INSTITUTIONAL ADVISORY & SOLUTIONS

WHEN THE DUST FLIES…

How Volatility Events Affect Asset Class Performance

April 2018

AUTHOR

Amy Xie

PGIM's Institutional Advisory & Solutions advises institutional clients on a variety of asset allocation and portfolio construction topics, delivering bespoke quantitative research based on an institution's specific objectives.

For inquiries and to learn more about PGIM's investment advisory capabilities, email IAS@pgim.com or visit pgim.com/IAS

Some investors have been surprised by the duration of the current stock market rally and, until just recently, the very low level of equity market volatility (*e.g.*, VIX). However, many are concerned about the possibility of market volatility spikes. We investigate asset class performance before, during, and after volatility events. Specifically, how do stocks and bonds perform during such events? Is asset class performance leading into an event different than after the event?

We first define two types of volatility events: "spikes" and "post peaks". A volatility spike event is a significant sudden increase in volatility, and we measure asset class performance while "the dust is flying." In contrast, a volatility post peak event is a period of high volatility that is followed by volatility returning to its pre-peak level, and we measure asset class performance "after the dust has settled." While both types of events are of interest to investors, some investors may act at the onset of a volatility event (i.e., a spike), whereas others may wait until market volatility has calmed down (i.e., after the peak).

We examine 26 volatility spike events, and 25 post peak events, across a 68-year span, in a variety of market environments. History shows that while spike events produce large negative returns for equities and credit bonds (with positive returns for Treasuries), markets recover relatively quickly, approximately by the seventh month following the spike month.

For post peak events, we focus attention on asset class performance after the dust has settled, not around the peak volatility event itself. The increase in volatility and accompanying equity and credit market declines may be unnerving to some investment committees. These investors may wish to wait until the "dust settles" – either out of caution or time needed for deliberation – before re-examining their investment strategy. History shows that once the dust has settled, equity and credit markets tend to perform well, often better than before the volatility event.

The evidence from both types of volatility events suggests that the damage from volatility events is transitory and is likely to be repaired after a reasonable period. These results provide support for investment committees who intend to "stay the course," and possibly re-balance with increased allocations to risky assets.

The findings shown are derived from statistical models. Reasonable people may disagree about the appropriate model and assumptions. Models should not be relied upon to make predictions of actual future account performance. See additional disclosures.

PGIM

Introduction

Each year, the recipient of the Nobel Memorial Prize in Economic Sciences is asked for their view on the market. This year's recipient, Dr. Richard Thaler, shared the following last October:

> "I don't know about you, but I'm nervous, and it seems like when investors are nervous, they're prone to being spooked," Thaler said. "Nothing seems to spook the market … We seem to be living in the riskiest moment of our lives, and yet the stock market seems to be napping. I admit to not understanding it."[1]

Some investors are surprised by the duration of the current stock market rally and, until just recently, the low level of US equity market volatility. Given robust current stock and bond valuations, geopolitical concerns, and record low implied volatility, many fret about potential volatility events and the market corrections that typically accompany them.[2]

Recently, PGIM Fixed Income's Dr. Arvind Rajan argued that it is very difficult to predict such market corrections:

> "… [w]e live in a dynamic and in many ways unprecedented macroeconomic environment, in which global regulation, trade, banking, and politics have all changed substantially over the past few decades and especially since the 2008 crisis – and partly in response to it. While historical data remain very useful in understanding our current macroeconomic conditions and relationships, it is unreasonable to expect that the challenges facing market participants will likely be captured by primarily looking at variables and relationships derived only from past history and prior crises." [3]

Following market volatility events, investment committees may question whether their investment strategy in place before the event remains the appropriate strategy. We explore if there is a fundamental change in the market (*e.g.,* returns, volatilities, and correlations) following a volatility event that would require a re-evaluation of a committee's investment strategy.

Why might market fundamentals change after a volatility event? Periods of low volatility may reflect investor complacency and a relatively high level of risk tolerance. A volatility event, however, can increase investor risk aversion and the risk premia demanded, producing a change in relative asset class performance going forward. A volatility event may produce worries of a slowing economy, prompting a fiscal and monetary policy reaction that alters investor forecasts of risk and asset class performance. Volatility events may also reveal structural weaknesses (*e.g.,* excessive leverage) which can diminish investor outlook for certain industry sectors and strategies. From an international perspective, a volatility event may diminish demand for USD assets, producing downward pressure on the dollar. While such changes might be expected immediately after a spike in volatility, do these changes persist "after the dust settles," once volatility returns to its pre-event level?

Identifying Volatility Events

We construct a modified "VIX" index as our measure of US equity market volatility, measured monthly and calculated as the average daily VIX value during a month.[4]

There are many possible ways to define a "volatility event," and we consider two types:

1. **VIX Spike Event.** A VIX spike event is a significant sudden increase in the VIX.[5] An example might be a 1.5x change (*i.e.,* a 50% increase) in the average VIX over two months, from month $t_{0\text{-}2}$ to t_0. In this case, month t_0 would be labelled as the spike month, and the two-month period (*i.e.,* months $t_{0\text{-}1}$ and t_0) encompasses the spike event period. We classify spike events according to the change multiple (*e.g.,* 1.5x, 2x, or 3x). Some investors may view a spike event (*i.e.,* ***"when the dust flies"***) as an immediate signal to act, even though it is unknown whether the volatility event is transitory or a harbinger of further increases.

   A spike event captures the *initial* sharp increase in volatility. Volatility may continue to increase, producing consecutive spike events, one month after the next. To capture only the initial sharp volatility spike, we impose an exclusion window so that another spike event is not included in this study until at least nine months after the current spike event.

1 "Nobel Economist Thaler Says He's Nervous about Stock Market," Jeanna Smialek, Bloomberg, 10 October 2017.

2 Not everyone considers the current low level of volatility to be an anomaly. While volatility is low relative to history, it is at a level consistent with the standard Gordon growth model for equity valuation. See, "The Low Volatility Puzzle: Are Investors Complacent?" Federal Reserve Bank of New York, 13 November 2017 [http://liberty street economics.newyorkfed.org; accessed 13 November 2017].

3 A. Rajan, "Can We Predict the Next Market Crash?", PGIM Fixed Income *Perspectives*, p. 16, October 2017.

4 The VIX is a measure of forward-looking volatility constructed using implied volatilities on equity index options. We use the VXO (calculated from options on the S&P 100) from Jan 1986 to Dec 1989 and the VIX (calculated from options on the S&P 500) from Jan 1990 to Oct 2017. To extend our VIX time series prior to Jan 1986 we generate a monthly market volatility index using daily price returns for the Dow Jones Industrial Average (DJI). Using month-end VIX values, rather than the monthly averages of daily VIX values, does not materially change the results of this study.

5 To qualify as an event, the two-month VIX change must also be greater than 5 VIX points. This condition screens out "noisy" volatility events when volatility values are extremely low.

Some investors may wish to wait until the change in volatility has passed (*i.e.,* ***"after the dust has settled"***) – either out of caution or time needed for deliberation – before re-examining their investment strategy. This leads to our second type of volatility event.

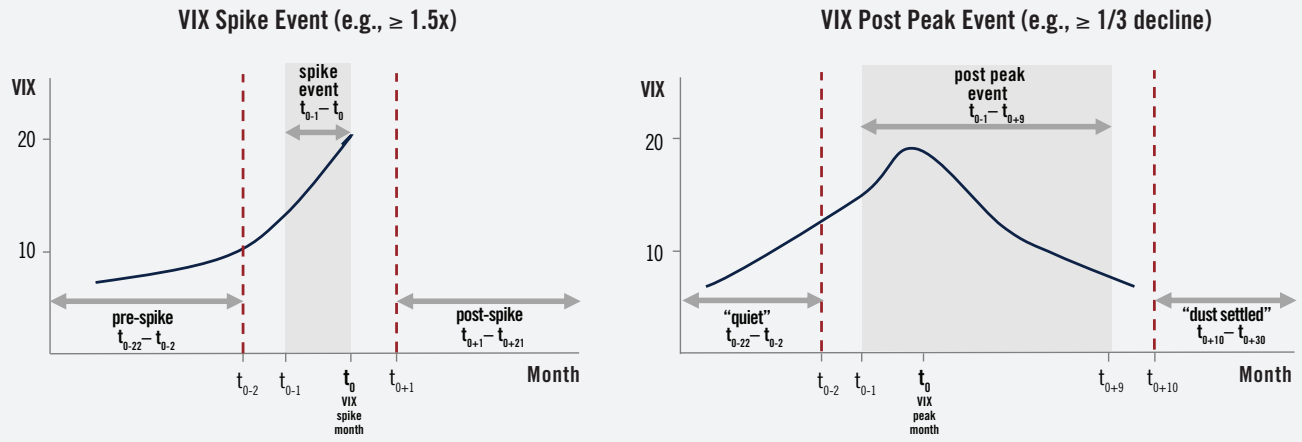
2. **VIX Post Peak Event.** A VIX post peak event occurs when, after a period of several months, the VIX has fallen significantly from its recent peak toward pre-peak levels. If the VIX in month t_{0+9} falls to less than 2/3 the value in month t_0, we call month t_0 a VIX peak month. The post peak event period includes the two months leading into the peak month (*i.e.,* month t_{0-1} and month t_0) and the nine months following the peak month (*i.e.,* month t_{0+1} through month t_{0+9}). Consequently, we assume a post peak event has a duration of 11 months.

   As volatility declines from its peak, there could be a succession of post peak events. To avoid treating a series of overlapping post peak events, which are part of the same volatility event, as independent events, we apply an exclusion window to post peak events so that another post peak event is not included in this study until at least nine months after the current post peak event.

The following schematics (Figure 1) illustrate our two types of volatility events. Both types of events are forward looking as an investor can identify both events contemporaneously, using currently available information. Consequently, any investment decisions made in reaction to these volatility events are implementable.

We examine equity market volatility events (both spikes and peaks) over the past 68 years, spanning many market environments. How do asset class fundamentals change, if at all, following these volatility events?

Figure 1: Schematic of Two Types of Volatility Events



Source: PGIM IAS

VIX Spike Events

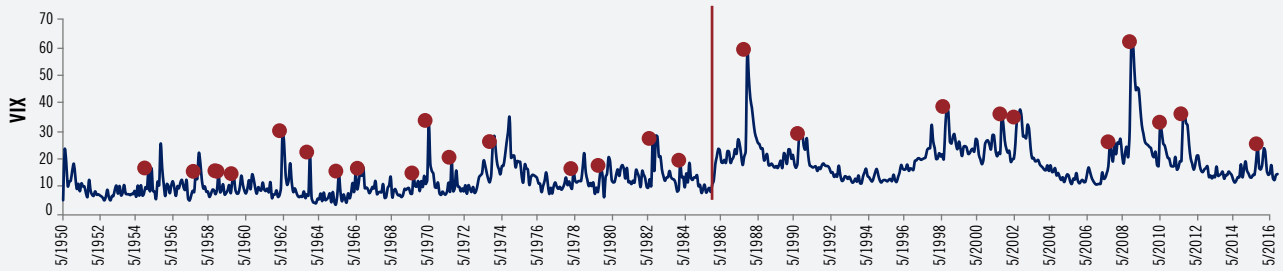
We first consider VIX spike events. We identify 26 distinct spike months in which there is a two-month increase in the average VIX of at least 50%, or 1.5x (Figure 2).[6]

Figure 3 sorts spike events by the magnitude of the VIX change (*i.e.,* the multiplier) and compares performance leading into the spike event with that following the spike. We define the **pre-spike period** as the 21-month period ending in month t_{0-2} (*i.e.,* includes returns for month t_{0-22} through month t_{0-2}) and the **post-spike period** as the 21-month period after month t_0 (*i.e.,* includes returns for month t_{0+1} through month t_{0+21}). We choose 21 months as our period length as a compromise between being too long and overlapping with other volatility events and too short making performance statistics too noisy. We identify 26 VIX spikes (≥ 1.5x); 11 spikes (≥ 2.0x); and 3 spikes (≥ 3.0x).

Figure 3 shows that, on average, the VIX in the post-spike period is higher than its pre-spike level. For example, for all 26 spike events, the average VIX value (indexed at t_{0-2}) in the pre-spike period is 1.18, and 1.33 in the post-spike. We have DJI data for all 26 spike events, but SPX data for only 15 of those events. We also see that 9 months is a good approximation of how long it takes the VIX to recover back to its pre-spike level. The figure shows that there is little relationship between the multiplier size and the time it takes the VIX to recover to its pre-spike level.

6 We have chosen a two-month change in the average VIX, expressed as the ratio of $VIX(t_0)/VIX(t_{0-2})$ to identify a spike event because we use monthly average VIX values. A monthly VIX average may not reflect a sudden volatility increase if it occurs towards the end of the month. A two-month change criterion is more likely to capture increases in monthly average volatility. While we identified Jul 1950 as a VIX spike event, we do not include it in this study because we do not have complete equity data available for the pre-spike period.

Figure 2: Monthly Equity Market Volatility and VIX Spike Events
(≥ 1.5 multiple; Jun 1950 – Oct 2017; 26 events)



Note: The vertical axis is our modified "VIX" index. The vertical line is the month in which our volatility time series switches from using DJI price returns to using the option volatility-based, VIX time series from the CBOE. The dots correspond to spike months (t_0).
Source: CBOE, Global Financial Data, PGIM IAS.

Figure 3: VIX Spike Events (sorted by multiplier value)

Multiplier Value	Number of Spike Events [1950 – 2017]	Average VIX Value (Post/Pre)	Average VIX Recovery Time (Months) [Range]	Number of S&P 500 Spike Events [1970 – 2017]	Cumulative S&P 500 Performance (Post/Pre)	Number of DJI Spike Events [1950 – 2017]	Cumulative DJI Performance (Post/Pre)
≥ 1.50+	26	1.33 / 1.18 = 1.13	9 [5, 16]	15	1.27 / 1.20 = 1.06	26	1.13 / 1.16 = 0.97
≥ 1.75+	16	1.40 / 1.28 = 1.09	9 [5, 16]	9	1.34 / 1.28 = 1.04	16	1.14 / 1.18 = 0.97
≥ 2.00 +	11	1.45 / 1.29 = 1.12	10 [6, 16]	6	1.30 / 1.27 = 1.02	11	1.11 / 1.15 = 0.96
≥ 2.50 +	6	1.43 / 1.23 = 1.16	10 [7, 16]	2	1.33 / 1.34 = 1.00	6	1.08 / 1.18 = 0.92
≥ 3.00 +	2	2.00 / 1.56 = 1.28	8 [7, 9]	0	--	2	1.05 / 1.19 = 0.88

Note: We define the pre-spike period as the 21-month period ending in month t_{0-2} (*i.e.,* month t_{0-22} to month t_{0-2}) and the post-spike period as the 21-month period following month t_0 (*i.e.,* month t_{0+1} to month t_{0+21}). The average VIX recovery time is nine months.
Source: CBOE, Datastream, Global Financial Data, PGIM IAS.

Asset Class Performance during Spike Events

How do various asset classes perform during the two-month volatility spike event period? Figure 4 (left panel) shows that, on average, the spike event period generally has very poor equity market performance. On average, the S&P 500 ("SPX") has a cumulative two-month (*i.e.,* months t_{0-1} and t_0) loss of -8.2%. However, the equity market generally recovers rather quickly, returning to its pre-spike level (*i.e.,* month t_{0-2}), on average, seven months after the spike month.

Figure 4 (right panel) illustrates performance in the fixed income markets. The 10y US Treasury has strong total returns (2.1%) during the two-month spike event period. In contrast, US high yield (HY) and investment grade (IG) credit exhibit a cumulative two-month excess returns of -9.2% and -3.3%, respectively, but both recover approximately nine months after the peak month.

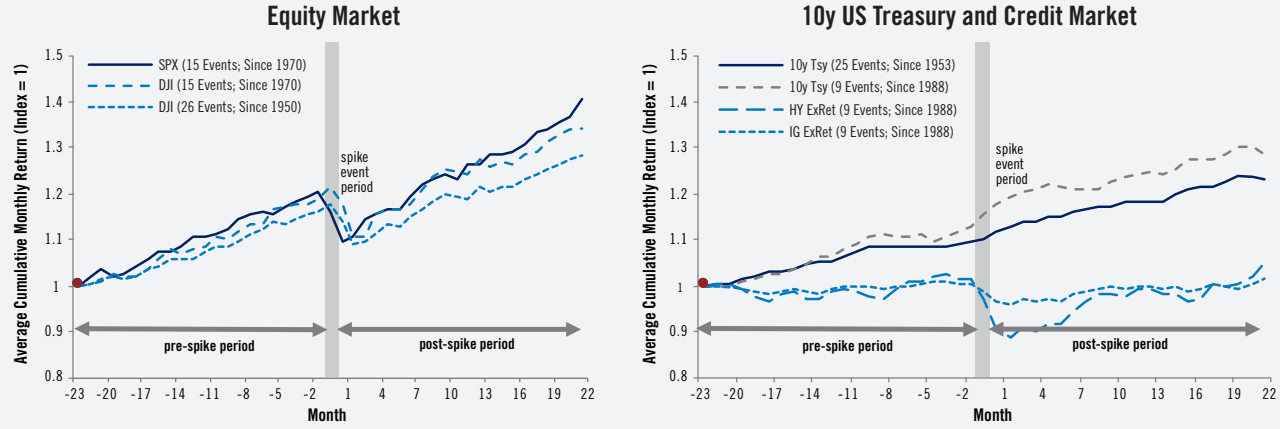
Asset Class Performance: Pre- & Post-Spike Events[7]
Broad Equity and Fixed-Income Markets

We examine broad equity and bond market performance pre- and post- volatility spikes. Figure 5 (left panel) shows that on average, equity markets displayed similar 21-month cumulative performance both before and after spikes. The average S&P 500 cumulative monthly total return at the end of the pre-spike period was 20.3%, and a bit higher, at 26.7%, in the post-spike period.

Figure 5 (right panel) provides results for the individual spike events. Of the 15 events covered by the S&P 500 index, only one event (8/07) has a significant negative return in the post-spike period. This event had the misfortune that its post-spike period included the 2008 financial crisis. Our definition of a spike event does not rule out the potential for further increases in volatility following the initial volatility spike.

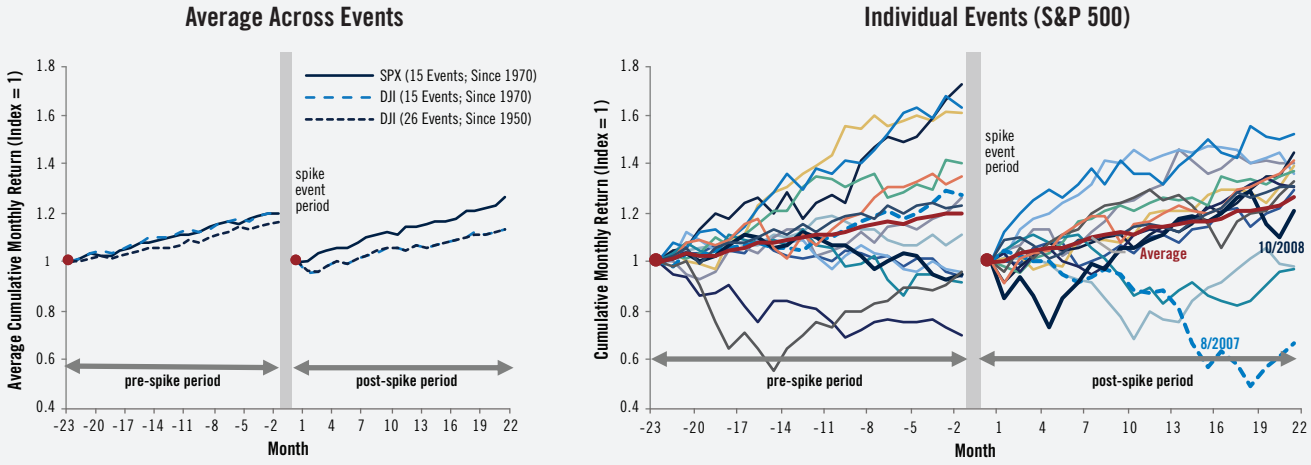
7 Monthly data for all asset classes do not exist for the entire period from 1950. For example, while we have price returns for the Dow Jones Industrial (DJI) index from 1950, monthly total returns for the S&P 500 (SPX) do not begin until 1986. Consequently, for our analysis we need to group sets of events so that we can measure and compare the relationship (*i.e.,* returns and volatilities) between asset classes using complete time series.

Figure 4: Cumulative Monthly Returns – Pre- & Post-VIX Spike Event Periods



Note: Figures show asset class cumulative returns before, during, and after spike events, averaged across all events available for the index (with the exception of "DJI (15 Events)" and "10y US Treasury (9 Events)" which cover fewer spike events so as to correspond to the 15 SPX and 9 IG/HY events). We measure cumulative monthly returns beginning in month t_{0-22} up to and including t_{0+21}, a 44-month period. Index = 1 at t_{0-23}.
Source: Barclays POINT, Datastream, FRB St. Louis (FRED), Global Financial Data, PGIM IAS.

Figure 5: Cumulative Equity Market Monthly Returns – Pre- and Post-VIX Spike Event Periods

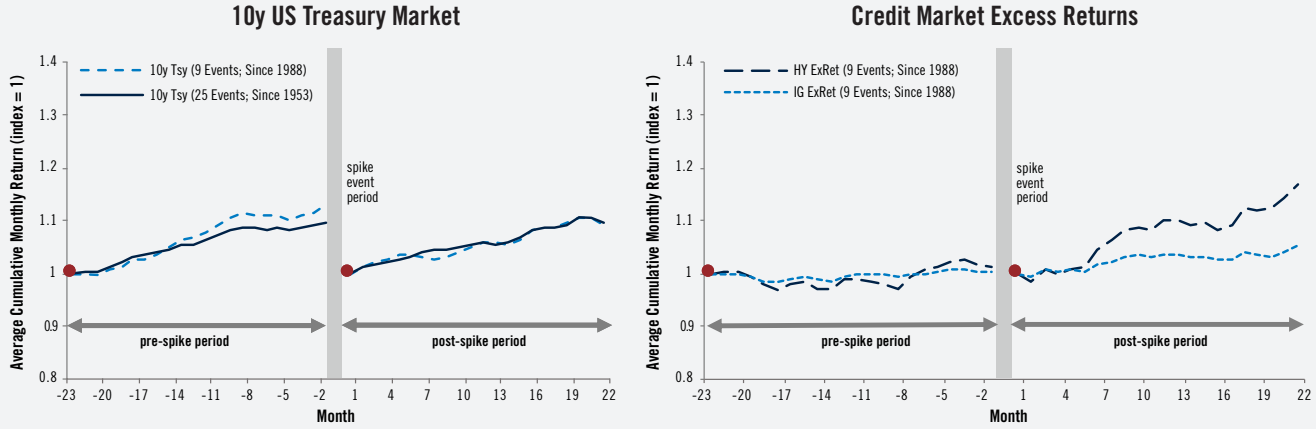


Note: The left panel shows the average cumulative total return for the indicated asset class; the right panel shows cumulative total returns for all 15 spike events available for the S&P 500. Index = 1 at t_{0-23} and at t_0.
Source: Barclays POINT, Datastream, Global Financial Data, PGIM IAS.

10y US Treasury returns were stronger in the pre-spike period with a 13.0% cumulative total return, but only 9.1% in the post-spike period (Figure 6; left panel). Credit markets performed much better in the post-spike period compared to the pre-spike. Average HY and IG cumulative excess returns were 1.3% and 0.5%, respectively, in the pre-spike period compared to 16.9% and 5.3%, respectively, after the spike.

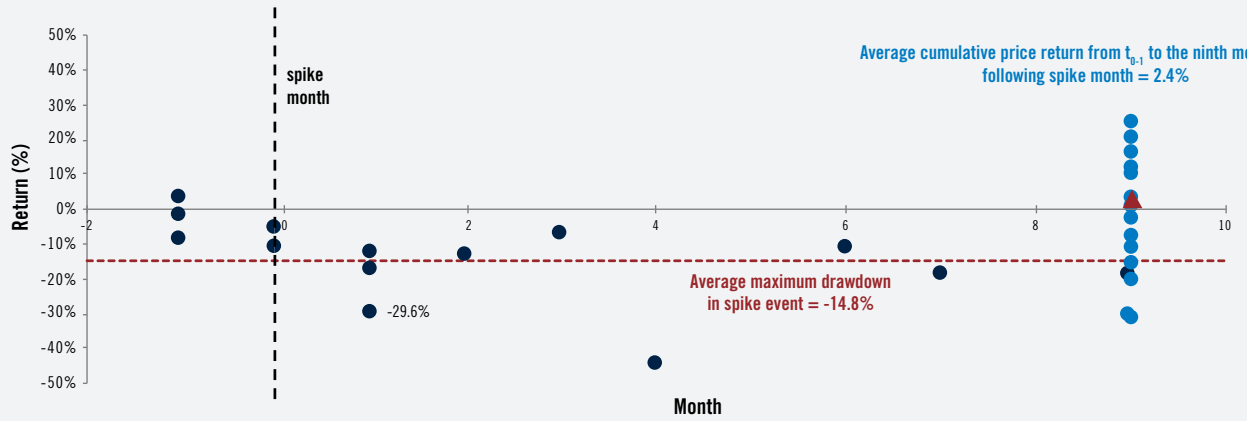
Figure 7 shows the maximum S&P 500 drawdown (for months t_{0-1} to t_{0+9}) for the 15 spike events covered by the S&P 500. For example, for the Oct 1987 spike month, the maximum drawdown was -29.6% which occurred in month t_{0+1} (*i.e.*, Nov 1987). For the 15 events, the average maximum drawdown was -14.8%. Figure 7 also shows cumulative total returns (since t_{0-1}) at month nine after the spike month. The average cumulative return was 2.4%.

Figure 6: Cumulative Fixed Income Monthly Returns: Pre- and Post-VIX Spike Event Periods



Note: Index = 1 at t_{0-23} and at t_0
Source: Barclays POINT, FRB St. Louis (FRED), PGIM IAS.

Figure 7: S&P 500 Maximum Drawdown in Spike Event & Cumulative Performance at Month Nine after Spike Month
(15 Spike Events)



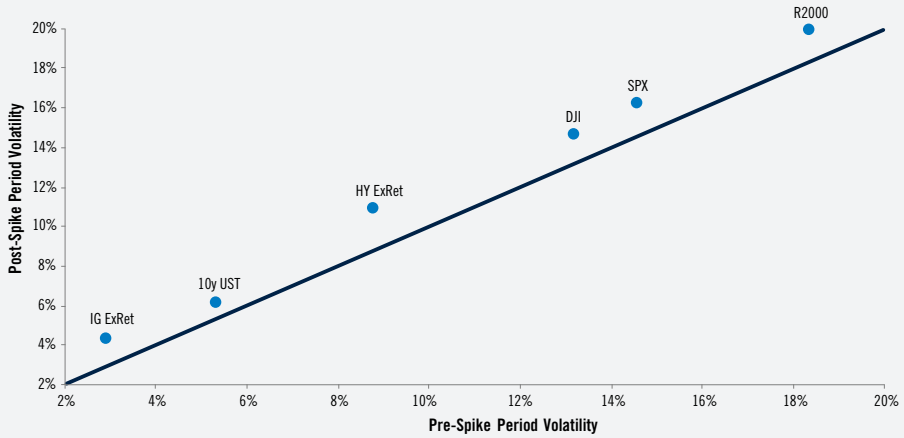
Note: This figure shows the maximum drawdown for the S&P 500 (after month t_{0-2}) and the month of the maximum drawdown, for the 15 spike events. In addition, the figure shows the S&P 500 cumulative total returns (month t_{0-1} through month t_{0+9}) for each event.
Source: Global Financial Data, PGIM IAS.

Figure 8 shows that all asset classes are more volatile in the post-spike period compared to the pre-spike period. This is consistent with the VIX (Figure 3) where the VIX is higher in the post-spike period compared to the pre-spike period. The pre-spike period, which does not include the peak month and the month immediately before, represents a relatively stable period of returns. In contrast, the post-spike period includes months immediately after the spike month during which volatility only gradually settles back to pre-spike levels which makes the post-spike period returns relatively more volatile. For example, S&P 500 index monthly total return volatility was 14.6% in the pre-spike period, rising to 16.2% in the post-spike period.

Equity "Winners" and "Losers"

After a volatility spike, do pre-spike "winners" continue winning and "losers" keep losing? For each spike event, we identify the equity sector with the best performance (*i.e.*, the "winner" sector) in the pre-spike period and the sector with the worst performance (*i.e.*, the "loser" sector). We then average the performance of the "winners" across all events, and likewise for the "losers." This produces average "winner" and "loser" performance. In the post-spike period we use the *same* "winner" sectors from the pre-spike period to

Figure 8: Volatility (annualized) of Asset Class Monthly Total Returns
Pre-Spike vs. Post-Spike Period



Note: Each point represents the average monthly total return volatility (annualized) of the asset class in the pre- and the post-spike period, averaged across all spike events in the date range. Date ranges for each index are: DJI (1950-2017); 10y Treasury (1953-2017); S&P 500 (1970-2017); Russell 2000 (1978-2017); HY Credit excess returns (1988-2017); and IG Credit excess returns (1988-2017).
Source: Barclays POINT, Global Financial Data, FRB St. Louis (FRED), PGIM IAS.

generate the average "winner" sector performance in the post-spike period, likewise for the "loser" sector. For example, Healthcare was the "winner" sector in the period before the 2015 spike event so it is classified as the "winner" sector in the 2015 event post-spike period irrespective of its actual relative performance in the post-spike period.[8]

By construction, "winner" and "loser" performance diverges in the pre-spike period. The average "winner" cumulative monthly total return in the pre-spike period was 44.5% and the average "loser" return was -20.2% (Figure 9). In the post-spike period, however, whatever relative return momentum the "winners" had over the "losers" is lost, at least for a while, as performance of "winners" and "losers" is roughly similar. Remarkably, the very brief spike event has been sufficient to break whatever momentum "winners" had over "losers."

Equity: Factors

Figure 10 displays the cumulative pre- and post-spike performance for the popular Fama-French equity factors (*i.e.,* market less risk-free rate, "market" (Mkt-RF); small minus big, "size" (SMB); and high minus low, "value" (HML)) as well as momentum (MOM). There is a large divergence in relative performance among these factors. In the pre-spike period, the momentum and value factors were the clear outperformers, but they performed particularly poorly post-spike, while the size and market factors perform better. Clearly, while the overall market performs well in the post-spike period, there are significant shifts in performance among the other equity market factors.

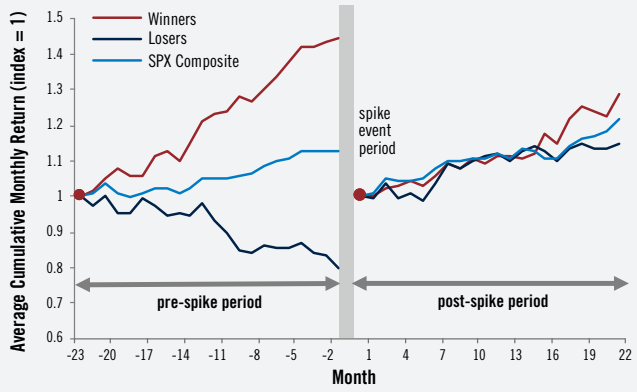
In summary, volatility spike events are rapid and large increases in volatility over a two-month period. Since 1950, there have been 26 spike events where the increase in the VIX has been at least 50%. During the two-month spike event period, the SPX (DJI) cumulatively loses, on average, -8.2% across 15 events (-6.4% across 26 events), 10y US Treasuries have a cumulative total return of 2.1% across 26 events (4.4% across 9 events), while HY and IG have cumulative excess returns of -9.2% and -3.3%, respectively, across 9 events. Furthermore, the average maximum drawdown for the SPX following a spike event was -14.8%. Spike events have certainly been traumatic.

However, the market reaction to spike events quickly fades (if not from memory!). Seven months after the spike month, on average, the SPX has recovered to its level immediately before the spike event, and the credit markets have recovered by the ninth month. The 21-month cumulative total returns for the equity market after the spike event have, on average, been better than the 21-month cumulative returns before the spike event.

While the markets recover relatively quickly following volatility spikes, some investors may wait for the dust to settle before re-examining their investment strategy. We now turn our attention to the performance of asset markets once we wait for the "dust to settle."

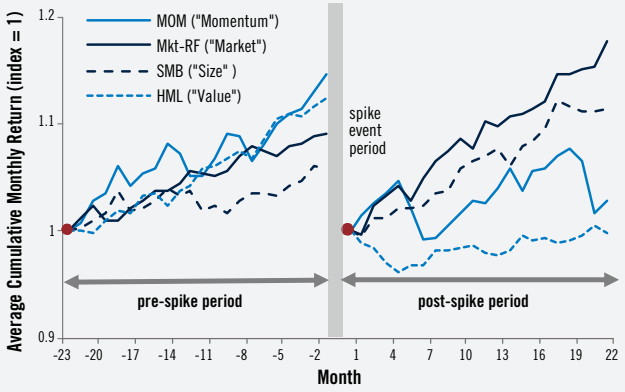
8 ("winner" sector / "loser" sector) for the eight spike events (1: IT/materials); (2: utilities/IT); (3: consumer staples/IT); (4: telecom/healthcare); (5: energy/financials); (6: consumer discretion/energy); (7: consumer discretion/financials); (8: healthcare/energy).

Figure 9: "Winner" and "Loser" Sector Cumulative Monthly Returns
(Oct 1989 – Oct 2017; 8 VIX spike events)



Source: Datastream, PGIM IAS.

Figure 10: Equity Factor Cumulative Returns
(Feb 1970 – Oct 2017; 18 VIX spike events)



Source: CRSP database, Factor returns from Prof. Kenneth R. French's data library, PGIM IAS.

VIX Post Peak Events

As discussed earlier, a volatility post peak event is fundamentally different than a spike event. A spike captures a sudden *initial increase* in the VIX ("when the dust starts to fly") whereas a post peak event captures the aftermath of a period of high volatility ("after the dust has settled"). Since 1950, we identify 25 distinct peaks, months in which there is a decline of at least 1/3 in the VIX nine months later (Figure 11).[9]

There is a high level of correspondence between peak and spike events (compare Figure 11 with Figure 2). In fact, of the 25 peak event months, 14 of them occur within ±1 month of a spike event month. However, a post peak event requires that volatility calms down whereas a spike event could be the beginning of a prolonged period of higher volatility. Nevertheless, when peak and spike events occur near each other, cumulative asset class returns immediately surrounding a peak or spike event will be similar. However, the "dust settled" and post-spike event returns may be very different as they cover different time windows in relation to the peak/spike month.

Figure 12 illustrates volatility dynamics, measured as the ratio of VIX(t_0), the VIX in the peak month, to VIX(t_{0-2}), the VIX value two months prior. On average, across the 25 events, the VIX begins its move to the peak approximately two months prior (*i.e.*, starting with the move from month t_{0-2} to month t_{0-1}). On average the VIX moves by a multiple of approximately 1.7x from month t_{0-2} to the peak month t_0. It then takes the VIX approximately 7 months following the peak month to decline to 2/3 (= 1/1.5) of its peak level, *and stay there* (*i.e.*, "for the dust to settle").

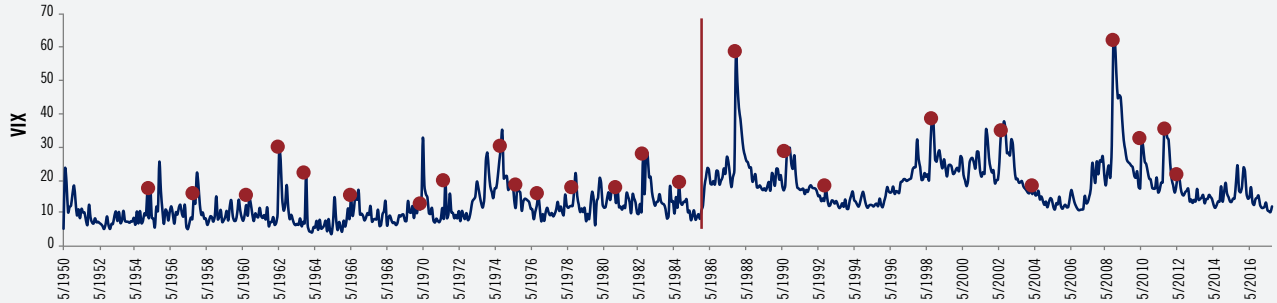
The actual duration of a VIX post peak event varies by event (see Appendix Figure A1). While the average time it took for the VIX to decline to ⅔ of its peak level was 7 months, some declines happened more quickly and some took longer – up to 14 months. While the VIX decline from a peak may be quick, there is a risk that this is only a temporary respite, to be followed by further VIX increases. Our goal is to identify VIX declines that are likely to remain at this lower level (*i.e.*, "the dust has settled"). Since investors don't know, *ex ante*, when "the dust will have settled", we conservatively assume it takes 9 months, a bit longer than the 7-month average. Consequently, for this study we assume a full VIX post peak event duration of 11 months which includes the two-month VIX increase period leading into the peak month, and the nine months following the peak.

For each post peak event, we define the **"quiet" period** as the 21-month period up to and including month t_{0-2} (*i.e.*, includes returns from month t_{0-22} through month t_{0-2}), and the **"dust settled" period** as the 21-months starting after t_{0+9} (*i.e.*, returns from month t_{0+10} through month t_{0+30}). Figure 12 shows the "quiet," post peak event, and "dust settled" periods.

Figure 13 presents detailed information for each VIX post peak event, assuming our full 11-month post peak event duration. The figure shows the months for the "quiet" and "dust settled" periods, as well as the cumulative DJI and S&P 500 total returns in these periods. The average spike in the VIX is approximately 1.7x its level in month t_{0-2}. As of 2017 year-end, with S&P 500 = 2,743 and VIX = 11.0, the average VIX post peak event would likely see a peak month VIX value of 18.7. In addition, Figure 13 shows the maximum equity drawdown during the 11-month duration (from month t_{0-1} to month t_{0+9}) of the post peak event, with an average equity market (S&P 500) drawdown of approximately -11.9%.

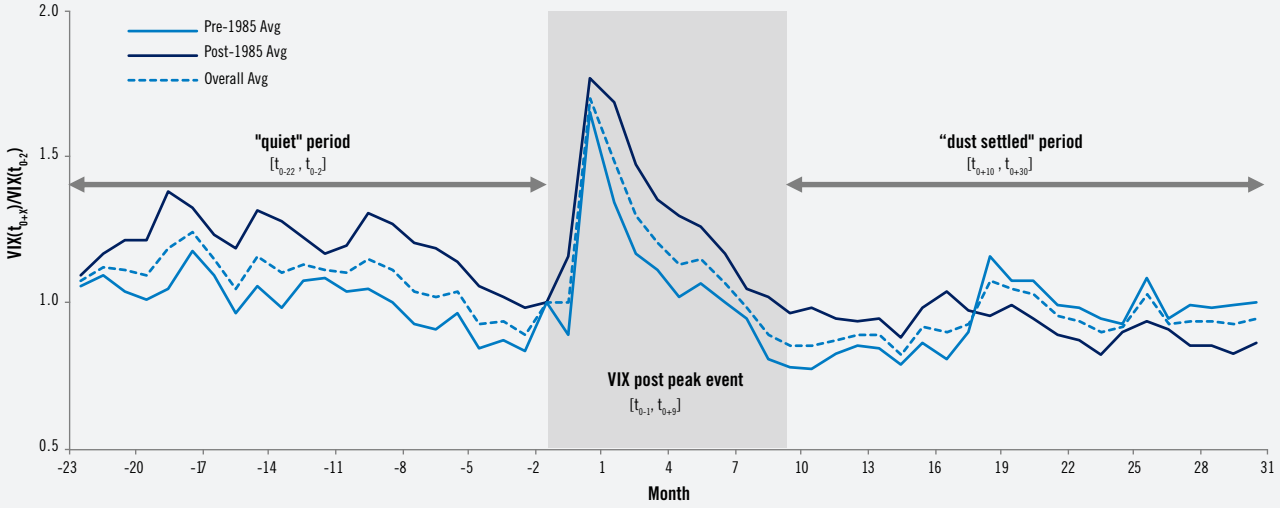
9 We identified 6/1950 and 1/2016 as post peak events, but do not include them in this study because equity data are unavailable for either the pre-peak or post-peak periods.

Figure 11: Monthly Equity Market Volatility and VIX Post Peak Events
(Jun 1950 – Oct 2017; 25 events)



Note: The vertical axis is our modified "VIX" index. The vertical line is the month in which the volatility time series switches from using DJI price returns to compute our VIX series, to using the CBOE's option implied volatility-based, VIX time series. The dots correspond to peak months (t_0) which the satisfy criterion: ($VIX(t_{0+9}) / VIX(t_0) \leq 0.67$).
Source: Global Financial Data, CBOE, PGIM IAS.

Figure 12: VIX Post Peak Events – Identifying "Quiet" and "Dust Settled" Periods
(Average Ratio of $VIX(t_{0+x})/VIX(t_{0-2})$ across all Post Peak Events)
(Jun 1950 – Oct 2017; 25 events)



Note: We define t_0 as the VIX peak month. This figure shows the average monthly VIX in month x, (*i.e.,* $VIX(t_{0+x})$), relative to the VIX two months prior to t_0 (*i.e.,* $VIX(t_{0-2})$) across all the events. By construction, this ratio peaks at time t_0. We see that, on average, the ratio is back to approximately 1.0 (actually, 0.86) in the ninth month after the peak month. The average VIX value in the "quiet" period is 1.08, and 0.94 in the "dust settled" period.
Source: CBOE, Global Financial Data, PGIM IAS.

Figure 13: Identification of VIX Post Peak Events, "Quiet" Periods and "Dust Settled" Periods

(assuming a full 11-month post peak event period)
(Jun 1950 – Oct 2017)

Peak Month (t_0)	"Quiet" Period ($t_{0-22} - t_{0-2}$)	"Dust Settled" Period ($t_{0-10} - t_{0-30}$)	(DJI/ SPX) Cumulative Total Return during "Quiet" Period	(DJI/ SPX) Cumulative Total Return during "Dust Settled" period	$\frac{VIX(t_0)}{VIX(t_{0-2})}$	(DJI/ SPX) Cumulative Total Return during Post Peak Event Period	Maximum (DJI/ SPX) Drawdown during Post Peak Event Period	10y Tsy Cumulative Total Return during Post Peak Event Period
3/1955	5/1953-1/1955	1/1956-9/1957	46.0%	0.7%	1.1	18.1%	-0.7%	0.4%
8/1957	10/1955-6/1957	6/1958-2/1960	6.6%	37.3%	1.7	-8.8%	-13.7%	11.7%
9/1960	11/1958-7/1960	7/1961-3/1963	20.2%	-5.4%	1.2	8.8%	-9.9%	2.5%
5/1962	7/1960-3/1962	3/1963-11/1964	13.0%	28.2%	4.2	-3.9%	-18.6%	2.9%
11/1963	1/1962-9/1963	9/1964-5/1966	0.4%	9.7%	2.9	14.8%	1.7%	3.1%
5/1966	7/1964-3/1966	3/1967-11/1968	15.3%	10.6%	1.3	-8.4%	-19.1%	6.2%
4/1970	6/1968-2/1970	2/1971-10/1972	-17.6%	13.8%	0.9	10.8%	50.8%	14.2%
8/1971	10/1969-6/1971	6/1972-2/1974	10.2%	-9.6%	1.7	1.3%	-8.5%	10.5%
9/1974	11/1972-7/1974	7/1975-3/1977	-16.9% / -24.6%	12.1% / 11.0%	1.4	6.7% / 25.4%	-25.9% / -19.2%	7.1%
8/1975	10/1973-6/1975	6/1976-2/1978	-4.7% / -5.3%	-22.2% / -5.8%	1.3	17.0% / 9.2%	-3.9% / -11.0%	8.9%
10/1976	12/1974-8/1976	8/1977-4/1979	48.9% / 58.1%	-4.9% / 12.9%	1.5	-7.8% / 0.0%	-7.9% / -3.5%	8.2%
10/1978	12/1976-8/1978	8/1979-4/1981	-7.3% / 10.3%	20.5% / 40.1%	1.4	-5.8% / 5.7%	-8.5% / -9.0%	4.2%
3/1981	5/1979-1/1981	1/1982-9/1983	12.0% / 39.7%	37.5% / 48.4%	1.0	-9.1% / -0.8%	-11.5% / -7.2%	4.7%
8/1982	10/1980-6/1982	6/1983-2/1985	-14.3% / -4.1%	5.8% / 20.8%	2.1	47.9% / 55.1%	-2.4% / -1.8%	31.0%
8/1984	10/1982-6/1984	6/1985-2/1987	21.5% / 37.8%	73.9% / 59.8%	1.3	10.9% / 28.9%	0.9% / -1.2%	33.5%
10/1987	12/1985-8/1987	8/1988-4/1990	83.9% / 72.8%	37.1% / 29.8%	2.8	-14.4% / -14.8%	-30.0% / -29.6%	9.3%
8/1990	10/1988-6/1990	6/1991-2/1993	50.8% / 40.7%	21.0% / 20.0%	1.7	4.6% / 11.6%	-13.3% / 13.6%	9.1%
10/1992	12/1990-8/1992	8/1993-4/1995	44.4% / 35.6%	25.6% / 20.0%	1.2	5.6% / 11.0%	-5.1% / 0.3%	11.8%
9/1998	11/1996-7/1998	7/1999-3/2001	57.0% / 62.9%	0.7% / -15.3%	1.9	20.1% / 25.7%	-14.6% / -11.1%	1.0%
8/2002	10/2000-6/2002	6/2003-2/2005	-11.0% / -31.0%	28.3% / 29.1%	1.3	-9.8% / 1.5%	-20.0% / -12.7%	15.3%
5/2004	7/2002-3/2004	3/2005-11/2006	13.5% / 20.6%	17.8% / 19.3%	1.0	1.9% / 8.7%	-3.7% / -1.7%	2.7%
10/2008	12/2006-8/2008	8/2009-4/2011	-1.5% / -4.9%	56.7% / 40.6%	3.0	-24.5% / -19.9%	-39.3% / -44.5%	3.2%
5/2010	7/2008-3/2010	3/2011-11/2012	-11.4% / -4.4%	13.7% / 12.1%	1.8	18.8% / 12.9%	-6.0% / -12.4%	6.4%
8/2011	10/2009-6/2011	6/2012-2/2014	36.2% / 34.7%	21.8% / 50.1%	1.8	11.3% / -2.6%	-11.6% / -17.5%	14.9%
6/2012	8/2010-4/2012	4/2013-12/2014	42.8% / 29.5%	32.6% / 36.7%	1.2	9.5% / 13.5%	-7.7% / -8.8%	1.9%
		Average	**17.5% / 21.7%**	**18.5% / 25.3%**	**1.7**	**4.6% / 10.1%**	**-11.5% / -11.9%**	**9.3%**

Source: CBOE, Datastream, FRB St. Louis (FRED), Global Financial Data, PGIM IAS.

Market Performance during Post Peak Events

In the months immediately surrounding the VIX peak, equity market (DJI) performance is typically poor with an average cumulative equity market return of -6.6% around the VIX peak month (t_{0-1} to month t_{0+2}). In contrast, the 10y US Treasury performed well around the peak month. For example, from month t_{0-1} to month t_{0+2}, the average cumulative return for the US Treasury was 5.2%.

However, perhaps surprisingly, the equity market recovers relatively quickly as the average cumulative total return for the DJI over the duration of the 11-month post peak event period is +4.6% across all 25 events and +10.3% for the S&P 500 across 15 events (Figure 13). It is important to note that by the time the "dust settled" period begins (*i.e.,* month t_{0+10}) the equity market has, on average, already recovered from the volatility event.

The 10y US Treasury performs well throughout the duration of the post peak event, although its performance starts to level off once the equity markets start to recover. Over the 11-month duration of the post peak event period, the 10y US Treasury produced an average cumulative total return of 9.0% (Figure 13).

Asset Class Performance: Before and After Post Peak Events

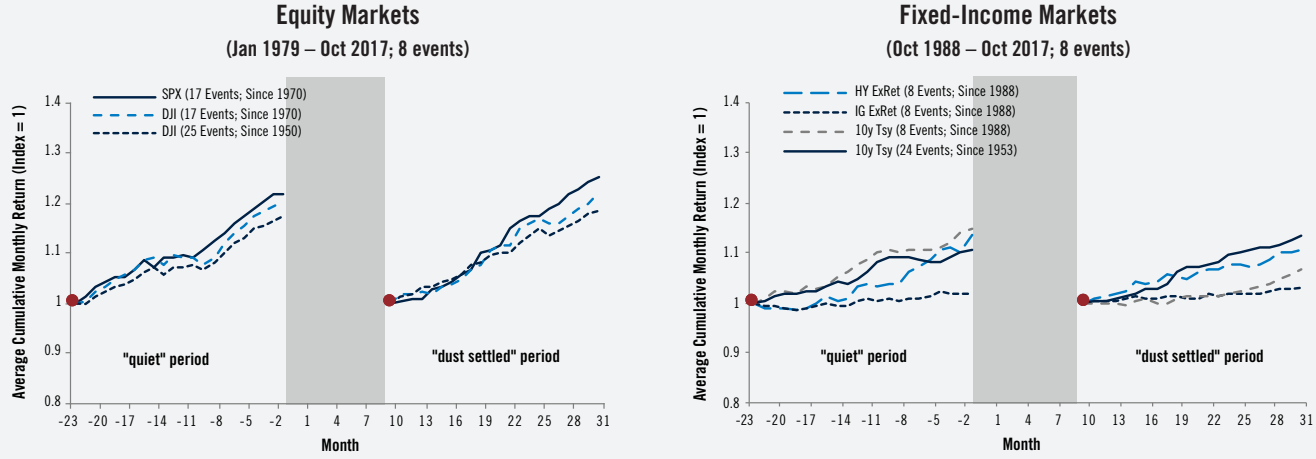
Broad Equity and Fixed-Income Markets

We examine the broad equity and bond markets preceding and following post peak events.[10] Figure 14 (left panel) shows that equity markets displayed similar performance both before and after post peak events. The average S&P 500 cumulative total return at the end of the "quiet" period was 21.7%, and higher at 25.3% in the "dust settled" period. This seems to suggest that reducing equity exposure in reaction to a traumatic volatility spike event may not be a good strategy.[11]

Figure 14 (right panel) shows that average credit market excess returns were broadly similar between the "dust settled" and "quiet" periods. Average HY and IG cumulative excess returns were 13.6% and 1.7%, respectively, in the "quiet" period compared to 10.8% and 3.0% in the "dust settled" period. 10y Treasury returns were stronger in the "quiet" period with cumulative total returns of 14.8%, but only 6.5% in the "dust settled" period.

Asset class performance during a post peak event period is related to its ensuing "dust settled" period performance – but the relationship is not strong. Figure 15 (left panel) shows that for the equity markets there is a negative correlation (ρ = -0.29 for S&P 500) between average "dust settled" period and post peak event period monthly returns. When post peak event performance is poor, "dust settled" performance tends to be a bit stronger. However, for Treasuries (middle panel) and credit bonds (right panel), the correlation between peak period performance and dust settled performance is weak.

Figure 14: Cumulative Asset Class Monthly Returns during "Quiet" and "Dust Settled" Periods
(Equity & Treasury Total Returns and Credit Excess Returns)



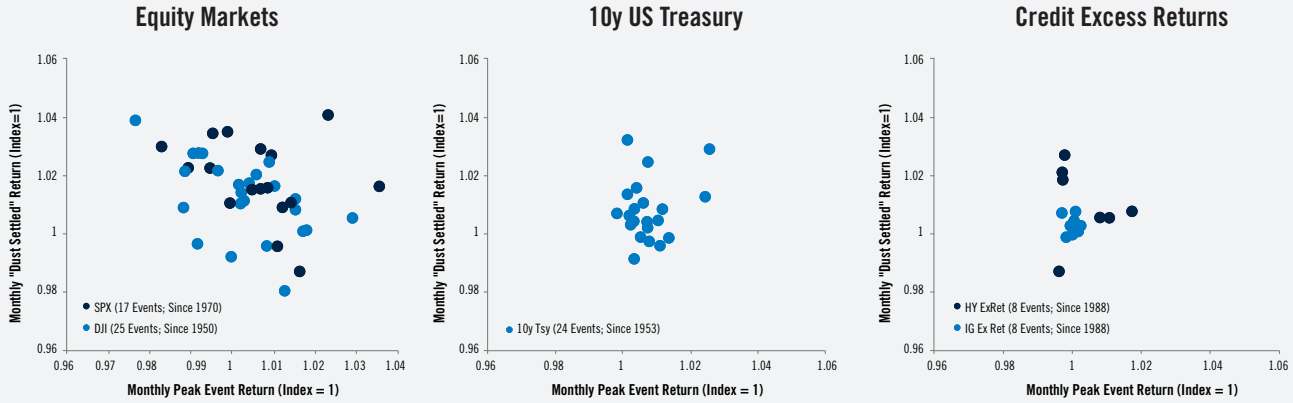
Note: In the "quiet" period prior to the start of the post peak event (month t_{0-2}) we measure cumulative monthly returns beginning in month t_{0-22} up to and including t_{0-2}, a 21-month period. In the "dust settled" period after the end of the post peak event (month t_{0+9}) we measure cumulative returns beginning in month t_{0+10} up to and including t_{0+30}, also a 21-month period. The vertical grey bar represents the 11m period between after the "quiet" period ends and before the "dust settled" period begins.
Source: Barclays POINT, Datastream, FRB St. Louis (FRED), Global Financial Data, PGIM IAS.

10 In the Appendix, we include "quiet" period and "dust settled" period cumulative performance for macroeconomic indicators (*e.g.,* 2-30y Treasury slope (Figure A8), unemployment (Figure A10; left panel), inflation (Figure A10; right panel), and GDP (Figure A10; right panel)).

11 Some investors have asked about equity and fixed-income market returns in the "dust settled" period conditional on the level of interest rates and the level of equity market valuation leading into the post peak event. Please see Figures A4 - A7 in the Appendix for these results.

Figure 15: VIX Post Peak Event Period Returns vs. Subsequent "Dust Settled" Period Returns

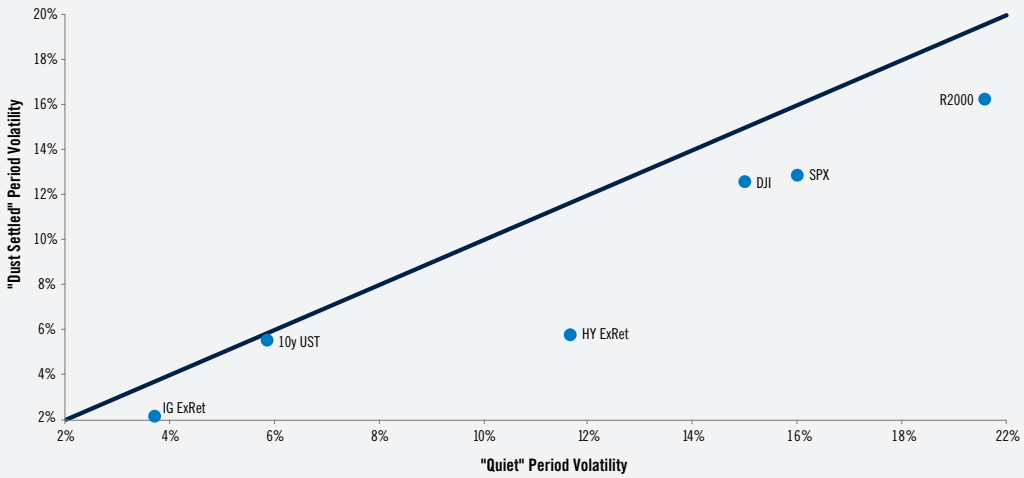
(Average Monthly Equity & Treasury Total Returns and Credit Excess Returns)



Note: Each point represents the average monthly performance of the specified asset class in the 11m post peak event period and in the ensuing 21m "dust settled" periods.
Source: Barclays POINT, Global Financial Data, FRB St. Louis, and FRED. PGIM IAS.

Figure 16: Volatility (annualized) of Asset Class Monthly Total Returns

("Quiet" Period vs. "Dust Settled" Period)



Note: Each point represents the average monthly total return volatility (annualized) of the asset class in the "quiet" and the "dust settled" periods, averaged across all post peak events in the date range. For example, across all 15 post peak events in the 1970 – 2017 period, the average monthly S&P 500 total return volatility in the "quiet" period was approximately 16.1%, and 12.9% in the "dust settled" period. Date ranges for each index are: DJI (1950-2017); 10y Treasury (1953-2017); S&P 500 (1970-2017); R2000 (1978-2017); HY ExRet (1988-2017); and IG ExRet (1988-2017).
Source: Barclays POINT, Datastream, FRB St. Louis (FRED), Global Financial Data, PGIM IAS.

Figure 16 shows that all asset classes are less volatile in the "dust settled" period compared to the "quiet" period. This is opposite to the spike event pre- and post-spike volatilities in which volatility pattern was higher after spike events. This result highlights that market volatility in the "dust settled" period has materially declined from the level before the volatility event. The "dust has clearly settled."

In terms of monthly total return correlations, following a post peak event there is a notable decrease (in absolute value) in the correlation between the S&P 500 and 10y Treasury returns as the average correlation moves from -0.19 in the "quiet" period to -0.01 in the "dust settled" period. In addition, while the average correlation between credit (HY and IG) excess returns and equity indices is little changed (slightly lower), the correlation between credit excess returns and Treasury returns declines (in absolute value). For example, the average correlation between IG and Treasuries moves from -0.26 in the "quiet" period to -0.10 in the "dust settled" period.

Figure 17: Average Asset Class Monthly Return Correlations during "Quiet" and "Dust Settled" Periods
(Oct 1988 – Oct 2017; 8 events)

"Quiet" Period

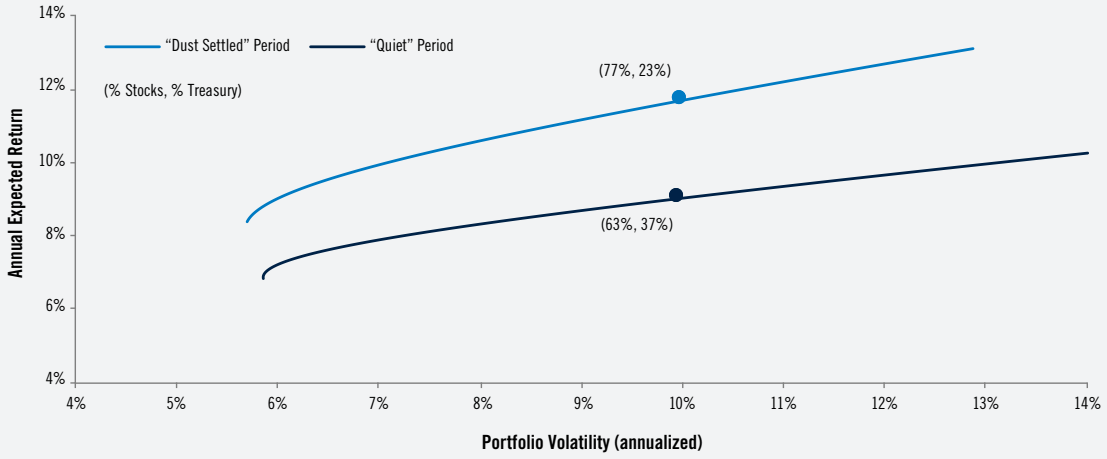
	S&P 500	R2000	DJI	10y Tsy	HY	IG
S&P 500	1					
R2000	0.79	1				
DJI	0.91	0.72	1			
10y Tsy	-0.19	-0.18	-0.20	1		
HY	0.45	0.55	0.38	-0.30	1	
IG	0.45	0.57	0.39	-0.26	0.75	1

"Dust Settled" Period

	S&P 500	R2000	DJI	10y Tsy	HY	IG
S&P 500	1					
R2000	0.75	1				
DJI	0.88	0.62	1			
10y Tsy	-0.01	-0.12	-0.02	1		
HY	0.42	0.48	0.41	-0.27	1	
IG	0.47	0.44	0.46	-0.10	0.67	1

Note: Each cell represents the correlation of monthly total returns for the indicated asset class, for either the "quiet" or "dust settled" period, averaged across all post peak events. Source: Barclays POINT, Datastream, FRB St. Louis (FRED), Global Financial Data, PGIM IAS.

Figure 18: Optimal Asset Allocation (S&P 500 and 10y Treasury); Mean-Variance Frontier
(Jan 1970 – Oct 2017, 17 events)



Note: We use annualized average total returns and annualized volatility to construct efficient mean-variance frontiers.
Source: Datastream, FRB St. Louis (FRED), PGIM IAS.

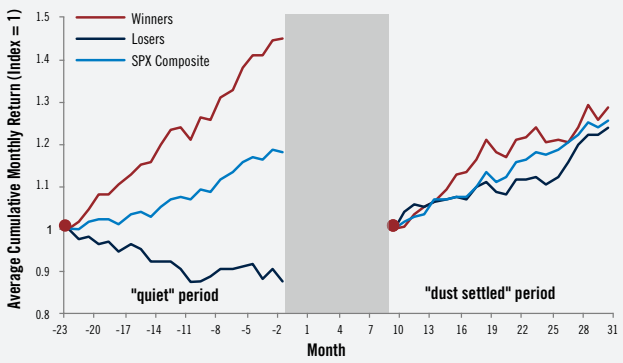
Asset Allocation

Following a volatility post peak event, the changes in broad asset class fundamentals (returns, volatilities and correlations) have implications for portfolio construction. The drop in the negative correlation between equities and 10y Treasury shift (*i.e.*, from negative in the "quiet" period to approximately zero in the "dust settled" period) suggests a decrease in the potential diversification benefit. Furthermore, equity returns have been higher with lower volatility and Treasury returns have been lower with little-changed volatility in the "dust settled" period, compared to the "quiet" period. The mean-variance frontier in Figure 18 shows the "dust settled" efficient frontier is shifted upward compared to the "quiet" period, with a higher allocation to stocks for an assumed 10% overall portfolio volatility target.

Equity: "Winners" and "Losers"

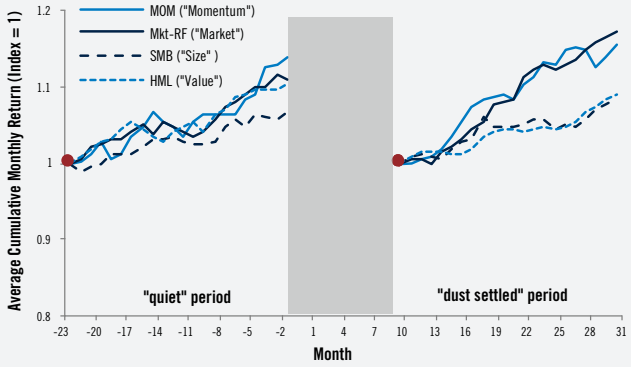
Figure 19 shows the performance of the "winner" and "loser" sector portfolios during volatility post peak events (same sectors as in Figure 9). Portfolios are constructed in the same way as for spike events. For each post peak event we identify the sector that had the best cumulative performance ("winner") and the sector with the worst cumulative performance ("loser") at the end of the

Figure 19: "Winner" and "Loser" Sector Cumulative Monthly Returns
(Oct 1989 – Oct 2017; 9 events)



Source: Datastream. PGIM IAS.

Figure 20: Equity Factor Cumulative Monthly Returns
(Jan 1970 – Oct 2017; 17 events)



Source: Datastream, CRSP database, Factor returns from Prof. Kenneth R. French's data library, PGIM IAS.

"quiet" period and follow this same "winner"/ "loser" into the "dust-settled" period. From this we calculate the average "winner" performance and the average "loser" performance.

The results are similar to those for spike events: "winners" and "losers" exhibit very divergent performance in the "quiet" period (by construction) with an average "winner" cumulative monthly total return at the end of the period of 44.9% and with an average "loser" return of -12.4%. In the "dust settled" period, much, but not all, of the relative return momentum the "winners" had over the "losers" is lost as their performance converges.

Equity: Factors

Figure 20 (right panel) shows that market, value, and momentum equity factors perform better than the size factor leading into the VIX post peak event. In the "dust settled" period following the post peak event, the market and momentum factors continue to do well, much better than the size and value factors. This post-peak event pattern is different than the observed post-spike event pattern (Figure 10) where the momentum and value factors significantly underperformed the market and size factors following spike events.

Summary

We examine the performance of several asset classes before, during and after major equity market volatility events. We define two types of volatility events: "spikes" (*i.e.*, a significant sudden increase in volatility) and "peaks" (*i.e.*, a high level of volatility that precedes a nine-month return to its pre-peak level).

We examine 26 volatility spike events, and 25 post peak events, across a 68-year span and in a variety of market environments. History shows that while spike events produce large negative returns for equities and credit bonds (with positive returns for Treasuries), the markets recover relatively quickly, approximately by the seventh month following the spike month.

For post peak events, while the markets behave similarly to spike events around the peak month, our attention is on asset class performance after the dust has settled, as this may be when investment committees re-evaluate their portfolio allocation and may take action. History shows that once the dust has settled, equity and credit markets tend to perform well, often better than before the volatility event.

The evidence from both types of volatility events supports investment committees who intend to "stay the course" and possibly re-balance with increased allocations to risky assets.

We wish to acknowledge Ms. Junying Shen for her valuable assistance on this project.

APPENDIX

Actual VIX Post Peak Events

Figure A1: Identification of VIX Post Peak Events; Actual "Quiet" and "Dust Settled" Periods

(Post peak event period varies by event)
(Jun 1950 – Oct 2017)

Peak Month (t_0)	Actual Post Peak Event Duration (months)	"Quiet" Period ($t_{0-22} - t_{0-2}$)	Actual "Dust Settled" Period	(DJI/ SPX) Cumulative Total Return in "Quiet" Period	(DJI/ SPX) Cumul. Total Return in Actual "Dust Settled" period	$\frac{VIX(t_0)}{VIX(t_{0-2})}$	DJI/ SPX) Cumulative Total Return in Actual Post Peak Event Period	Maximum (DJI/ SPX) Drawdown in Actual Post Peak Event Period	10y Treasury Cumulative Total Return in Actual Post Peak Event Period
3/1955	9	5/1953-1/1955	11/1995-7/1957	46.0%	12.6%	1.1	11.4%	-0.7%	0.0%
8/1957	7	10/1955-6/1957	2/1958-10/1959	6.6%	43.2%	1.7	-11.8%	-13.7%	9.8%
9/1960	9	11/1958-7/1960	5/1961-1/1963	20.2%	-3.0%	1.2	5.7%	-9.9%	3.7%
5/1962	12	7/1960-3/1962	4/1963-12/1964	13.0%	32.0%	4.2	-7.2%	-18.6%	2.9%
11/1963	9	1/1962-9/1963	7/1964-3/1966	0.4%	15.3%	2.9	10.9%	1.7%	2.5%
5/1966	15	7/1964-3/1966	7/1967-3/1969	15.3%	5.2%	1.3	-7.8%	-19.1%	2.8%
4/1970	6	6/1968-2/1970	9/1970-5/1972	-17.6%	29.1%	0.9	-4.6%	-9.0%	2.8%
8/1971	11	10/1969-6/1971	6/1972-2/1974	10.2%	-9.6%	1.7	1.3%	-8.5%	1.4%
9/1974	5	11/1972-7/1974	1/1975-9/1976	-16.9% / -24.6%	65.8% / 64.7%	1.4	-24.8% / -11.6%	-25.9% / -19.2%	10.5%
8/1975	6	10/1973-6/1975	1/1976-9/1977	-4.7% / -5.3%	5.7% / 15.2%	1.3	-2.4% / -3.2%	-3.9% / -11.0%	7.1%
10/1976	5	12/1974-8/1976	2/1977-10/1978	48.9% / 58.1%	-13.2% / -0.3%	1.5	1.0% / 0.9%	-4.0% / 0.3%	6.4%
10/1978	9	12/1976-8/1978	2/1979-10/1980	-7.3% / 10.3%	9.8% / 45.3%	1.4	-3.3% / -0.1%	-8.5% / -9.0%	4.4%
3/1981	8	5/1979-1/1981	10/1981-6/1983	12.0% / 39.7%	39.9% / 58.9%	1.0	-10.9% / -7.2%	-10.9% / -7.2%	-1.2%
8/1982	9	10/1980-6/1982	4/1983-12/1984	-14.3% / -4.1%	3.9% / 18.4%	2.1	39.4% / 45.1%	-2.4% / -1.8%	32.3%
8/1984	5	10/1982-6/1984	12/1984-8/1986	21.5% / 37.8%	45.0% / 65.7%	1.3	8.2% / 8.9%	0.9% / -1.2%	16.7%
10/1987	13	12/1985-8/1987	10/1988-6/1990	83.9% / 72.8%	50.8% / 40.7%	2.8	-16.8% / -14.4%	-30.0% / -29.6%	14.3%
8/1990	9	10/1988-6/1990	4/1991-12/1992	50.8% / 40.7%	18.8% / 23.9%	1.7	3.2% / 6.1%	-13.3% / 13.6%	9.4%
10/1992	6	12/1990-8/1992	3/1993-11/1994	44.4% / 35.6%	19.7% / 6.7%	1.2	0.9% / 7.7%	-5.1% / 0.3%	6.6%
9/1998	12	11/1996-7/1998	8/1999-4/2001	57.0% / 62.9%	-12.6% / -2.6%	1.9	25.6% / 21.0%	-14.6% / -11.1%	0.3%
8/2002	7	10/2000-6/2002	2/2003-10/2004	-11.0% / -31.0%	23.1% / 35.5%	1.3	-10.2% - 10.3%	-20.0% / -12.7%	8.7%
5/2004	5	7/2002-3/2004	9/2004-5/2006	13.5% / 20.6%	17.3% / 20.1%	1.0	-3.7% / -1.6%	-3.7% / -1.7%	3.6%
10/2008	16	12/2006-8/2008	1/2010-9/2011	-1.5% / -4.9%	13.6% / 2.1%	3.0	-4.3% / -10.1%	-39.3% / -44.5%	3.4%
5/2010	9	7/2008-3/2010	1/2011-9/2012	-11.4% / -4.4%	20.5% / 17.9%	1.8	11.8% / 9.6%	-6.0% / -12.4%	6.0%
8/2011	7	10/2009-6/2011	2/2012-10/2013	36.2% / 34.7%	26.7% / 38.3%	1.8	3.6% / 0.1%	-11.6% / -17.5%	10.6%
6/2012	8	8/2010-4/2012	1/2013-9/2014	42.8% / 29.5%	37.5% / 41.5%	1.2	0.1% / 3.1%	-7.7% / -8.8%	0.1%
Average	**9**			**17.5% / 21.7%**	**19.9% / 27.7%**	**1.7**	**0.6% / 2.6%**	**-11.5% /-10.3%**	**6.6%**

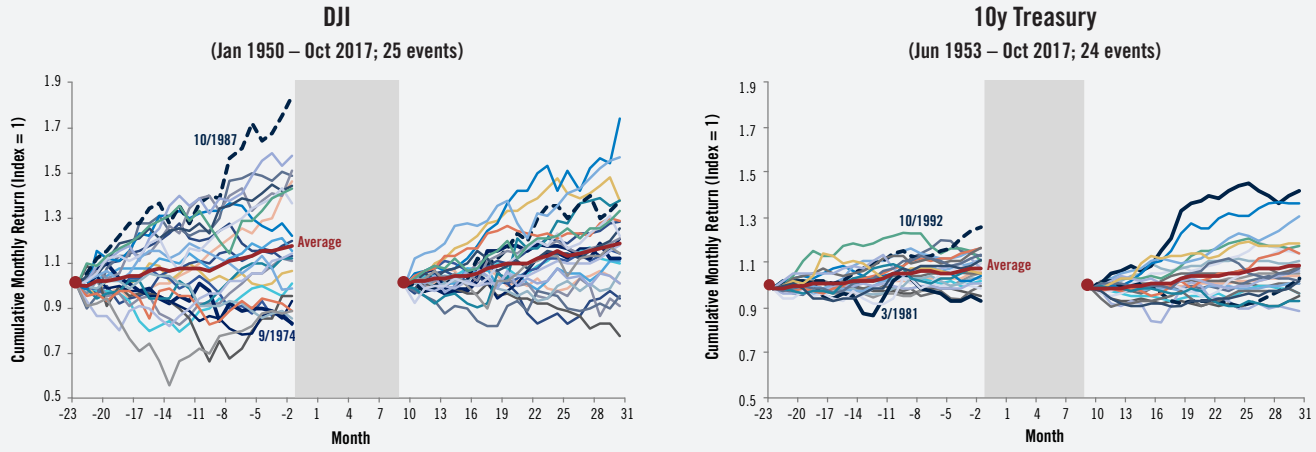
Note: Actual post peak event duration refers to the number of months (x) it takes the VIX to decline to 2/3 of its peak level, *and stay there*, that is when $VIX(t_{0+x})/VIX(t_{0-2}) \leq 0.67$, from and including month t_{0-1}.
Source: CBOE, Datastream, FRB St. Louis (FRED), Global Financial Data, PGIM IAS.

Cumulative Monthly Return by Post Peak Event: Equity and Treasury Markets

Figure A2 (left panel) shows performance volatility for the equity market (DJI) across post peak events in the "dust settled" period is much less than during the "quiet" period. The right panel shows that volatility was slightly higher in the "dust settled" period for the 10y Treasury.

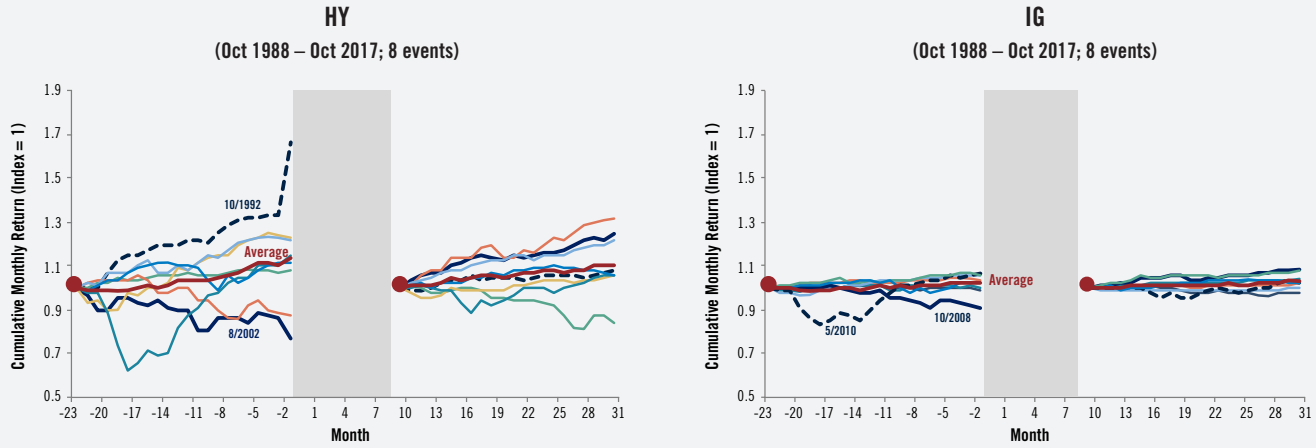
Figure A3 shows that the volatility of performance of HY and IG across VIX events in the "dust settled" period is also lower than during the "quiet" period.

Figure A2: Cumulative Monthly Returns by Post Peak Event: Equity & Treasury Total Returns



Source: FRB St. Louis (FRED), Global Financial Data, PGIM IAS.

Figure A3: Cumulative Monthly Returns by Post Peak Event: US Credit Excess Returns



Source: Barclays POINT, PGIM IAS.

Returns Conditional on Interest Rate Levels

We sort the VIX post peak events by the level of the 10y Treasury yield in month t_{0-2}. We then split the post peak events into "low" (LIR) and "high" (HIR) interest rate groups (Figure A4). We averaged the post peak events within each group for the cumulative monthly total return curves (Figure A5).

While we find that the general pattern for equity returns is the same for both the high and low interest rate groups, we see that cumulative monthly equity returns are higher in the "dust settled" period for the LIR group. In contrast, for 10y Treasury returns, we see that the LIR group exhibits significantly poorer performance in the "dust settled" period compared to the HIR group.

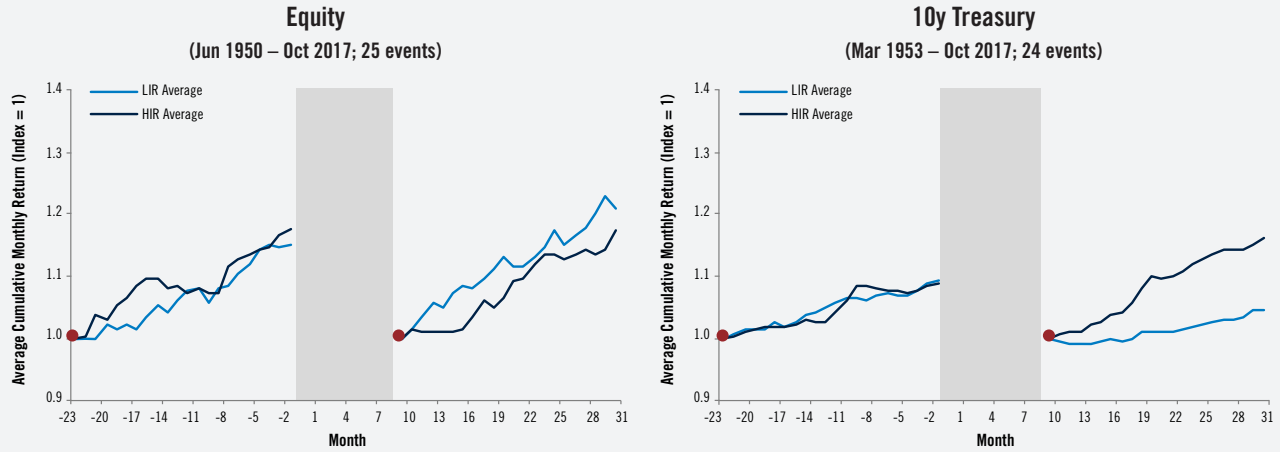
Figure A4: Average 10y Treasury Interest Rates

(May 1953 – Oct 2017; 24 events)
(Current 10y Treasury yield = 2.4%)

Interest Rate Group	Average 10y Treasury Yield	Event Yield Range
Low (12 events)	4.0%	[2.1%, 5.5%]
High (12 events)	9.2%	[6.5%, 14.3%]

Source: FRB St. Louis (FRED), Global Financial Data, PGIM IAS.

Figure A5: Cumulative Monthly Returns by Interest Rate Group



Note: "Equity" refers to the DJI and "Treasury" refers to the 10y US Treasury. Each line represents the cumulative 21-month return for the indicated interest rate group, both prior and post the VIX post peak event, averaged across all events in the specified group. Events were sorted based on their value at $t_{0\text{-}2}$. The vertical grey bar represents the 11m period between the end of the "quiet" period and the beginning of the "dust settled" period.
Source: Datastream, Global Financial Data, FRB St. Louis (FRED), PGIM IAS.

Returns Conditional on CAPE Levels

We sort the post peak volatility events by the cyclically adjusted price earnings ratio (CAPE) at $t_{0\text{-}2}$. We then split the post peak events into low and high CAPE groups (Figure A6). We averaged the events within each group for the cumulative monthly total return curves (Figure A7).

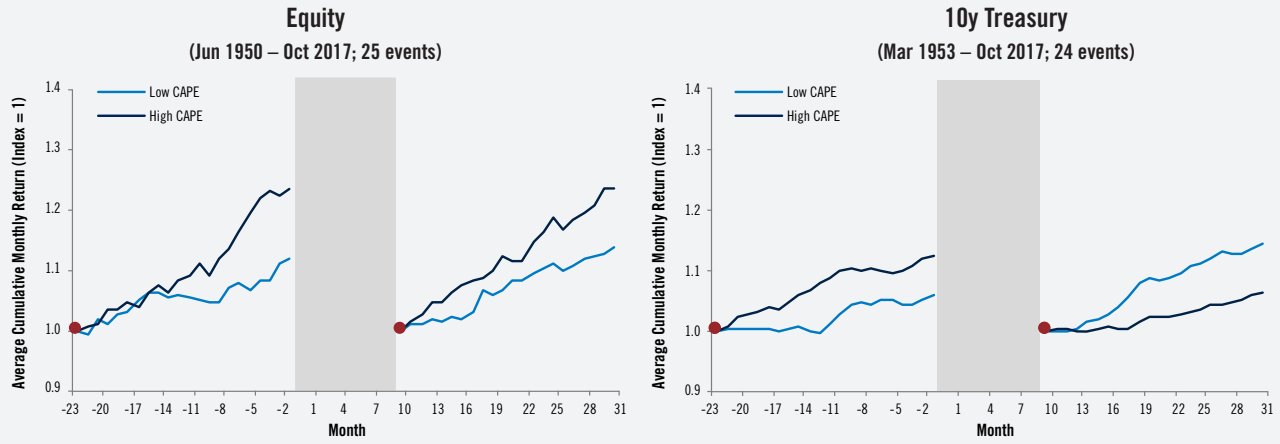
Figure A6: Average CAPE

(Jun 1950 – Oct 2017; 25 events)
(Current CAPE = 33.2)

CAPE Group	Average CAPE	Event CAPE Range
Low (13 events)	13.0	[6.7, 17.8]
High (2 events)	23.4	[18.3, 38.3]

Note: Our data comes from Prof. Shiller's online data collection.
Source: Stock market data used in *Irrational Exuberance,* Princeton University Press, 2000, 2005, 2015, updated, PGIM IAS.

Figure A7: Cumulative Monthly Returns by CAPE Group



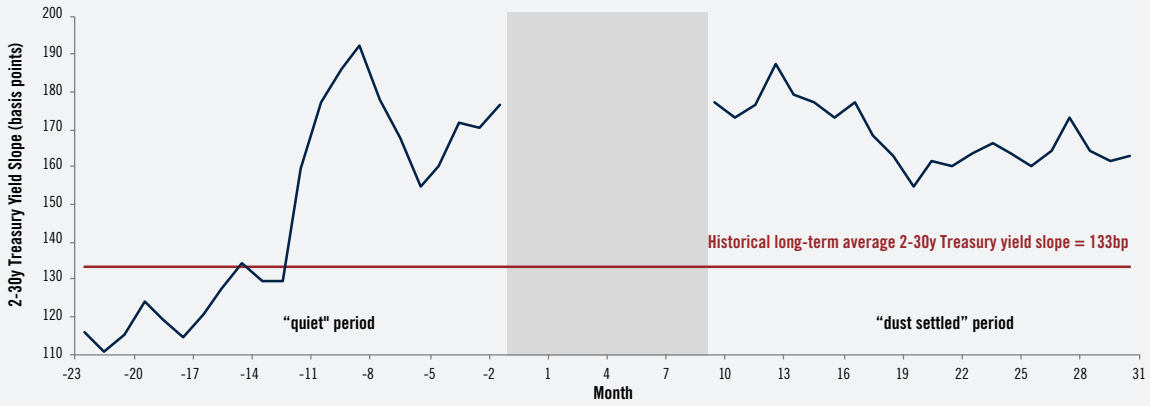
Note: "Equity" refers to the DJI and "Treasury" refers for the 10y US Treasury. Each line represents the cumulative 21-month return for the indicated CAPE group, both prior and post the VIX post peak event, averaged across all events in the specified group. Events were sorted based on their value at $t_{0\text{-}2}$. The vertical grey bar represents the 11m period between the end of the "quiet" period and the beginning of the "dust settled" period.
Source: Datastream, Global Financial Data, Stock market data used in *Irrational Exuberance,* Princeton University Press, 2000, 2005, 2015, updated, PGIM IAS.

Cumulative monthly equity total returns are high for both CAPE groups in the "dust settled" period. Interestingly, however, the high CAPE group outperforms the low CAPE group. For 10y Treasury returns, we see that while the high and low CAPE groups exhibit similar behavior in both periods the low CAPE group outperforms the high CAPE group in the "dust settled" period.

Macroeconomic Indicators: 2-30y Treasury Slope, Unemployment, Inflation and GDP

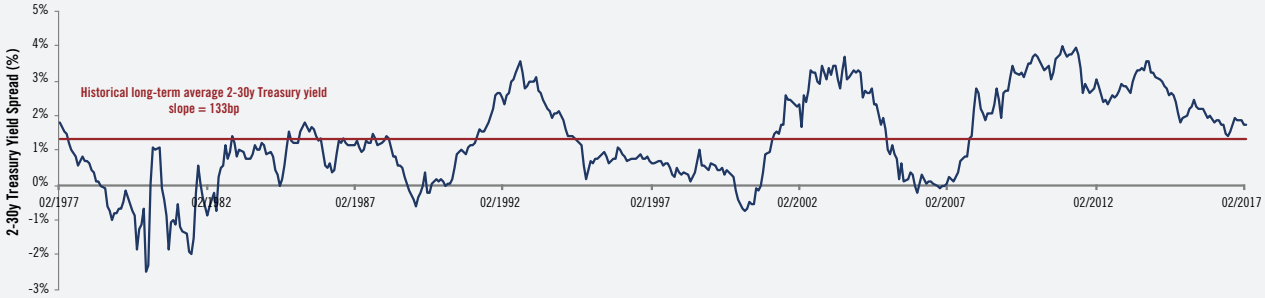
How does the macroeconomy change after post peak events? In the "quiet" period, we see that 2-30y Treasury yield curve slope starts, on average, from a relatively flat level 115bp and steepens substantially to 176bp leading into the post peak event (Figure A8). The fact that the curve has an above-average steepness in the "dust settled" period may reflect attempts by the Federal Reserve to lower short-term interest rates in response to the volatility event.

Figure A8: 2-30y Treasury Yield Slope During "Quiet" and "Dust Settled" Periods
(Feb 1977 – Oct 2017, 13 events)



Note: 2-30y Treasury yield slope is measured as the difference between month-end 30y CMT yield and 2y CMT yield.
Source: FRB St. Louis (FRED), PGIM IAS.

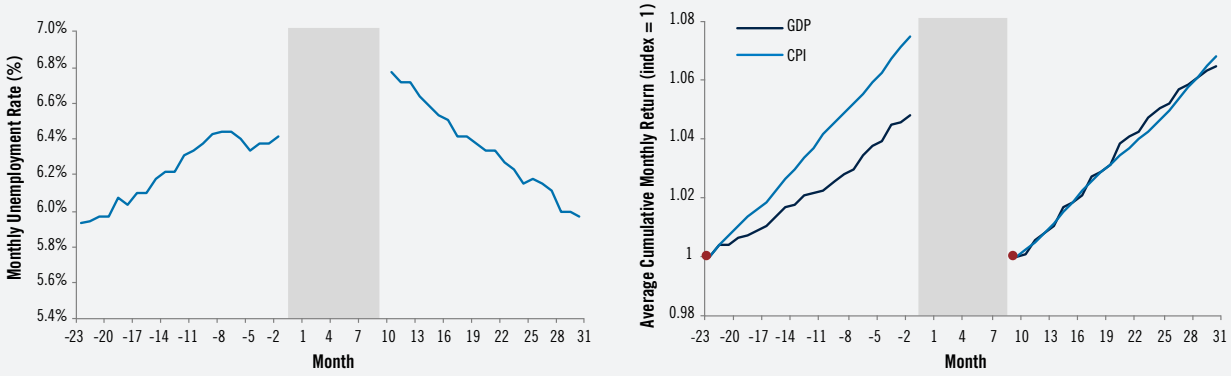
Figure A9: 2-30y Treasury Yield Spread
(Feb 1977 – Oct 2017)



Source: FRB St. Louis (FRED), PGIM IAS.

Figure A10 shows that the unemployment rate increases leading into the post peak event. By the end of the post peak event unemployment has increased from 6.4% at t_{0-2} to 6.7% by t_{0+10}. Furthermore, the beginning of the "dust settled" period is also the beginning of a sustained improvement in the unemployment rate: by the end of the "dust settled" period, unemployment is back close to the its level at the beginning of the "quiet" period. This helps to explain the stock market's relatively strong performance in the "dust settled" period as the economy appears to be on a sustained recovery path.

Figure A10: Unemployment Rate, Inflation, and GDP During "Quiet" and "Dust Settled" Periods
(Jan 1950 – Oct 2017, 25 events)



Source: Datastream, PGIM IAS.

The strong economic recovery is also reflected in the inflation and growth rates in the "dust settled" period. Over the 21 months of the "quiet" period, GDP increased 4.8%, but increased 6.5% over the "dust settled" period. Meanwhile, average inflation (CPI) was roughly the same in both periods.

IMPORTANT INFORMATION

The information contained herein is provided by PGIM, Inc., the principal asset management business of Prudential Financial, Inc. (PFI), and an investment adviser registered with the US Securities and Exchange Commission. PFI is not affiliated in any manner with Prudential plc, a company incorporated in the United Kingdom.

In the United Kingdom and various European Economic Area jurisdictions, information is issued by PGIM Limited with registered office: Grand Buildings, 1-3 Strand, Trafalgar Square, London, WC2N 5HR. PGIM Limited is authorised and regulated by the Financial Conduct Authority of the United Kingdom (registration number 193418) and duly passported in various jurisdictions in the EEA. Prudential Financial, Inc. of the United States is not affiliated with Prudential plc, which is headquartered in the United Kingdom. The PGIM logo and the Rock design are service marks of PFI and its related entities, registered in many jurisdictions worldwide.

In certain countries in Asia, information is presented by PGIM Singapore, a Singapore investment manager registered with and licensed by the Monetary Authority of Singapore. In Japan, information is presented by PGIM Japan Co., Ltd., a registered investment adviser with the Japanese Financial Services Agency. In South Korea, information is presented by PGIM, Inc., which is licensed to provide discretionary investment management services directly to South Korean investors. In Hong Kong, information is presented by representatives of PGIM (Hong Kong) Limited, a regulated entity with the Securities and Futures Commission in Hong Kong to professional investors as defined in Part 1 of Schedule 1 of the Securities and Futures Ordinance. It is anticipated that certain investment management services would be delegated to PGIM, Inc. the above listed entities' U.S. registered investment advisory affiliate.

These materials are for informational or educational purposes only. The information is not intended as investment advice and is not a recommendation about managing or investing assets. In providing these materials, PGIM is not acting as your fiduciary as defined by the Department of Labor.

These materials may contain hypothetical and simulated examples, which are provided for illustrative purposes only. Simulated examples have certain inherent limitations and are generally prepared through the retroactive application of a model designed with the benefit of hindsight. There are frequently sharp differences between simulated results and actual results. PGIM routinely reviews, modifies, and adds risk factors to its proprietary models. There is no guarantee, and no representation is made, that an investor will achieve results similar to those shown.

All charts contained herein were created as of February 2018, unless otherwise noted. Performance results for certain charts and graphs may be limited by date ranges, as stated on the charts and graphs. Different time periods may produce different results. Charts are provided for illustrative purposes and are not an indication of past or future performance of any PGIM product.

These materials represent the views, opinions and recommendations of the author(s) regarding the economic conditions, asset classes, securities, issuers or financial instruments referenced herein. Distribution of this information to any person other than the person to whom it was originally delivered and to such person's advisers is unauthorized, and any reproduction of these materials, in whole or in part, or the divulgence of any of the contents hereof, without prior consent of PGIM is prohibited. Certain information contained herein has been obtained from sources that PGIM believes to be reliable as of the date presented; however, PGIM cannot guarantee the accuracy of such information, assure its completeness, or warrant such information will not be changed. The information contained herein is current as of the date of issuance (or such earlier date as referenced herein) and is subject to change without notice. PGIM has no obligation to update any or all of such information; nor do we make any express or implied warranties or representations as to the completeness or accuracy or accept responsibility for errors. These materials are not intended as an offer or solicitation with respect to the purchase or sale of any security or other financial instrument or any investment management services and should not be used as the basis for any investment decision. Past performance is no guarantee or reliable indicator of future results. No liability whatsoever is accepted for any loss (whether direct, indirect, or consequential) that may arise from any use of the information contained in or derived from this report. PGIM and its affiliates may make investment decisions that are inconsistent with the recommendations or views expressed herein, including for proprietary accounts of PGIM or its affiliates. The opinions and recommendations herein do not take into account individual client circumstances, objectives, or needs and are not intended as recommendations of particular securities, financial instruments or strategies to particular clients or prospects. No determination has been made regarding the suitability of any securities, financial instruments or strategies for particular clients or prospects. For any securities or financial instruments mentioned herein, the recipient(s) of this report must make its own independent decisions.

0319-300