short-term based on the market's expectation of monetary policy and demand for US investment, and observe lasting shifts when policy change occurs and/or long-term demand is altered (Lange *et al* 2003; Krishnamurthy & Vissing-Jorgensen 2012). Therefore, my choice to observe fixed-income markets surrounding data releases and policy announcements for both foreign and domestic central banks is optimal, and provides an example of rational responses in yields following a fundamental change (Lange *et al* 2003).

In my observations of market behavior surrounding terrorism, I illustrate large surges in VIX that are suggestive of fear-driven panic selling (Durand *et al* 2011). My observation of irrational market participation as a fear-based response to terrorism is consistent with the effect of noise traders discussed by De Long *et al* (1990), Brown (1999), and Campbell and Kyle (1993). De Long *et al* (1990) describe noise traders as those investors who, acting on erroneous beliefs, cause prices to diverge from fundamental values, regardless of the presence of fundamental risk. The terror-triggered response of fear invites this type of irrational agent to the marketplace, observed as post-event volatility above.

I observe rational moves in 10-year Treasury yields that respond to the terror event only if expectations of investment demand are altered or if the event might effect the achievement of the Fed's dual mandate. Altered expectations of investor demand might be a response to uncertainty in equity markets causing a flight to quality (Krishnamurthy & Vissing-Jorgensen 2012), particularly when equity valuations have diverged from fundamentals (De Long *et al* 1990). Such a response was observed following the attack on 9-11, as a decrease in risk appetite resulted in an increase in demand for safe-haven assets (Obi 2007). The Boston Marathon attack prompted a slight tightening in 10-year yields the day of the attack, but corrected back to pre-event levels by the next day's close, which is suggestive of the market discount of event as insignificant to fundamental values (Krishnamurthy & Vissing-Jorgensen 2012). The November 2015 Paris attacks saw an initial decrease in yields of 4 basis points, but continued a steady decline through the end of the month. The attack was concurrent with a discussion on the Fed's likelihood of increasing their target rate at their December meeting. After the FOMC cited the stability of global markets as an additional consideration before tightening policy (Federal Reserve Board 2015), expectations for a December hike dropped, causing investors to prop up the value of Treasuries (Lange *et al* 2003).

I observe a decline in the duration of VIX response to terror over time as investors become increasingly exposed, consistent with previous studies on responsiveness and exposure (Becker & Rubinstein 2011). Observing this theory in aggregate with De Long *et al* (1990) and statistics from the Global Terrorism Database (START 2013), an increased exposure to terror had allowed for a decline in noise trading surrounding attacks –the subject of terrorism provoked declining magnitudes of fear, or responsiveness to “noise”, as the volume of attacks increased.

A few potential conflicts should be addressed before concluding. First, economists have observed a correlation between the number of deaths in a terror event and the magnitude of the reaction by financial markets (Eldor & Melnick 2004). The attacks on 9-11 observed more fatalities than did the Paris and Boston attacks, which may affect my conclusion. The effect on investor fear, however, should have been unaffected. Assuming that fear alters risk tolerance (Lerner *et al* 2003), using the Becker and Rubinstein (2011) definition of fear, and defining magnitude as the average percentage change in VIX day-over-day, Boston and Paris saw a similar magnitude, regardless of large differences in fatalities.

Second, Paris and Boston do not have the same status as a financial market capital as New York City does, potentially affecting the response in markets to 9-11. Again, I counter with the consistency in the range of magnitude of fear in the market's initial reaction to each event. Additionally, within the same cultural range, Eldor and Melnick (2004) found a negligible effect of the location of terrorism in its response from financial markets.

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