S&P Dow Jones Indices

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APPLIED ACADEMICS

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Market Timing With Implied Volatility Indices

EXECUTIVE SUMMARY

This applied methodology paper introduces an intuitive framework for constructing robust market timing signals based on implied volatility indices. In particular, we define the object of prediction as drawdown events, which tend to coincide with periods of high realized volatility. The simple regime-based approach depends on the hypothesis that option-implied volatility indices possess some predictive power with respect to future realized volatility and hence drawdowns. Compelling empirical evidence supporting this hypothesis is presented, and the study concludes with illustrative applications of the signal for market timing strategies.

Highlights

- Drawdowns tend to coincide with periods of high realized volatility.
- Implied volatility indices tend to lead future realized volatility.
- A simple volatility regime framework may produce robust market timing signals.

OVERVIEW OF THE VIX® ECOSYSTEM

In 1993, the CBOE Volatility Index® (VIX) was the first implied volatility index to be introduced. The index has since become the most widely tracked measure of market volatility and is known as the “fear gauge” of general market participant sentiment. Trading activity in VIX futures and options has significantly expanded in volume in recent years, and there has been a rise in the popularity of exchange-traded products, structured products, and over-the-counter trades referencing the index as well.

The success of VIX was followed by an extension of the implied volatility index family to include different asset classes and geographies.

1. CBOE Volatility Index (VIX)
2. CBOE Interest Rate Swap Volatility Index (SRVIX)
3. CBOE/CBOT 10-Year Treasury Note Volatility Index (TYVIX)
4. S&P/JPX JGB VIX (SPJGBV)
5. CBOE Crude Oil ETF Volatility Index (OVX)
6. CBOE Gold ETF Volatility Index (GVZ)
7. CBOE/CME FX Euro Volatility Index (EUVIX)

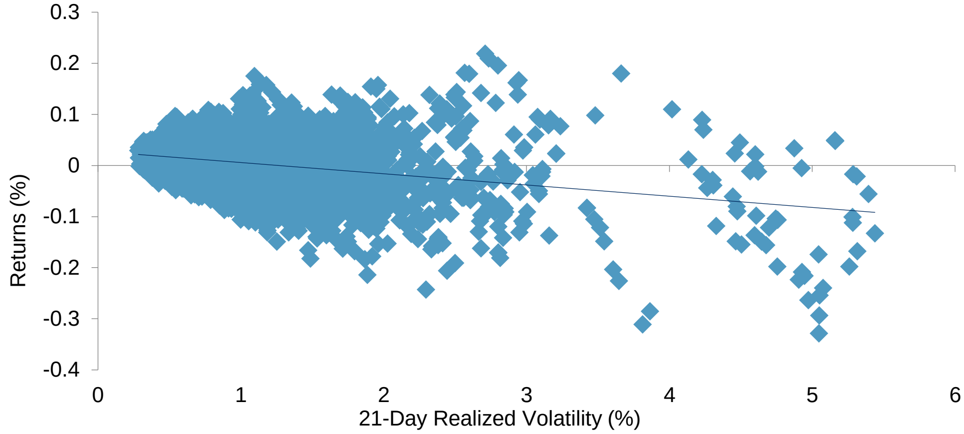
8. CBOE/CME FX Yen Volatility Index (JYVIX)
9. CBOE/CME FX British Pound Volatility Index (BPVIX)

Volatility Spikes and Drawdowns

The focus of this empirical study on market timing is the potential use of implied volatility indices to help anticipate future downside events in various markets. While there is no mathematical condition forcing volatility to be directionally correlated with positive or negative security returns, periods of pronounced losses have historically been associated with elevated volatility in the data. Exhibits 1 and 2 illustrate the prevalence of this negative and convex relationship using scatterplots of monthly returns on various securities against contemporaneous 21-day realized volatilities. Theories abound regarding the origins of this phenomenon, which is an interesting topic in and of itself, but our present analysis remains agnostic to this debate and simply uses this observation as an empirical building block.

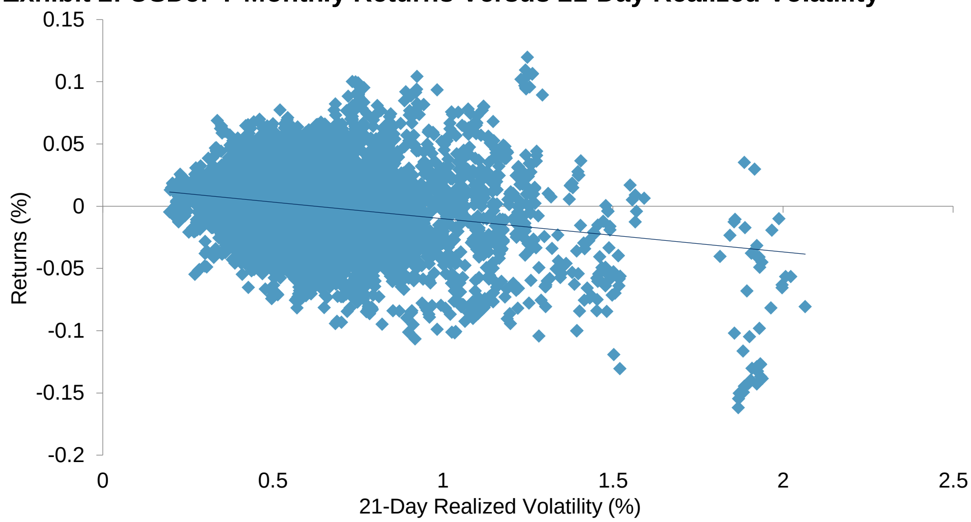
While there is no mathematical condition forcing volatility to be directionally correlated with positive or negative security returns, periods of pronounced losses tend to be associated with elevated volatility in the data.

Exhibit 1: S&P 500® Monthly Returns Versus 21-Day Realized Volatility



Source: Bloomberg. Data as of July 11, 2017. Past performance is no guarantee of future results. Chart is provided for illustrative purposes.

Exhibit 2: USDJPY Monthly Returns Versus 21-Day Realized Volatility

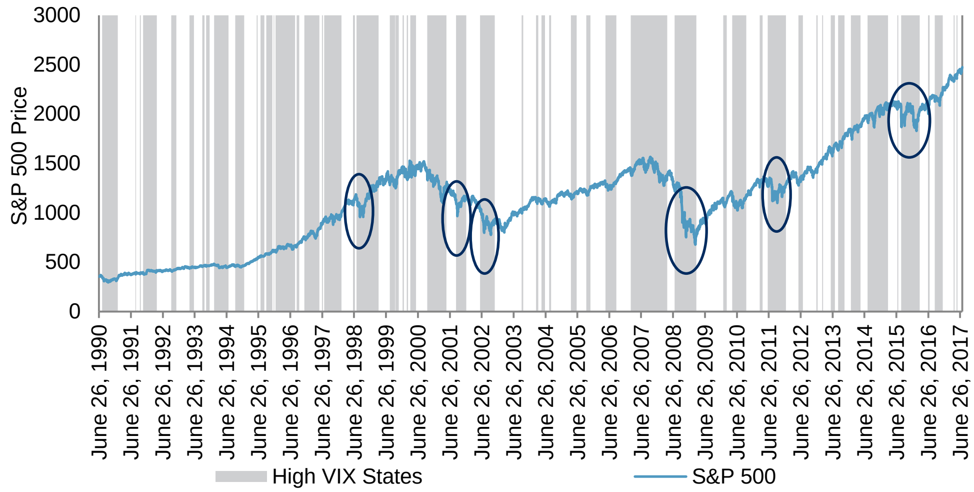


Source: Bloomberg. Data as of July 11, 2017. Past performance is no guarantee of future results. Chart is provided for illustrative purposes.

When viewed as a time series, an additional facet of the relationship between volatility and returns emerges in the form of pronounced drawdowns during periods of high volatility. This temporal clustering of negative returns makes high volatility periods particularly painful for market participants. Exhibits 3 and 4 show how the largest drawdowns in the S&P 500 and 10-Year U.S. Treasury Note futures prices coincide with heightened volatility. This relates to a core concept underpinning the growing interest in factor-based investing in which the long-term premium earned by taking exposure to factors is commonly interpreted as compensation for underperformance during "bad times" when market participants experience pain most acutely; being long volatility is expensive because it pays off when the average market participant needs it the most.

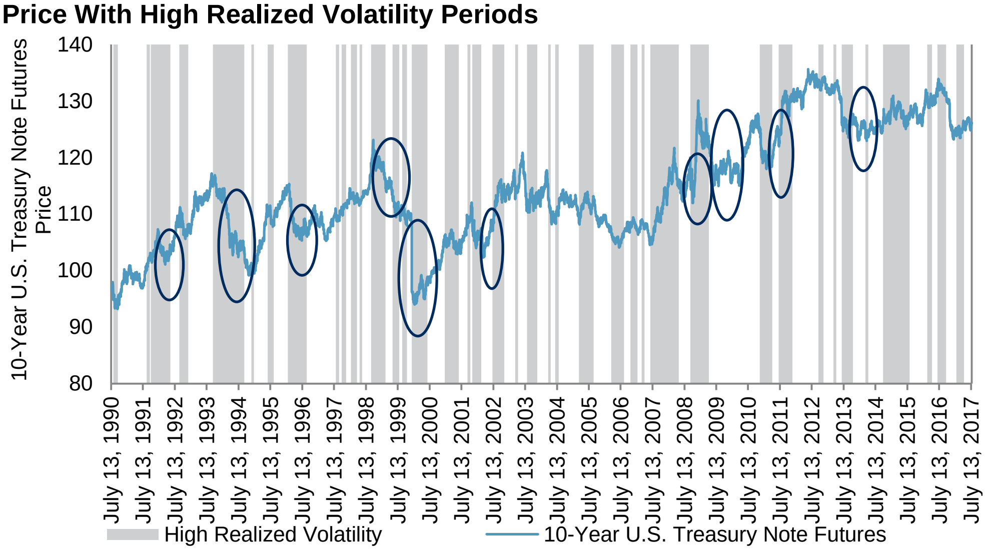
When viewed as a time series, an additional facet of the relationship between volatility and returns emerges in the form of pronounced drawdowns during high volatility periods.

Exhibit 3: Coincidence of Drawdowns in the S&P 500 With High Realized Volatility Periods



Source: Bloomberg. Data as of July 21, 2017. Past performance is no guarantee of future results. Chart is provided for illustrative purposes.

Exhibit 4: Coincidence of Drawdowns in10-Year U.S. Treasury Note Futures Price With High Realized Volatility Periods



Source: Bloomberg. Data as of July 21, 2017. Past performance is no guarantee of future results. Chart is provided for illustrative purposes.

If drawdowns coincide with high realized volatility periods, it stands to reason that forecasting spikes in realized volatility should also allow market participants to anticipate impending drawdowns. Arguably, the best volatility forecasting expertise can be found in options markets, where traders sink or swim by the accuracy of their views on future volatility, which is the main determinant of option prices. Option quotes are often accompanied by an “implied volatility” number, which is a model-based estimate of future volatility as implied by option prices. In theory, one may interpret option-implied volatility as the aggregate view on how volatile the underlying security will be between a given day and the option expiry, and hence should be as good a predictor as any. In practice, however, standard models, such as Black-Scholes, fail to deliver this interpretation, as options with different strikes often produce different model-implied volatilities for the same underlying security and future time period (also known as the volatility “smile” or “smirk”), which is clearly nonsensical.

Option quotes are often accompanied by an “implied volatility” number, which is a model-based estimate of future volatility as implied by option prices.

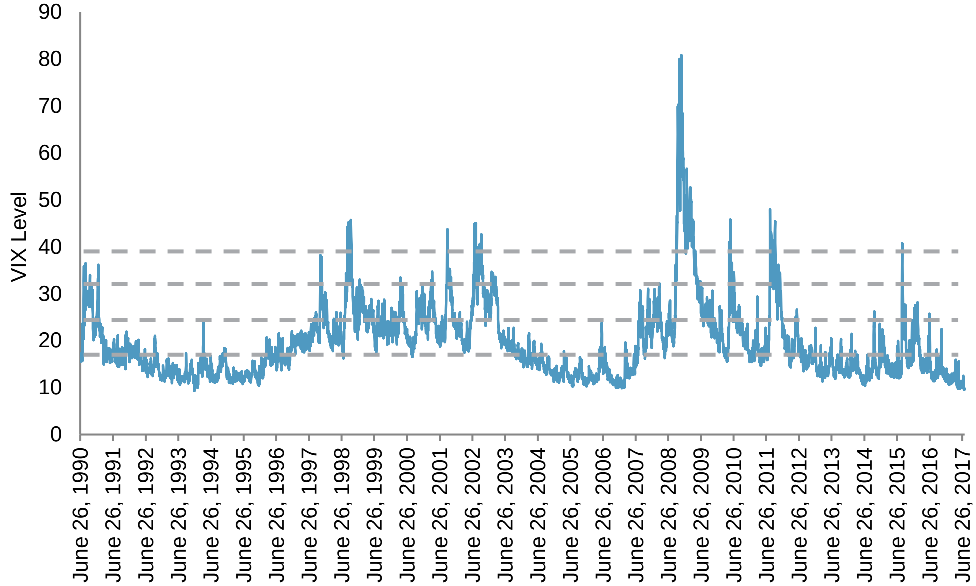
The VIX family of implied volatility indices gets around this inherent inconsistency by using a mathematical technique for extracting information about future volatility from options across all strikes and distilling it down into one clean (i.e., model-independent) implied volatility number. Without getting into the technical details, clean implied volatility may be interpreted as the fair strike of a realized volatility swap,[1] which gives it the designation of the market-clearing price of volatility. As such, this study rests on the hypothesis that option traders are skilled at forecasting volatility and that the resulting VIX values serve as effective predictive signals.

TIME SERIES BEHAVIOR OF VOLATILITY

In order to frame the prediction problem precisely, one must first define the object of prediction. Traditional assets, such as stocks and bonds, tend to exhibit upward trends in the long run, as dividends and coupons are paid and market capitalization grows with the economy over time. In contrast, the price of volatility has a default state of being low during protracted periods of market calm, mixed with spurts of high periods brought on by various shocks. The ascent of a volatility spike is usually much steeper than the descent, which suggests that heightened volatility tends to linger for some time after the initial burst. In our view, these are the only two time series characteristics that matter for volatility from a high-level fundamental perspective, and we disregard the higher-frequency, lower-amplitude oscillations as noise.

[1] More precisely, the square root of an annualized strike of a variance swap.

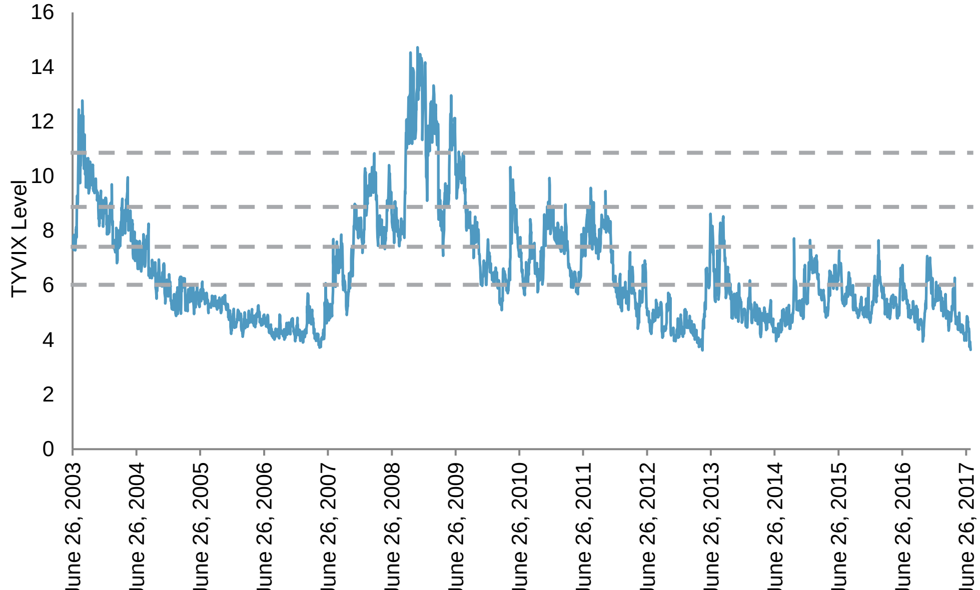
Exhibit 5: VIX With Hypothetical Fixed Thresholds



Source: Bloomberg. Data as of July 21, 2017. Past performance is no guarantee of future results. Chart is provided for illustrative purposes.

Using fixed cutoff levels of the absolute index values, as marked in the figure, does not lead to consistent identification through time of what our eyes can easily identify as spikes, given the varying amplitudes.

Exhibit 6: TYVIX With Hypothetical Fixed Thresholds



Source: Bloomberg. Data as of July 21, 2017. Past performance is no guarantee of future results. Chart is provided for illustrative purposes.

A bird's eye view of VIX and TYVIX in Exhibits 5 and 6 suggests that the prediction target should be some definition of a volatility spike or, more generally, high volatility. However, even a casual glance could suffice to conclude that using fixed cutoff levels of the absolute index values, as marked in the figures, does not lead to consistent identification through time of what our eyes can easily identify as spikes, given the varying amplitudes. Instead, what market participants experience as a spike is context and level dependent, meaning that an effective definition of a spike must account for what the world looked like leading up to it; what feels like a blip during a total market meltdown may feel like a jolt during peaceful times. Moreover, the steep ascent likely narrows the window for timely prediction, and therefore any successful signal must be at once sensitive to sudden moves and robust in its resistance to noisy jitters.

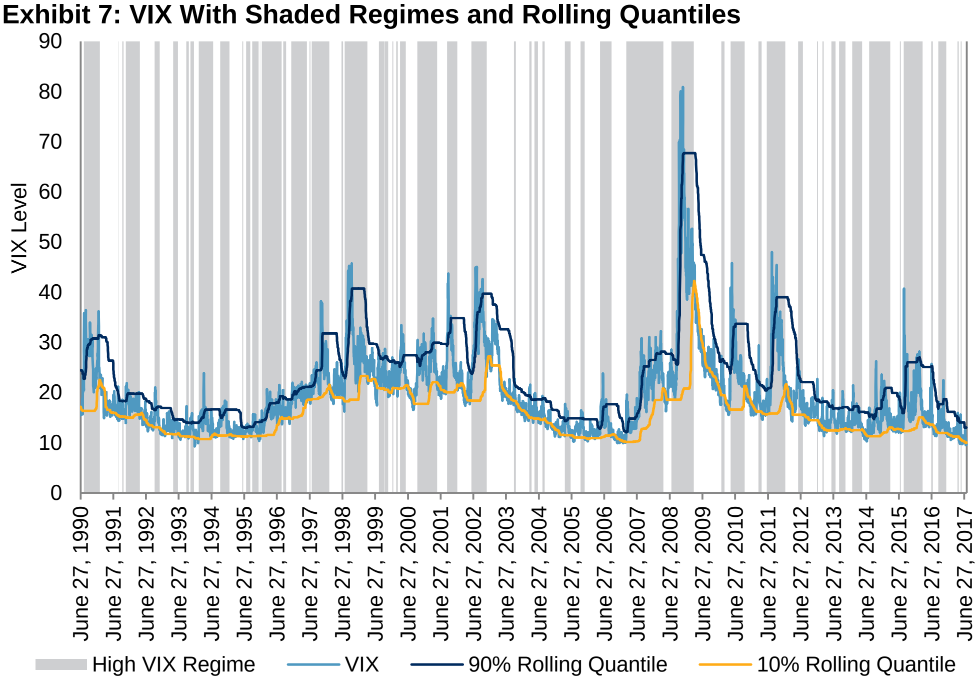
Concept of Volatility Regimes

A simple and intuitive approach that satisfies the desired criteria discussed above is to define high and low volatility regimes whereby transitions are triggered by the upward and downward crossings of two rolling quantiles. If our hypothesis about clean implied volatility holds, high realized volatility regimes would then be preceded, and hence predicted, by high implied volatility regimes. In other words, the binary regime construct serves as both the object of prediction and the signal.

A simple and intuitive approach that satisfies the desired criteria discussed above is to define high and low volatility regimes whereby transitions are triggered by the upward and downward crossings of two rolling quantiles.

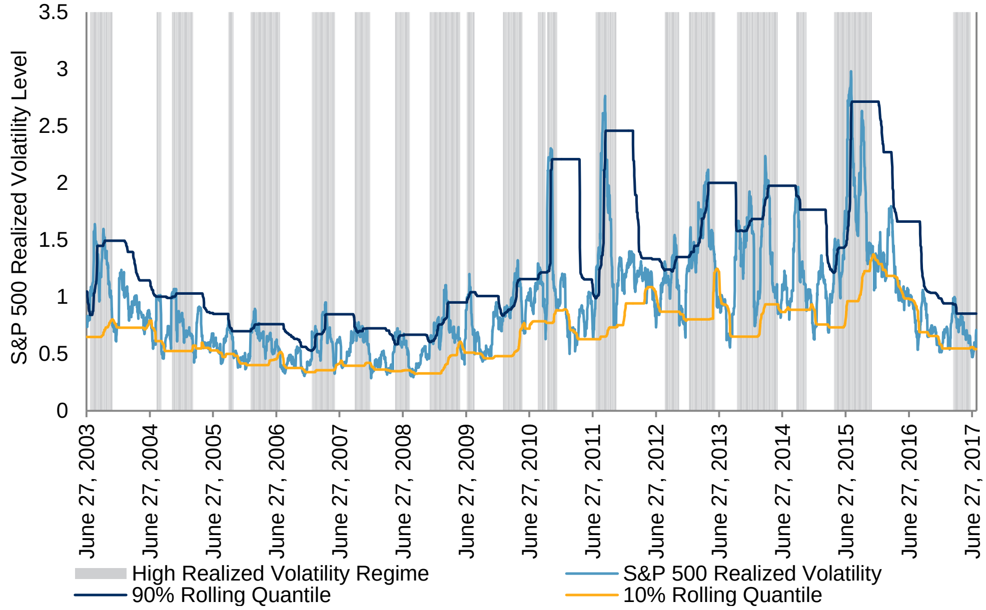
Exhibits 8 and 10 show high realized volatility regimes for the S&P 500 and 10-Year U.S. Treasury Note futures shaded in light gray, which is based on six-month rolling 10% and 90% quantiles. Exhibits 7 and 9 show the analogous regimes based on VIX and TYVIX. One can see that the thus-defined high regimes generally agree with what the average market participant would consider to be jumps in volatility. It is of course trivial to add more parameters to this framework to catch (in back-testing) every perceived jump and drawdown, but our view is that a sprinkling of misclassification is a small price to pay for the benefits of a parsimonious approach.

Exhibit 7: VIX With Shaded Regimes and Rolling Quantiles



Source: Bloomberg. Data as of July 21, 2017. Past performance is no guarantee of future results. Chart is provided for illustrative purposes.

Exhibit 8: S&P 500 Realized Volatility With Shaded Regimes and Rolling Quantiles

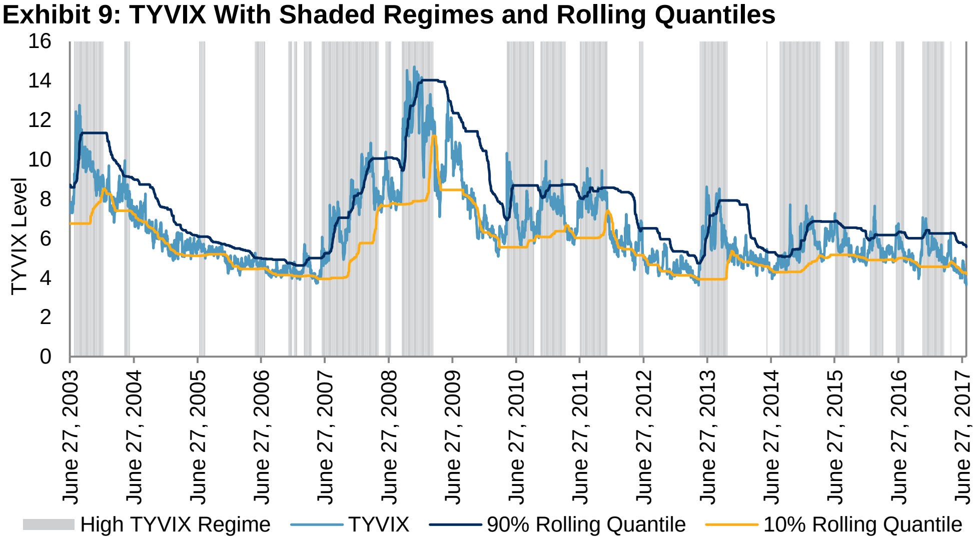


Source: Bloomberg. Data as of July 21, 2017. Past performance is no guarantee of future results. Chart is provided for illustrative purposes.

The distance between the two quantiles mitigates erratic switching between the two regimes while setting a threshold for what constitutes a spike, and the rolling window controls how quickly the bands adjust to the most recent returns.

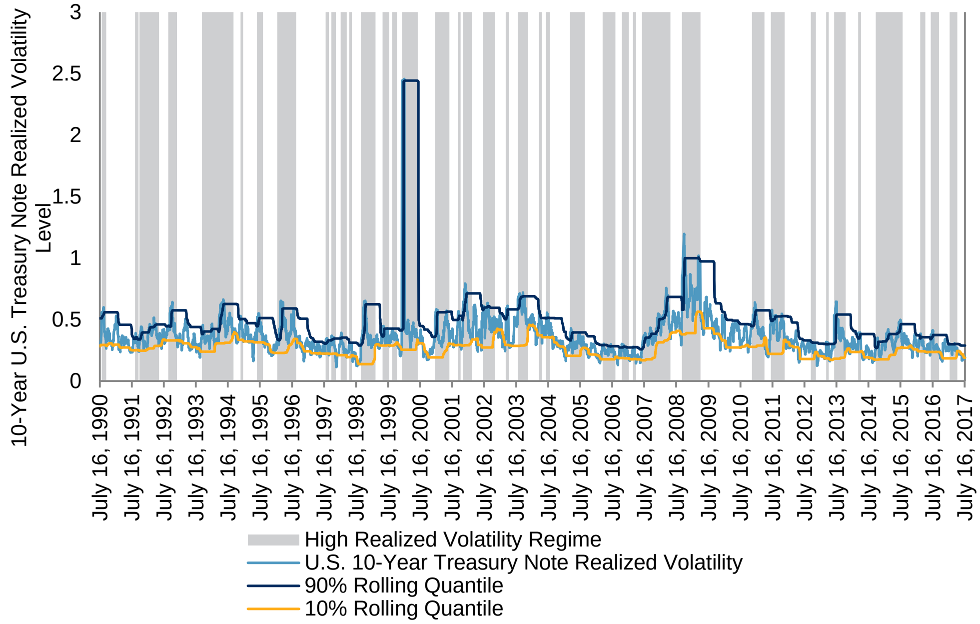
The distance between the two quantiles mitigates erratic switching between the two regimes while setting a threshold for what constitutes a spike, and the rolling window controls how quickly the bands adjust to the most recent returns. One should set these parameters independently for realized and implied volatilities such that they reasonably separate high and low regimes in one's opinion; this would help avoid overfitting the lead-lag relationship between the two. A caveat is that one may be justified in using different parameter values when dealing with different target assets or when combining two or more volatility indices to define regimes, as we will show in the Applications section.

Exhibit 9: TYVIX With Shaded Regimes and Rolling Quantiles



Source: Bloomberg. Data as of July 21, 2017. Past performance is no guarantee of future results. Chart is provided for illustrative purposes.

Exhibit 10: 10-Year U.S. Treasury Note Realized Volatility With Shaded Regimes and Rolling Quantiles



Source: Bloomberg. Data as of July 21, 2017. Past performance is no guarantee of future results. Chart is provided for illustrative purposes.

This framework significantly reduces the dimensionality of an otherwise unruly problem by (a) collapsing the entire range of volatility into two categorical states, (b) using only three parameters to define the regimes, and (c) precisely and identically defining the object of prediction and signal based on economic rationale.

The merits of the parsimony in our volatility regime framework should not be glossed over as a mere technical point. This framework significantly reduces the dimensionality of an otherwise unruly problem by (a) collapsing the entire range of volatility into two categorical states, (b) using only three parameters to define the regimes, and (c) precisely and identically defining the object of prediction and signal based on economic rationale. While these considerations do not completely remove the possibility of overfitting—the dominant risk when performing any kind of predictive exercise—they significantly reduce it, especially compared with the less principled approaches seen in some volatility-based strategies with more numerous parameters.

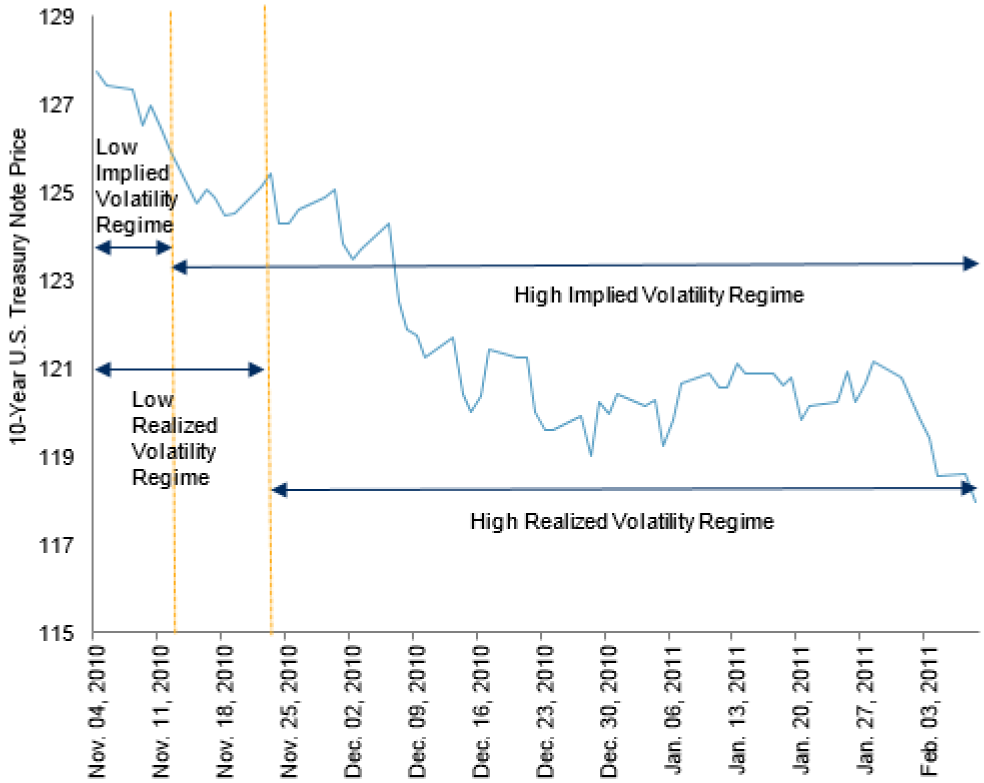
Two Empirical Building Blocks

To generalize the visual case studies above regarding the association between high volatility regimes and drawdowns, we expanded the analysis to document the contemporaneous relationship across eight implied volatility indices in the VIX series and 15 major securities. To do so, we identified the peak-to-trough dates of the top 10 drawdowns for each security, and subtracted the sum of returns on high regime days from those on low regime days within the peak-to-trough period. If the hypothesis is that the worst of drawdowns happen in high-realized-volatility regimes, then we should expect this difference to be negative. This analysis is silent on what happens in regimes outside of drawdowns, but this will be implicitly explored in the applications section. Exhibit 13 shows the results of this calculation.

Exhibit 11 illustrates this analysis with a drawdown in 10-Year U.S. Treasury futures from Nov. 4, 2010, to Feb. 8, 2011. Out of the 68 days from peak to trough, 55 days fall under the high realized volatility regime, with a cumulative difference in return between the high and low regime days of -4.8%. In this instance, the high implied volatility regime can be seen to precede the high realized volatility by about one week.

Out of the 68 days from peak to trough, 55 days fall under the high realized volatility regime, with a cumulative difference in return between the high and low regime days of -4.8%.

Exhibit 11: 10-Year U.S. Treasury Note Realized Volatility Drawdown Period



Source: Bloomberg. Data from Nov. 4, 2010, to Feb. 8, 2011. Past performance is no guarantee of future results. Chart is provided for illustrative purposes.

Exhibit 12: 10-Year Treasury Note Realized Volatility Drawdown Period

DATA POINT	IMPLIED VOLATILITY	REALIZED VOLATILITY
Low Regime Dates	Nov.4, 2010, to Nov. 12, 2010	Nov. 4, 2010, to Nov. 23, 2010
Number of Low Days	6	13
Cumulative Low Returns (%)	-0.77	-1.19
High Regime Dates	Nov. 15, 2010, to Feb. 8, 2011	Nov. 24, 2010, to Feb. 8, 2011
Number of High Days	62	55
Cumulative High Returns (%)	-6.4	-6.0
Cumulative High Minus Low Return (%)	-5.67	-4.84

Source: Bloomberg. Data from Nov. 4, 2010, to Feb. 8, 2011. Past performance is no guarantee of future results. Table is provided for illustrative purposes.

Exhibit 13: Difference in Cumulative Returns of High and Low Regimes in Drawdown Periods

INSTRUMENTS	DIFFERENCE (%)							
	VIX	TYVIX	OVX	GVZ	EUVIX	JYVIX	BPVIX	JGB VIX
S&P 500	-28.50	-46.10	-83.00	-44.70	-64.40	-26.50	-86.30	-28.00
Euro Stoxx 50	-42.80	-29.00	-67.50	-54.00	-63.00	-12.20	-35.60	-4.50
Nikkei 225	-40.90	-36.00	-71.60	-11.10	-62.70	7.70	-114.00	-45.40
10-Year U.S. Treasury Note	-25.90	-20.70	-17.50	-23.60	-13.70	-29.70	-9.90	-10.30
United States Oil Fund	36.20	-55.30	-124.10	-129.40	-99.70	-0.70	-24.90	-168.90
SPDR Gold Shares Fund	6.60	-44.20	-14.70	-34.40	39.30	-39.80	70.20	-55.30
Euro Spot	9.90	7.00	-3.80	-58.80	-40.00	-43.20	1.20	-33.80
Japanese Yen Spot	-26.70	-6.10	-22.00	-0.70	-12.20	9.00	-30.10	-15.00
British Pound Spot	-18.60	-5.40	-17.90	-36.50	-43.70	-82.10	-30.20	-38.20
Japanese 10-Year Bond Futures	-1.40	-4.30	-6.20	-5.90	-5.90	-6.50	4.30	-10.40
iShares iBoxx $ Investment Grade Corporate Bond ETF	-38.60	-19.50	-43.70	-35.70	-47.00	-9.90	-48.80	-10.30
iShares Core U.S. Aggregate Bond ETF	-8.30	-12.00	-18.20	-17.10	-11.90	-12.90	-17.90	-15.20
iShares iBoxx $ High Yield Corporate Bond ETF	-37.70	-13.60	-56.50	-50.40	-60.50	-24.80	-40.60	-41.60
iShares 7-10 Year Treasury Bond	4.60	-2.50	-10.80	-11.70	-5.80	8.90	-4.70	-2.80
JPMorgan Equity Income Fund	-3.00	-5.90	-5.60	-3.60	-6.10	-7.60	-6.60	-10.00

Source: Bloomberg. Data as of July 21, 2017. Past performance is no guarantee of future results. Table is provided for illustrative purposes.

Realized volatilities are associated with drawdowns across asset class boundaries; when crossed with sound economic rationale, this empirical fact may be used to consider strategies not only for drawdown avoidance but also for asset rotation.

Consistent with our hypothesis, 107 out of the 120 volatility-security combinations are negative. Of the 13 combinations that are positive, five are in gold and treasuries; this is consistent with the fact that those assets are traditionally considered to be flight-to-quality assets that perform well during market upheavals. Another notable observation is that realized volatilities are associated with drawdowns across asset class boundaries; when crossed with sound economic rationale, this empirical fact may be used to consider strategies not only for drawdown avoidance but also for asset rotation, as we will allude to in one of the applications that follow.

The next empirical building block we must generalize in our chain of reasoning is the lead-lag relationship between implied and realized volatility regimes. To this end, we started by analyzing the cross-correlation function (CCF) between realized and implied volatility regimes, and then conducted Granger causality tests to summarize the lead-lag effect.

To construct a CCF, we codified high and low regimes to 1s and 0s and took the first difference to obtain a sequence of -1s (high to low), 0s (no change), and 1s (low to high) for both implied and realized volatilities and calculate their cross correlation at various lags.

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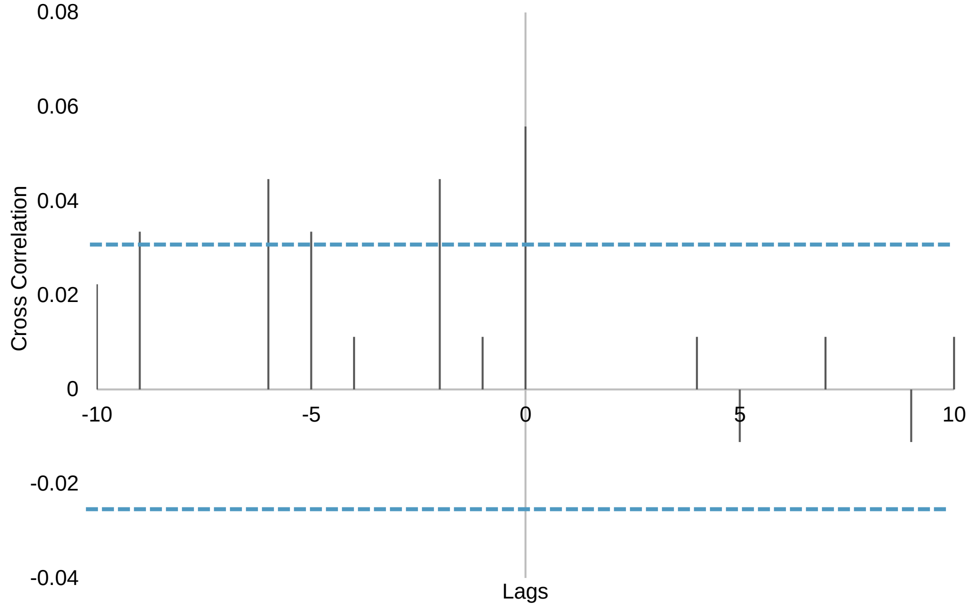
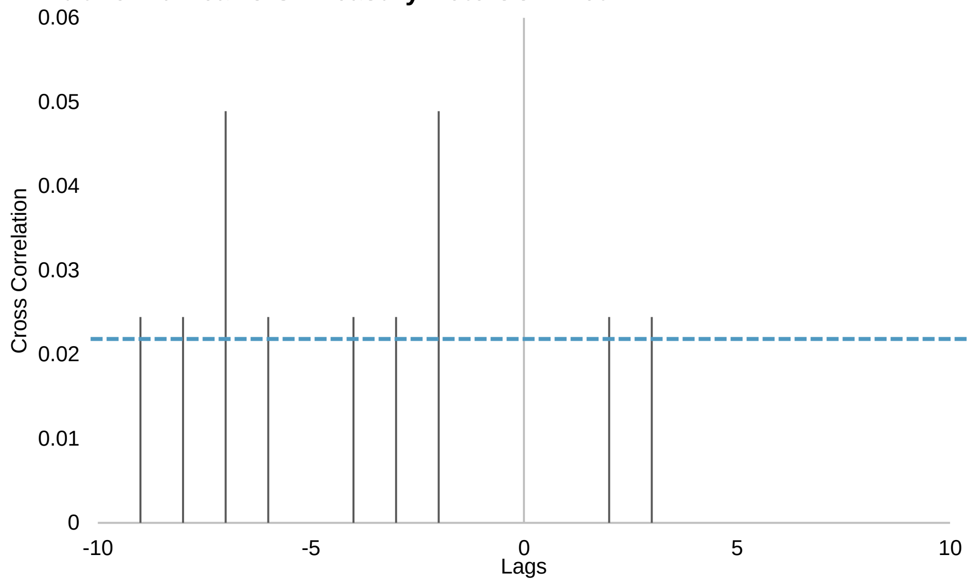
Exhibit 14: S&P 500 CCF Plot



Source: Bloomberg. Data as of July 21, 2017. Past performance is no guarantee of future results. Chart is provided for illustrative purposes.

Exhibit 15: 10-Year U.S. Treasury Note CCF Plot



Source: Bloomberg. Data as of July 21, 2017. Past performance is no guarantee of future results. Chart is provided for illustrative purposes.

The CCF plots show statistically significant lead-lag effects for both the S&P 500-VIX and 10-Year U.S. Treasury Note-TYVIX pairs, with implied leading realized volatility regimes. To summarize the predictive relationship, we ran Granger causality tests for the eight VIX indices and their respective realized volatilities. Exhibit 16 shows the p-value for the hypothesis that implied volatility regimes do not Granger-cause realized volatility regimes, and the test comfortably rejects this hypothesis in six out of the eight indices at the 5% significance level, with the BPVIX just being on the cusp of rejection. The test fails to reject for oil with a high p-value of 23%. These results provide strong evidence to corroborate our core hypothesis that implied volatility indices are good predictors of future realized volatility across various asset classes, at least when collapsed into binary regimes.

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Exhibit 16: P-Values of the Granger Causality Tests for 8 Implied Volatility Indices

IMPLIED VOLATILITY INDEX	P-VALUES
VIX	0.0000
TYVIX	0.0000
OVX	0.2331
GVZ	0.0001
EUVIX	0.0000
JYVIX	0.0032
BPVIX	0.0567
SPJGBVIX	0.0000

Source: Bloomberg. Data as of July 21, 2017. Past performance is no guarantee of future results. Table is provided for illustrative purposes.

Applications

With the empirical building blocks solidly in place to support our prediction framework, we turn to two illustrative examples of how they may be used in market timing strategies. An obvious application based on the results already shown is to use one of the VIX indices to time drawdowns of its underlying asset. However, to make things a bit more interesting, we explored applications that cross equity and fixed income VIX indices to create four regimes (high-high, high-low, low-high, and low-low) that profile the relative levels of anxiety in the two markets.

We began in Japan with the Nikkei 225 and the USDJPY carry trade as the investible quantities of interest. We used VIX and SPJGBVIX as broad-based gauges of anxiety in their respective countries to define four regimes.

- SPJGBVIX low/VIX low: Calm in the U.S. and Japan
- SPJGBVIX high/VIX low: Isolated anxiety in Japan
- SPJGBVIX low/VIX high: Isolated anxiety in the U.S.
- SPJGBVIX high/VIX high: Anxiety in the U.S. and Japan

Exhibit 17 shows the return decomposition of the Nikkei 225 and the USDJPY carry trade across the four regimes during 2008-2017 (SPJGBVIX data starts in 2008). Each color block represents the cumulative return of each security attributable to the corresponding regime. The Japanese yen rallied against the U.S. dollar in the SPJGBVIX low/VIX high regime, which was consistent with the economic intuition that capital tends to flow into the Japanese yen as a safe haven currency when general risk aversion is high, while Japanese yen rates remain stable. Given the widely acknowledged near impossibility of predicting FX spot returns and the parsimony of this approach, even a slight return separation is noteworthy here. As a side note, using VIX regimes alone significantly mutes the carry trade return separation. Moreover, the negative Nikkei 225 returns in this regime are consistent with the mainstream narrative that Japanese corporate equity valuations suffer when the Japanese yen rallies, given their heavy reliance on exports.

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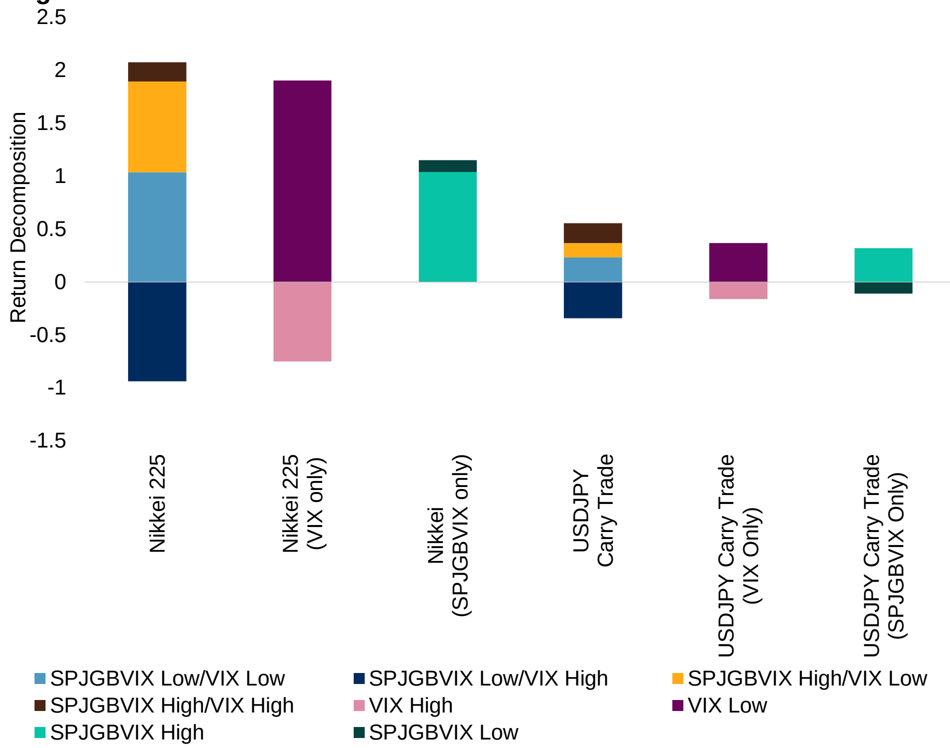
Exhibit 17: Return Decomposition for Japanese Assets Based on Combined SPJGBVIX and VIX Regimes, VIX Regimes, and SPJGBVIX Regimes



Source: Bloomberg. Data as of July 21, 2017. Past performance is no guarantee of future results. Chart is provided for illustrative purposes and reflects hypothetical historical performance. Please see the Performance Disclosure at the end of this document for more information regarding the inherent limitations associated with back-tested performance.

These return separation results may be turned into simple long-short strategies: (a) a carry trade investor could reverse, or gets out of, the trade in low/high regimes and (b) go short in the Nikkei 225 in low/high regimes and long otherwise. Exhibits 18-21 show cumulative returns for these long-short strategies along with their performance statistics compared with being long-only. The outperformance is evident.

Exhibit 18: Nikkei 225 Long-Short Strategy Based on SPJGBVIX and VIX Regimes

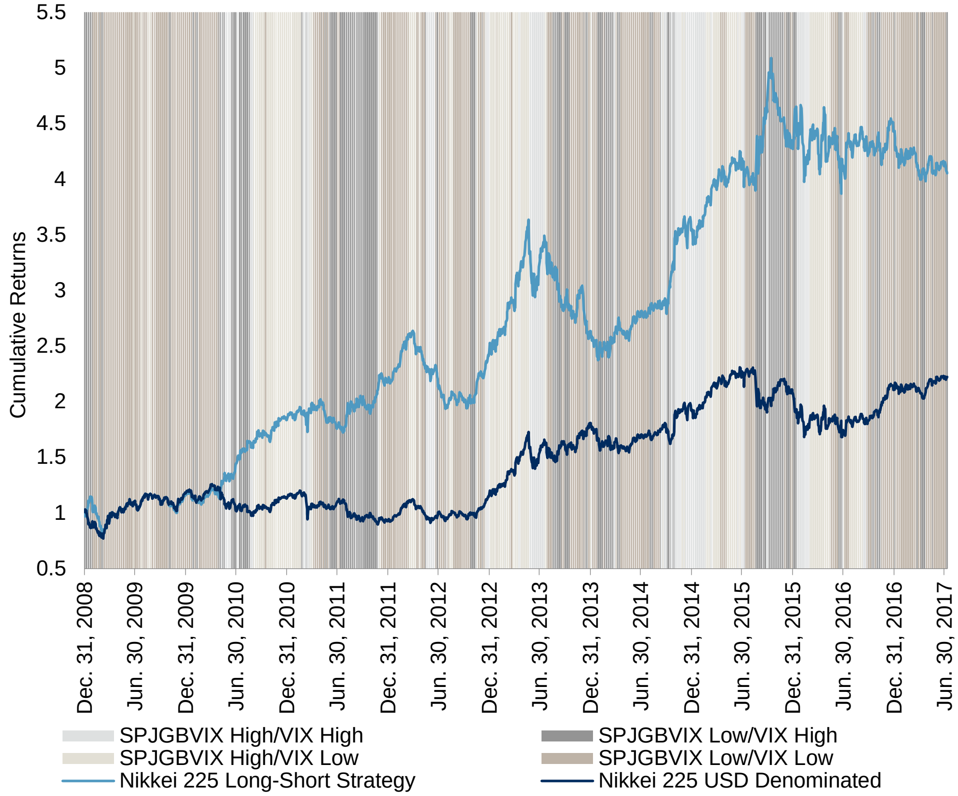


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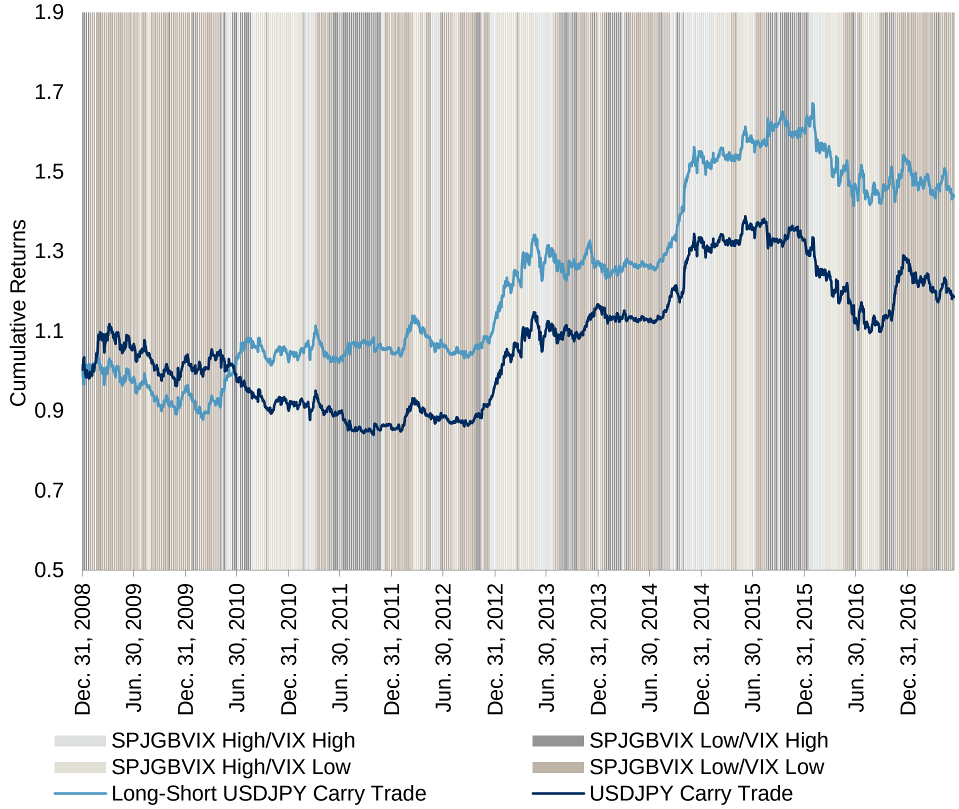
Exhibit 19: Performance Statistics for the Nikkei 225 Long-Short Strategy Based on SPJGBVIX and VIX Regimes

STATISTIC	LONG-SHORT STRATEGY	NIKKEI 225
Sharpe Ratio	0.77	0.41
Annualized Return (%)	17.42	9.34
Volatility (%)	22.55	22.39
Maximum Drawdown (%)	34.70	28.74
Maximum Recovery	221 Days	313 Days

Source: Bloomberg. Data as of July 21, 2017. Past performance is no guarantee of future results. Table is provided for illustrative purposes and reflects hypothetical historical performance. Please see the Performance Disclosure at the end of this document for more information regarding the inherent limitations associated with back-tested performance.

Exhibit 20: USDJPY Long-Short Strategy Based on SPJGBVIX and VIX Regimes



Source: Bloomberg. Data as of July 21, 2017. Past performance is no guarantee of future results. Chart is provided for illustrative purposes and reflects hypothetical historical performance. Please see the Performance Disclosure at the end of this document for more information regarding the inherent limitations associated with back-tested performance.

In the low/low regime, equities outperformed credit, which in turn outperformed U.S. Treasuries.

Exhibit 21: Performance Statistics for USDJPY Carry Trade Strategy Based on SPJGBVIX and VIX Regimes

STATISTIC	LONG-SHORT STRATEGY	USDJPY CARRY TRADE
Sharpe Ratio	0.42	0.17
Annualized Return (%)	4.30	1.78
Volatility (%)	10.16	10.11
Maximum Drawdown (%)	16.48	25.44
Maximum Recovery	94 Days	402 Days

Source: Bloomberg. Data as of July 21, 2017. Past performance is no guarantee of future results. Table is provided for illustrative purposes and reflects hypothetical historical performance. Please see the Performance Disclosure at the end of this document for more information regarding the inherent limitations associated with back-tested performance.

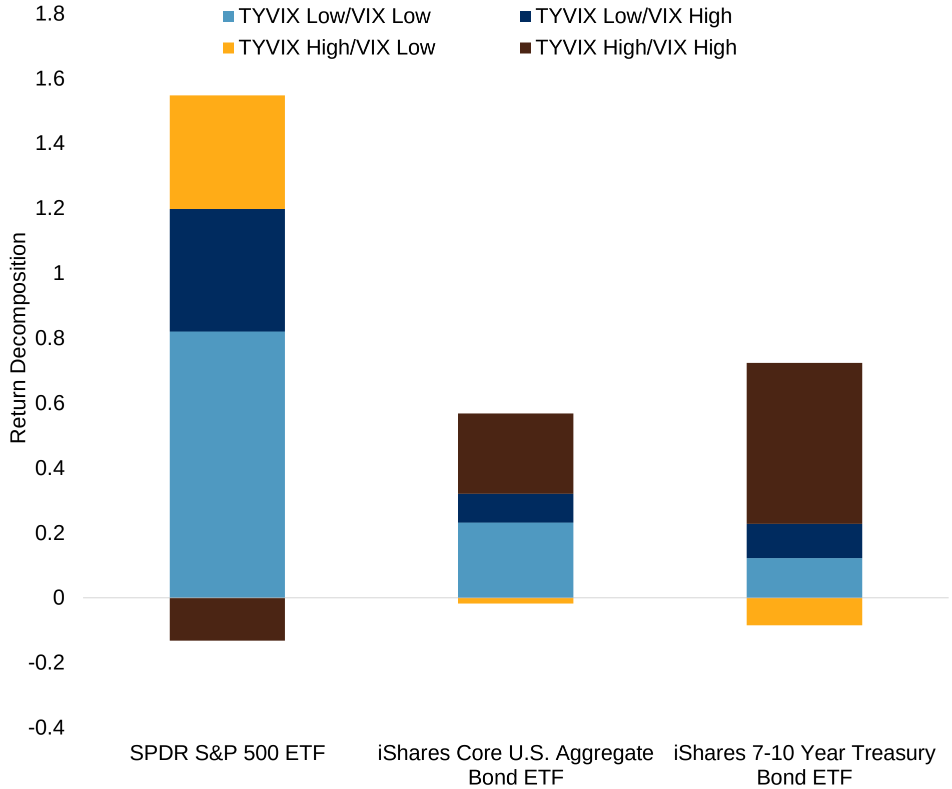
In the second example, we studied the relative performance across equities, corporate bonds, and U.S. Treasuries within four TYVIX/VIX-based regimes during 2003-2017.

- TYVIX low/VIX low: Calm in equity and bond markets
- TYVIX high/VIX low: Isolated anxiety in bond markets
- TYVIX low/VIX high: Isolated anxiety in equity markets
- TYVIX high/VIX high: Anxiety in equity and bond markets

One application of the relative return decomposition above is asset rotation based on the four TYVIX/VIX regimes, in which the strategy would overweight (underweight) assets that are likely to do well (poorly) in each regime.

Exhibit 22 shows return decompositions that are in line with economic intuition. In the low/low regime, equities outperformed credit, which in turn outperformed U.S. Treasuries. In the high/high regime, the order was reversed, with equities negative and a rally in U.S. Treasuries due to a flight to quality. In the high/low regime, equities performed best, while U.S. Treasuries declined and credit was flat, presumably as spreads tightened but yields increased. The low/high regime was the only one that did not align with this narrative, since equities still performed the best, while credit and U.S. Treasuries also gained, but this may be due to the protracted climb in asset values across the board during this time period, especially in equities.

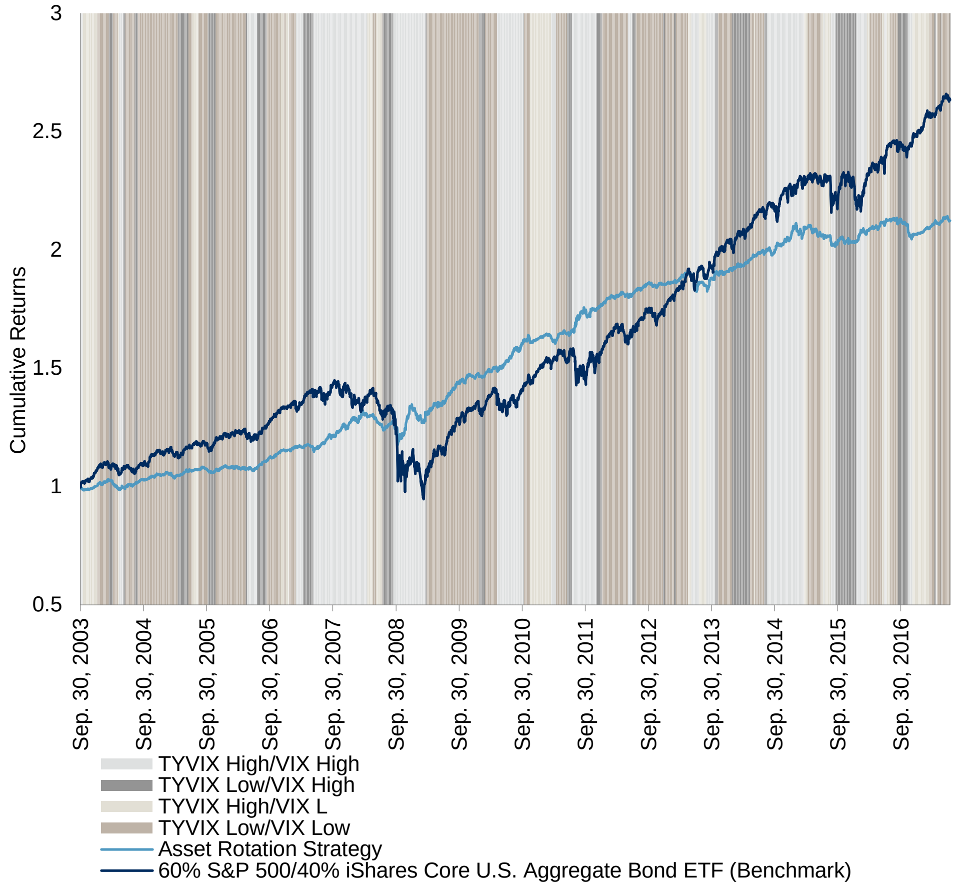
Exhibit 22: Return Decomposition of U.S. Assets Based on TYVIX and VIX Regimes



Source: Bloomberg. Data as of July 21, 2017. Past performance is no guarantee of future results. Chart is provided for illustrative purposes.

One application of the relative return decomposition above is asset rotation based on the four TYVIX/VIX regimes, in which the strategy would overweight (underweight) assets that are likely to do well (poorly) in each regime. Exhibit 23 shows cumulative returns and performance statistics for this strategy compared to a traditional 60/40 allocation. The regime-based strategy has double the Sharpe Ratio at 1.30, and an 11% drawdown compared to 35% for the traditional allocation; this is consistent with the two themes of drawdown avoidance and timing cross-asset performance.

Exhibit 23: U.S. Asset Rotation Strategy Based on TYVIX and VIX Regimes



Source: Bloomberg. Data as of July 21, 2017. Past performance is no guarantee of future results. Chart is provided for illustrative purposes.

As the two empirical building blocks and efficacy of even the simplest applications suggest, there are endless possibilities for incorporating VIX indices into market timing strategies across various asset classes.

Exhibit 24: Performance Statistics for U.S. Asset Rotation Strategy Based on TYVIX and VIX Regimes

STATISTIC	STRATEGY	60/40 BLEND
Sharpe Ratio	1.3	0.65
Annualized Return (%)	5.51	7.18
Volatility (%)	4.24	10.96
Max Drawdown (%)	11.20	34.70
Max Recovery	46 Days	418 Days

Source: Bloomberg. Data as of July 21, 2017. Past performance is no guarantee of future results. Table is provided for illustrative purposes.

CONCLUSION

As the two empirical building blocks and efficacy of even the simplest applications suggest, there are endless possibilities for incorporating VIX indices into market timing strategies across various asset classes. The key is to fight the temptation to abuse the empirical building blocks and regime framework, and only invoke this technique in applications based on firm economic rationale that justify its use.

REFERENCES

CBOE (2015). Introduction to the TYVIX Index.
http://www.cboe.com/micro/volatility/tyvix/pdf/tyvixguidepart1.pdf

CBOE (2015). Compendium of Empirical Findings.
http://www.cboe.com/micro/volatility/tyvix/pdf/tyvixguidepart3.pdf

S&P Dow Jones Indices and Japan Exchange Group (2015). S&P/JPX JGB VIX Methodology.
https://spindices.com/documents/methodologies/methodology-sp-jpx-jgb-vix.pdf
http://www.jpx.co.jp/markets/derivatives/sp-jpx-jgb-vix/nlsgeu0000017vg5-att/WhitePaper.pdf

S&P Dow Jones Indices and Japan Exchange Group (2015). S&P/JPX JGB VIX: Basic Empirical Properties. http://www.spindices.com/documents/research/research-jpx-jgb-vix-basic-empirical-properties.pdf

S&P Dow Jones Indices (2016). S&P/JPX JGB VIX and the Japanese Yen: Part 1.
http://spindices.com/documents/research/research-sp-jpx-jgb-vix-and-the-japanese-yen.pdf

TYVIX 101. Online primer on TYVIX. http://www.tyvix101.com

PERFORMANCE DISCLOSURE

The S&P/JPX JGB VIX was launched on October 2, 2015. All information presented prior to an index's Launch Date is hypothetical (back-tested), not actual performance. The back-test calculations are based on the same methodology that was in effect on the index Launch Date. Complete index methodology details are available at www.spdji.com.

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