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Todd Feldman, Alan Jung, and Shengle Lin

Todd Feldman
is an associate professor in the Finance Department at San Francisco State University in San Francisco, CA.
tfeldman@sfsu.edu

Alan Jung
is associate vice president of Academic Resources at San Francisco State University in San Francisco, CA.
alanjung@sfsu.edu

Shengle Lin
is an assistant professor in the Finance Department at San Francisco State University in San Francisco, CA.
sl@sfsu.edu

The purpose of this article is to determine whether new ways of exploiting the slope of the VIX futures curve can aid in detecting inflection points in the U.S. stock market. Many traders use the simple slope of the VIX futures curve to determine when to hedge, trade the VIX, or time market crashes. However, the simple slope signals many false positives. Our goal is to create a better indicator that limits the number of false positives for traders. We exploit the slope of the curve using an exponential moving average and polynomial fitting techniques. We test our new methods in two ways. First, we benchmark our market-timing VIX futures strategies against a buy-and-hold strategy consisting of holding the S&P 500. Second, we use a probit probabilistic model to determine whether our VIX future strategies can improve the ability to signal large U.S. stock market downturns.

To date, there is limited research on VIX futures, mainly because VIX futures contracts have only been around since 2004. Consequently, data are insufficient to demonstrate statistical significance. Nonetheless, as of 2017, the global markets have experienced the 2008 global financial crisis, 2010 flash crash, 2011 European debt crisis, and 2015–2016 oil crash.

The analysis of the VIX futures curve is compelling because the shape of the curve may provide market signaling information. The VIX futures curve links daily settlement prices of individual VIX futures contracts to maturities across time. Typically, the VIX futures curve is upward sloping or in contango because investors expect volatility to rise in the future. When the spot VIX is low and the market is stable, investors can hedge against future volatility by buying longer-dated VIX futures. This shifts the VIX futures curve upward. On the other hand, when investors anticipate near-term volatility, they can hedge against it by buying shorter-dated VIX futures. This buying pressure pushes the near-term curve up, generating a downward sloping curve, (i.e., backwardation). This typically occurs during market corrections, and the point at which the slope shifts from positive to negative may provide relevant market-timing information. However, this simple slope signal tends to be noisy, with many false positives. In addition, there are many instances in which one end of the curve has a positive slope and the other end has a negative slope. To minimize the noise, and to take into account the nonlinearity of the curve, we consider two new approaches. This may allow traders to minimize the number of trades they make when trading the VIX or market portfolio.

First, we develop two ways of utilizing an exponential moving average of the VIX futures slope. Second, we capture the curvature of the VIX futures curve by fitting a polynomial to it to estimate the second-order coefficient. In the following analysis, we explore three strategy types. The first strategy is the simple slope strategy used by many in the investments industry. The second and third strategy types are the exponential moving average and polynomial fitting. One of the motivations of this article is to test whether our new approaches are better predictors of financial market stress than the simple slope strategy.

LITERATURE REVIEW

To date, authors have mostly studied the relationship between the VIX term structure and future volatility, as opposed to the VIX futures term structure. The VIX term structure is based on the implied volatility from VIX options data. Luo and Zhang [2012] pointed out that the VIX term structure contains insight into the market's expectation of future realized volatilities across different maturities. They argued that both the level and slope of the term structure curve provide information in forecasting future volatility, but they also showed that the convexity effect is small.

Johnson [2017] used the VIX term structure to test the relationship between VIX term structure and future returns of variance assets, which are assets that are volatile. He used the VIX term structure to predict synthetic S&P variance swaps, VIX futures, and S&P 500 straddles for different maturities returns by applying principal component analysis to the term structure. He showed the first component accounts for 95% of the total movement in the curve, and its slope is positively correlated with future variance asset returns.

To date, no one has analyzed the relationship between the VIX futures curve and market crashes. Simon and Campasano [2014] tested trading strategies that buy and sell VIX futures contracts, based on the slope of the VIX futures curve. They found that selling (buying) VIX futures contracts when the curve is in contango (backwardation) and simultaneously hedging market exposure with a short (long) S&P futures positions is a profitable trade. We specifically look at not only the simple slope of the VIX futures curve but also new ways of exploiting the curve to signal future market crashes and corrections.

DATA

We use VIX futures data, from March 2004 to September 2016, obtained from the Chicago Board Options Exchange. Although the earliest data available for VIX futures start in 2004, data are relatively limited until 2006. To test for robustness, we use VIX term structure data calculated from index options prices, from January 4, 1996 to August 31, 2015. We use the one-month Treasury rate, three-month Treasury rate, and 10-year Treasury rate from the Federal Reserve Saint Louis website as control variables in our probit regression.

METHODOLOGY

We explore three market-timing approaches using the VIX futures term structure: (1) slope, (2) exponential moving average, and (3) curvature.

Slope

We calculate the monthly slope as

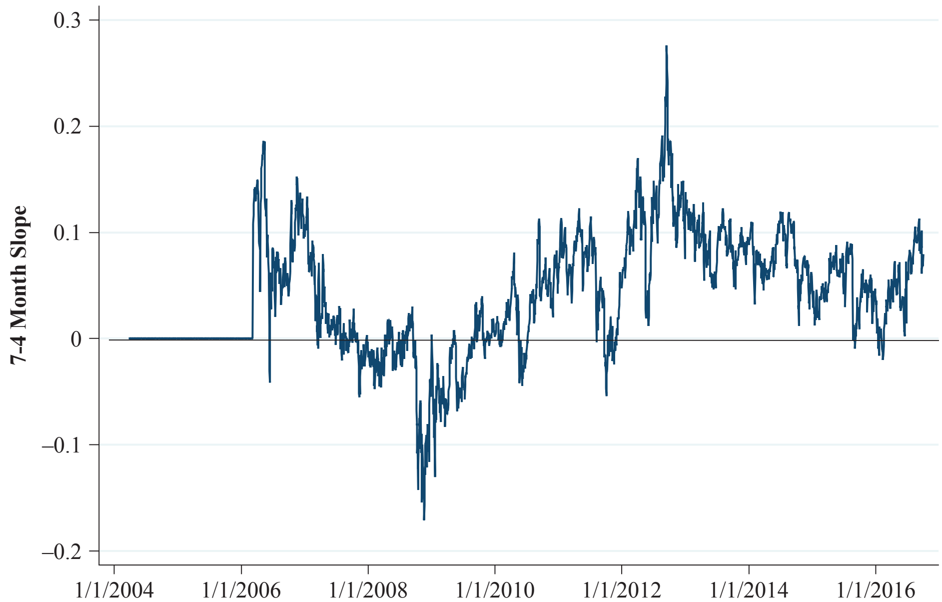
$$Slope_{n-i} = \frac{VF_n - VF_i}{VF_i} * \frac{1}{n-i} \tag{1}$$

where VF signifies VIX futures, n equals the number of months until maturity on the long end of the curve, and i equals the number of months until maturity on the short end of the curve. For example, the 7-to-4 month VIX futures slope is $\frac{VF_7 - VF_4}{VF_4} * \frac{1}{7\text{–}4}$. Exhibit 1 displays the 7-4 month slope, which shows several periods in which the slope becomes negative. The dates on which the slope switches from positive to negative are June 14, 2006; March 16, 2007; July 27, 2007; November 1, 2007; January 22, 2010; May 18, 2010; September 22, 2011; and January 15, 2016. November 1, 2007 and May 18, 2010 are the only dates on which the negative slope coincides with major financial stress.

Exponential Average and Backwardation Index

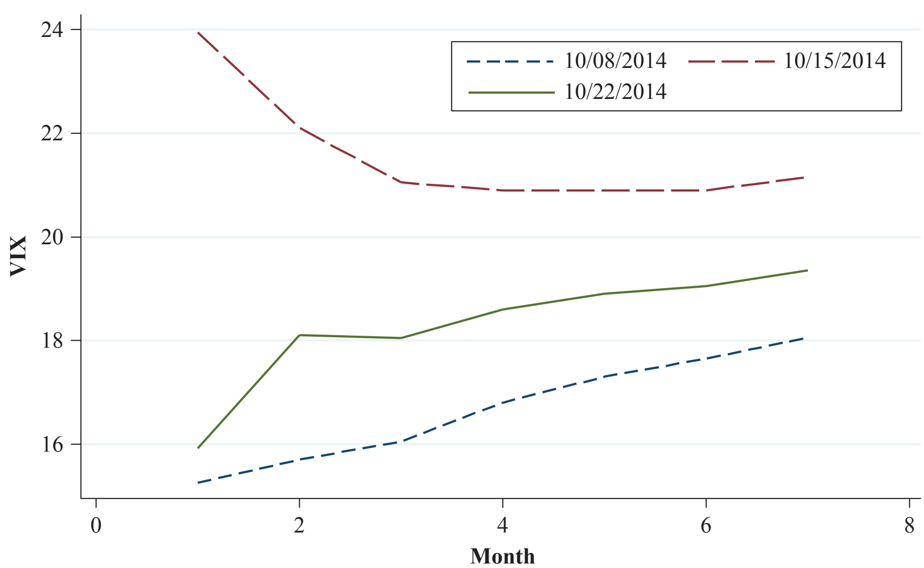
We use an exponential moving average to smooth and reduce the noise of the VIX futures curve as it moves in and out of backwardation. For example, Exhibit 2

Exhibit 1
7-4 Month Slope



Note: VIX futures contracts with four or seven months to expirations are rare prior to 2006.

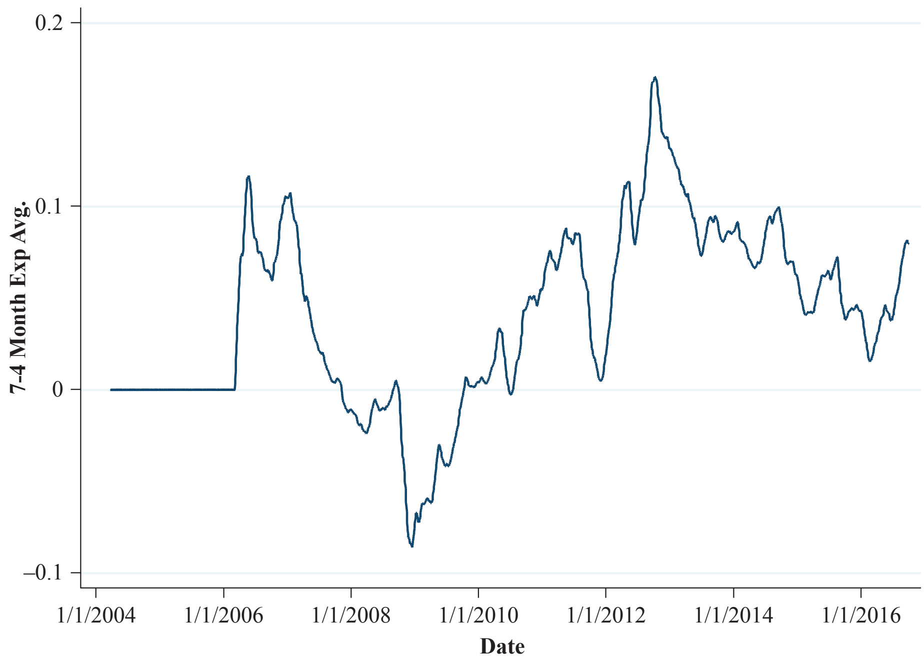
Exhibit 2
Moving in and out of Backwardation



displays the movement from contango to backwardation and back to contango during October 2014 that resulted in a false positive. In Exhibit 2, the curve was upward sloping on October 8, 2014. It then shifted to downward sloping on October 15, 2014 before returning to upward sloping on October 22, 2014. From October 8 to 22, 2014, the S&P 500 fell by only 2%.

Exhibit 3

VIX Futures Curve Slope Based on Seven- and Four-Month Contracts, $\widehat{slope}_{7-4}$



We chose an exponential moving average, rather than a simple moving average, because behavioral finance research has shown investors exhibit a behavioral bias, called *recency*, in which they put more weight on the most recent price movements, as opposed to past price movements. Also, today's prices contain the most up-to-date market information; consequently, it makes more sense to weight them more heavily. The calculation of the exponential average is

$$\widehat{slope}_{n-i}(t) = e^{-\delta}\,\widehat{slope}_{n-i}(t-1) + (1-e^{-\delta})slope_{n-i}(t) \qquad (2)$$

where δ is the memory rate. A larger δ results in a shorter memory; conversely, a smaller δ results in a longer memory. We chose a one-month half-life ($\delta = 8$) because the VIX contracts are one month in duration. Exhibit 3 displays the exponential average of $Slope_{7-4}$, which turns negative on November 9, 2007 prior to the 2008 global financial crisis. It also turned negative on June 17, 2010 during the flash crash.

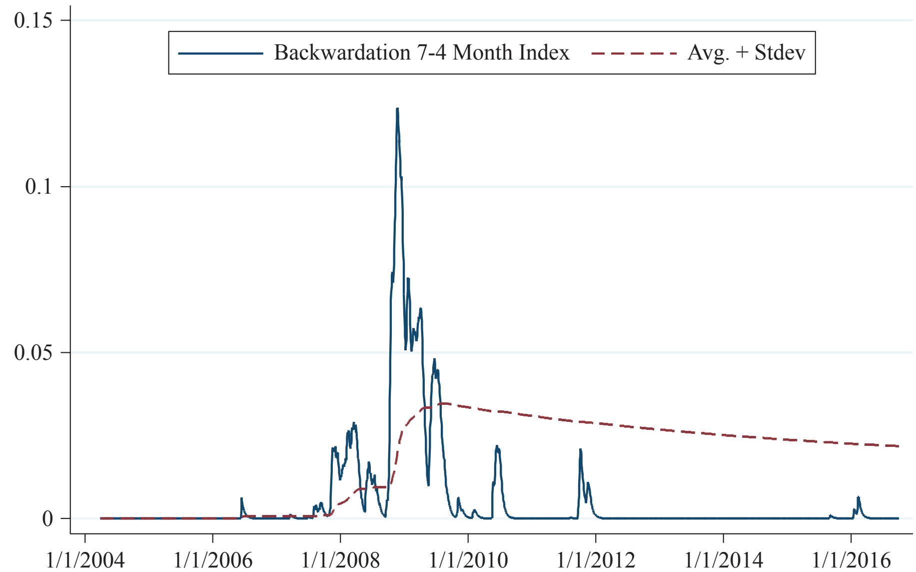
Next, we create a new indicator that tracks the periods of negative slopes or backwardation, weighting the most recent observations the heaviest. The reason behind the index is that the periods of backwardation are the points in time that may signal a future market crash or correction. Our idea is to catalog all the prior periods of backwardation, in which a large change in the index would signify a possible inflection point. We calculate the index in two steps. First, we set all positive slopes to zero and take the absolute value of all negative slopes, $B_{n-i,t} = \max[0, -slope_{n-i}(t)]$. Second, we calculate an exponential average of the backwardation periods:

$$\widehat{B_{n-i}}(t) = e^{-\delta}\,\widehat{B_{n-i}}(t-1) + (1-e^{-\delta})B_{n-i}(t) \qquad (3)$$

where δ is the memory rate. Exhibit 4 displays the time series of the 7-4 month slope backwardation index. The dashed line in the exhibit is the threshold, which we calculate as the running average plus one running standard deviation. Using a weighting scheme with a half-life of one month, we find the backwardation index does not change much because the VIX futures curve is typically in contango. Therefore, we use a shorter half-life of 10 trading days for the memory rate. An important question for both investors and policymakers is whether a 10% drop in the stock market signals a simple correction or something even more ominous, like

EXHIBIT 4

Backwardation Index on Seven- and Four-Month Contracts, $\widehat{B}_{7\text{-}4}$



Note: The dashed line delineates the backwardation 7-4 month index, plus one running standard deviation of past index values.

a crash. Examining the backwardation index by varying the memory rate may help to answer this question.

Curvature Indexes

There are many instances in which the VIX futures curve has positive carry in one part of the curve and negative carry in other parts of the curve. Curvature measures account for this nonlinearity. We use two different measures to measure the degree of curvature. First, we use the curvature measure as outlined by Liu [2015]. The curvature calculation takes the difference between the long end and short end of the curve:

$$Slope\_Curvature_{7-4,2-1} = \frac{VF_2 - VF_1}{VF_1} - \frac{VF_7 - VF_4}{VF_4} * \frac{1}{3} \quad (4)$$

This curvature measure nicely takes into account which end dominates the curve, contango or backwardation. Second, we fit a polynomial equation to the VIX futures curve, using all expiration months, from month 1 to month 7. Typically, the VIX futures curve slopes upward. However, when the curve moves in a nonlinear fashion, it could be signaling an inflection point in the market. To capture this, we use a second-degree polynomial. Exhibit 5 displays the shape of a first-, second-, and third-degree polynomial.

We estimate the second-order coefficient, a_2, from the following polynomial:

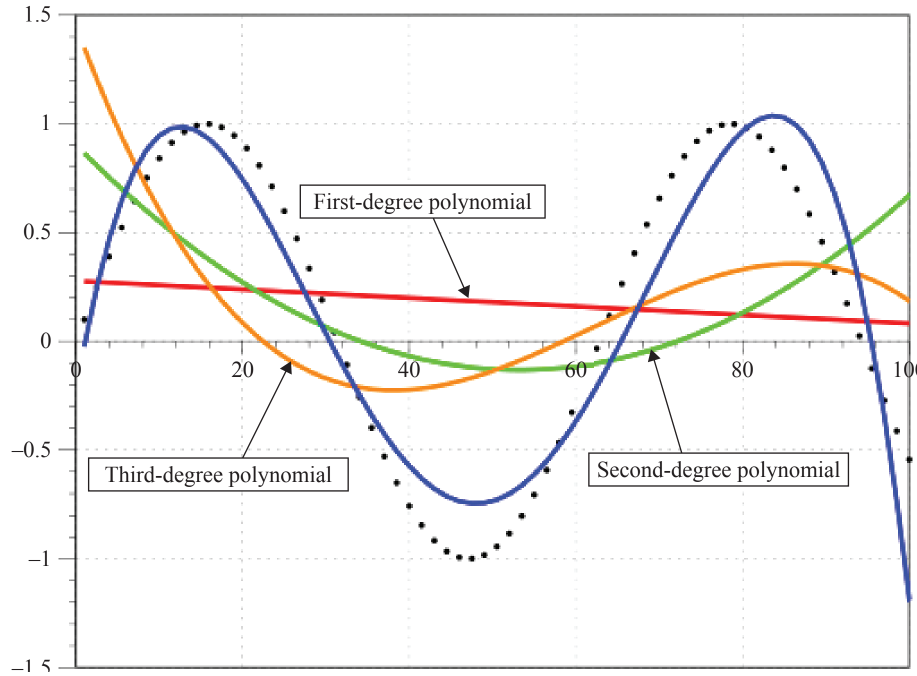
$$Polynomial_{Curvature} = a_2x^2 + a_1x + a_0. \quad (5)$$

Exhibit 6 displays the estimated second-order coefficient. The dashed line in the exhibit is the threshold, which we set as the running average plus two times the running standard deviation. We also multiply the running standard deviation by two because we are estimating a second-order polynomial. The time series is also consistent with the results from our exponential average (Exhibit 3) and backwardation index (Exhibit 4) approaches.

STRATEGIES

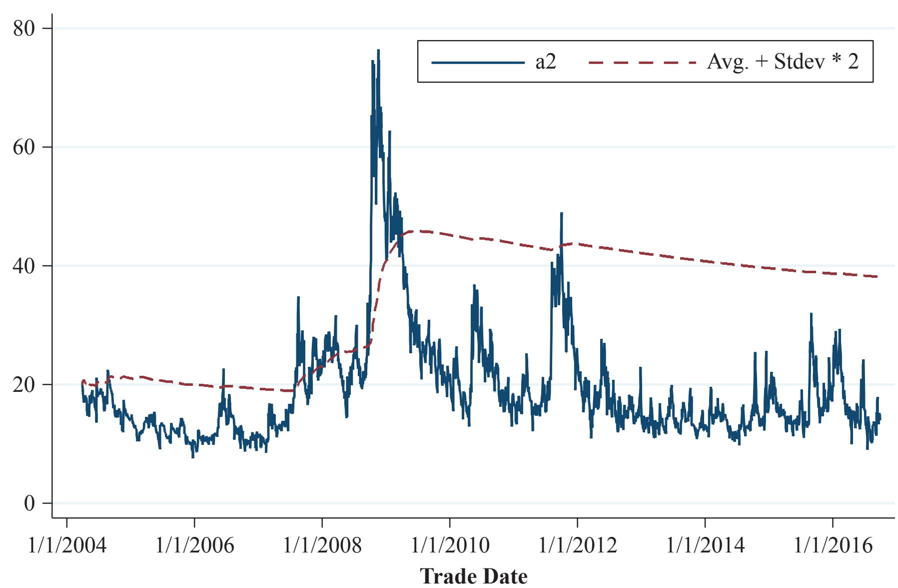
The main purpose of our strategies is not to test whether the VIX futures curve is a factor in explaining market returns, but rather to test whether it can capture pivotal moments in the U.S. stock market. If it does, then

Exhibit 5
Polynomial Fitting



Note: The dotted line represents the empirical data to be fitted into.

Exhibit 6
Coefficient Estimates from Second-Order Polynomial Fitting on VIX Future Curve



Note: The dashed line delineates the estimated second-order coefficient, plus two running standard deviations of past coefficient estimates.

EXHIBIT 7
Summary Statistics

Strategy: Slope Selection	Backwardation Count	Backwardation Return	Contango Return	Backwardation VIX	Contango VIX	Min Slope	Max Slope
2-1 Month	535	–43.11%	25.48%	30.81	16.16	–33.03%	37.32%
4-1 Month	529	–39.43%	23.73%	32.39	15.87	–45.66%	58.99%
7-1 Month	530	–34.16%	21.69%	33.21	15.70	–51.21%	80.55%
7-4 Month	547	–30.08%	20.65%	32.98	15.63	–17.11%	27.60%
Combo 2-1, 7-4	527	–39.65%	23.71%	32.01	15.96	–28.46%	29.85%
Entire Curve	599	–28.18%	21.23%	30.32	15.91	–5.57%	10.71%

Notes: VIX futures curve data, April 1, 2004 to September 30, 2016. Backwardation count equals the number of trading days in which the slope is negative. Return equals the S&P 500 total return index during the backwardation and contango periods. VIX equals the VIX during the backwardation and contango periods.

a switching strategy between 100% stocks or 100% U.S. Treasuries should outperform a buy-and-hold strategy.

Our first exercise is to test the performance of the slope indicators against a buy-and-hold strategy. We use the indicators as a signal to switch out of (into) the S&P 500 total return index and into (out of) long-term Treasuries. We perform back testing from April 1, 2004 through September 30, 2016 and assume trades occur at the end-of-the-day closing price. We switch from the S&P 500 to long-term Treasuries at the end of the day if the 7-4 month slope turns negative during the day. For example, Monday's return is calculated based on Monday's closing S&P price relative to the Friday's closing price. Tuesday's return is calculated based on Tuesday's Treasury closing price relative to Monday's closing price.

The simple slope, exponential average, and slope curvature strategies work in the following manner: If the slope is positive, we fully invest in the S&P 500; if the slope is negative, we fully invest in long-term Treasuries. For the backwardation index strategy, we follow a slightly different approach,[1] investing in the S&P 500 total return index when the backwardation index is below the threshold, which is its running average plus one standard deviation, and investing in long-term Treasuries when the index is equal to or above the threshold. We use the 7-4 month slope to calculate the exponential and backwardation index strategies because the 7-4 month slope results in the most successful strategy of the simple slope strategies (shown later). For the polynomial strategy, we fully invest in the S&P 500 total return index when the second-order coefficient is below the threshold, which is its running average plus two standard deviations, and fully invest in long-term Treasuries when it is above the threshold. We use two standard deviations in this case because we are analyzing the second-order coefficient in the polynomial.

[1] We add one standard deviation to the running average of the backwardation index and two standard deviations to the running average of the polynomial coefficient to increase the threshold and reduce the number of turnovers.

REGRESSION

Our main regression follows that of Estrella and Mishkin [1996]. In their model, the dependent variable equals one if the U.S. economy is in a recession and zero otherwise. Their recession indicator variable is a 12-month-ahead variable. The logic behind their regression is to test whether the Treasury yield curve can predict recessions 12 months ahead. We set the indicator variable to one if the S&P 500 falls by 20% or more over the preceding six months and zero otherwise because we are interested in predicting all large downward moves in the S&P 500, not just recessions. Specifically, we identify the highest value of the S&P 500 just prior to a 20% drop. We then set the indicator variable to one, corresponding to the period from the highest to the lowest value of the S&P 500. We repeat the process for the case in which the S&P 500 drops by only 10%. Lastly, we move this period ahead 12 months, as done by Estrella and Mishkin.

Our independent variables are those used by Estrella and Mishkin, including the spread between the 10-year Treasury note and the three-month Treasury

EXHIBIT 8

Strategy Return–Risk Statistics

Strategy	Annual Return	Annual Standard Deviation	Sharpe Ratio	Worst Drawdown	Total Turnover	Annual Turnover
Buy and Hold	7.74%	21.35%	0.30	–46.70%	0	0
2-1 Month Slope	6.18%	15.20%	0.33	–27.08%	181	14.48
4-1 Month Slope	4.40%	14.85%	0.21	–28.40%	134	10.72
7-1 Month Slope	4.40%	14.70%	0.21	–22.91%	115	9.20
7-4 Month Slope	5.33%	15.17%	0.27	–31.39%	110	8.80
Combo 2-1, 7-4 Month Slope	6.89%	15.14%	0.37	–29.33%	0	0.00
Entire Futures Curve Slope	5.44%	15.20%	0.28	–31.39%	165	13.20
Exponential Moving Average	10.27%	16.78%	0.54	–16.38%	6	0.48
Exponential Backwardation Index	10.72%	17.03%	0.56	–20.84%	4	0.32
Slope Curvature	8.04%	16.83%	0.40	–22.80%	279	22.32
Polynomial X^2	10.77%	17.02%	0.56	–21.09%	37	2.96

Notes: VIX futures curve data April 1, 2004 to September 30, 2016. Buy and Hold refers to holding the S&P 500 total return index. The average three-month Treasury bill rate is used to calculate Sharpe ratio. Daily standard deviation is annualized using method from Kaplan [2013]. Total turnover equals the total number of switches from stocks to Treasuries and Treasuries to stocks.

EXHIBIT 9

Estrella and Mishkin Regression Results without VIX Futures Variable

Indep. Variable	Coefficient	Std. Error	*t*-statistic	*p*-value
Panel A: When Dependent Variable is 10% Decline in Next 12 Months				
Constant	–1.046	0.13	–7.96	0.00
T_Yield_3 mth_1 mth	–96.38	37.23	–2.59	0.00
T_Yield_10 yr_3 mth	–16.62	4.37	–3.81	0.00
Panel B: When Dependent Variable is 20% Decline in Next 12 Months				
Constant	0.22	0.19	1.16	0.24
T_Yield_3 mth_1 mth	–276.14	45.59	–6.06	0.00
T_Yield_10 yr_3 mth	–158.10	7.43	–21.29	0.00

Notes: The exhibit displays the estimated coefficients of the base Estrella–Mishkin regression only: $R_{t+k} = \beta_0 + \beta_1 Spread_{3mth-1mth,t} + \beta_2 Spread_{10year-3mth,t}$. The dependent variable is a 12-month-ahead variable that equals one if the S&P declined 20% over a six-month period and zero otherwise. Sample data are from April 1, 2004 to September 30, 2016. The pseudo $R^2 = 0.348$.

bill. We also add the three-month to one-month Treasury spread and the VIX futures slope variable:

$$R_{t+k} = \beta_0 + \beta_1 Spread_{3mth-1mth,t} + \beta_2 Spread_{10year-3mth,t} + \beta_3 VIXf_t \quad (6)$$

where $R_{t+k} = 1$ if the S&P 500 has fallen by at least τ and $R_{t+k} = 0$ otherwise. τ is a threshold indicator that equals 10% or 20%.

RESULTS

Exhibit 7 provides summary slope statistics for the short, medium, long, a combination of the short and long, and the entire VIX futures curve. The statistics suggest there is little difference among the different slope measures.

Exhibit 8 displays the results from our back testing. The backwardation index, exponential moving average, and polynomial strategies all outperform the buy-and-hold and simple slope strategies. Their Sharpe ratios are 0.56, 0.54, and 0.56, respectively, which are almost twice that of the buy-and-hold and simple slope strategies. The backwardation index trades approximately only once every three years, the exponential moving average approximately once every two years, and the polynomial strategy once every eight months. None of the simple slope strategies performs better than the buy-and-hold strategy. Results suggest that using our strategies would aid a trader in reducing the number of trades per year and offset risk. A 7-4 month slope strategy incurs on average approximately nine trades per year. In comparison, the exponential strategies incur on average less than one trade per year.

Panels A and B of Exhibit 9 display the results from the baseline Estrella and Mishkin regression using the spread between Treasury yields. Panels A and B

Exhibit 10
Estrella and Mishkin Regression Results

Indep. Variable	Coefficient	Std. Error	*t*-Statistic	*p*-Value	Pseudo R^2
Panel A: When Dependent Variable is 10% Decline in Next 12 Months					
7-4 Slope	–7.57	1.09	–6.90	0.00	0.18
Exponential Avg.	–9.29	1.30	–7.16	0.00	0.20
Backwardation Index	19.02	6.02	3.16	0.00	0.16
Slope Curvature	0.02	0.91	0.02	0.98	0.16
Polynomial	0.06	0.01	6.82	0.00	0.18
Panel B: When Dependent Variable is 20% Decline in Next 12 Months					
7-4 Slope	–11.39	1.45	–7.87	0.00	0.38
Exponential Avg.	–14.78	1.76	–8.38	0.00	0.39
Backwardation Index	55.51	9.46	5.87	0.00	0.36
Slope Curvature	2.42	1.22	1.98	0.05	0.35
Polynomial	0.16	0.01	12.60	0.00	0.42

Notes: The exhibit displays the estimated coefficients of the $VIXf_t$ variable from the regression: $R_{t+k} = \beta_0 + \beta_1 Spread_{3mth-1mth,t} + \beta_2 Spread_{10year-3mth,t} + \beta_3 VIXf_t$. The dependent variable is a 12-month-ahead variable that equals one if the S&P declined 20% over a six-month period and zero otherwise. Sample data are from April 1, 2004 to September 30, 2016.

Exhibit 11
Probability of 20% Market Decline in Next 12 Months

VIX Futures Slope (*VIX_f*)	Probability Using Exponential Moving Average	Probability Using 7-4 Month Slope
0.00	88.33%	78.07%
–0.01	90.79%	78.18%
–0.05	96.94%	78.60%
–0.10	99.47%	79.11%
–0.50	100.00%	82.96%
–1.00	100.00%	87.09%
–2.00	100.00%	93.15%
–3.00	100.00%	96.73%

Notes: The exhibit displays the estimated probability of a 20% decline in the U.S. stock market over the next 12 months using Equation (7). We set the coefficients for the Treasury rate variables to zero and calculate the probit equation using the intercept and various values for the VIX futures variable, VIX_f. We determine the probability using the estimated value and normal distribution table.

of Exhibit 10 display the regression results from our modified version of Estrella and Mishkin's regression, which we use to test (1) whether the VIX futures slope adds to the predictive power of Estrella and Mishkin's original regression and (2) whether our new VIX futures indicators provide more information than the simple slope alone. We show only the coefficients pertaining to the VIX futures slope and not those for the interest rate spread variables because the coefficients only change slightly from the addition of any of the VIX futures variables. We expect the 7-4 slope, exponential average, and slope curvature coefficients to be negative because an increase in the slope reduces the probability of a stock market decline in the next 12 months. Conversely, the backwardation index and polynomial coefficients should be positive.

We first exclude the VIX futures variables to better understand how the addition of the VIX futures variables affects the regression. Exhibit 9 displays the coefficients from the Estrella and Mishkin regression. The pseudo R^2, without the VIX futures variable, is 0.16 (0.35) when the dependent variable uses the 10% (20%) decline definition. Results from Exhibit 10 indicate that the 7-4 simple slope, exponential average, and polynomial variables add to the predictive power of Estrella and Mishkin's original regression. The pseudo R^2 is 0.20 (0.39) when the dependent variable uses the 10% (20%) decline definition. In addition, we find that the exponential average of the 7-4 month slope has a larger economic magnitude and greater statistical significance than that of the 7-4 simple slope. The polynomial indicator also has greater statistical significance in predicting large downward stock movements 12 months ahead than the 7-4 month slope.

Exhibit 12

Strategy Return–Risk Statistics

Strategy	Annual Return	Annual Std. Dev.	Sharpe Ratio	Worst Drawdown	Total Turnover	Annual Turnover
Buy and Hold	8.08%	19.62%	0.29	–46.70%	0	0
2-1 Month Slope	5.47%	14.27%	0.22	–21.82%	533	27.10
4-1 Month Slope	7.22%	14.25%	0.51	–25.33%	413	21.00
7-1 Month Slope	8.80%	13.87%	0.46	–17.22%	349	17.74
7-4 Month Slope	9.42%	13.91%	0.51	–15.26%	380	19.32
Combo 2-1, 7-4 Month Slope	8.19%	14.14%	0.41	–15.26%	392	19.93
Entire Futures Curve Slope	6.19%	13.33%	0.29	–15.26%	278	14.13
Exponential Moving Average	12.43%	14.01%	0.72	–19.28%	32	1.63
Backwardation Index	8.62%	15.83%	0.39	–24.13%	48	2.44
Slope Curvature	3.05%	16.16%	0.04	–54.00%	764	38.84
Polynomial	12.66%	16.43%	0.63	–24.44%	134	6.81

Notes: VIX term structure data, April 1, 2004 to September 30, 2016. Buy and Hold refers to holding the S&P 500 total return index average three-month Treasury bill rate used to calculate the Sharpe ratio. Daily standard deviation is annualized using the method from Kaplan [2013]. Total turnover equals the total number of switches from stocks to Treasuries and Treasuries to stocks.

Exhibit 11 displays the probability of a 20% decline in the S&P 500 over the next 12 months, for different values for the VIX futures slope (VIX_f), and assuming the Treasury spread variables equal zero. The probit model indicates the probability of a 20% drop in the U.S. stock market in the next 12 months is 69%, assuming the two Treasury spread variables are equal to zero and excluding the VIX futures slope variables. The probability of a 20% decline in the next 12 months is 88.33% (78.07% when the 7-4 month slope is zero) when we include the exponential average VIX futures slope variable set at zero. The probability of a 20% decline increases when the VIX futures variables becomes negative. The results from Exhibit 11 indicate that the Treasury spread and VIX futures spread are more powerful when used together than when used separately.

Robustness Testing

For robustness testing, we run the same strategies but use the slope from the VIX term structure, as opposed to the VIX futures curve. We would prefer to use the latter because it is based on actual VIX futures prices in the open market, as opposed to the VIX term structure, which is the calculated expected volatility from index options. Unfortunately, VIX futures data only go back to 2004, whereas the VIX itself goes as far back as 1996. We use the term structure data obtained from Johnson [2017] to compare our results from the VIX futures data. Both time series are similar, exhibiting a 70% correlation between the slopes calculated using both data sets over the period from 2004 to 2015. Exhibit 12 displays the risk–return statistics using the Johnson term structure data.

Results from Exhibit 12 indicate that the exponential moving average and polynomial strategies are still the top performers. The backwardation index does not perform as well using the VIX term structure data.

CONCLUSION

We create new ways of exploiting the VIX futures curve and test whether these new ways can better signal inflection points in the U.S. stock market than the simple VIX futures slope. We find evidence to indicate that it does provide a benefit to traders in the reduction of trades per year and risk. The exponential average and polynomial fitting strategy outperform both the buy-and-hold and simple slope strategies, almost doubling the Sharpe ratio from 0.30 to 0.56. This result also holds using VIX term structure data.

Regression results indicate that adding a VIX futures curve variable to a probabilistic regression aids in improving the predictive accuracy of a market crash in the next 12 months. Although we do find some promise in using the VIX futures curve as a market crash indicator, the lack of data prevents us from performing out-of-sample experiments. As more data become available, we believe the VIX futures curve will become an active area of finance research.

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