Understanding the VIX

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Financial news services have begun reporting the VIX with increasing regularity. This "new" barometer of investor fear—the Chicago Board Options Exchange (CBOE) Market Volatility Index—is claimed to have reached unprecedented levels and is now, in fact, causing stock market volatility.[1] While such misconceptions will, undoubtedly, continue to flow, the purpose of this article is to help stem the tide of investor fear by explaining what VIX is and is not, why it was created, what causes it to move, and why it should be viewed as an important piece of market information for investors. Among the lessons to be learned are that the VIX is not new, is not at unprecedented levels, and does not cause market volatility.

THE VIX

The VIX is an index, like the Dow Jones Industrial Average (DJIA), that is computed on a real-time basis throughout each trading day. The only meaningful difference between the VIX and DJIA is that the VIX measures volatility and the DJIA measures price. The VIX was introduced in 1993 with two purposes in mind. First, it was intended to provide a benchmark of expected short-term market volatility. To facilitate comparisons of the then-current VIX level with historical levels, minute-by-minute values were computed using index option prices dating back to the beginning of January 1986. This was particularly important because documenting the level of market anxiety during the worst stock market crash since the Great Depression—the October 1987 Crash—would provide useful benchmark information in assessing the degree of market turbulence subsequently experienced. Second, VIX was intended to provide an index upon which futures and options contracts on volatility could be written. The social benefits of trading volatility have long been recognized. The Chicago Board Options Exchange launched trading of VIX futures contracts in May 2004 and VIX option contracts in February 2006.

It is important to emphasize that the VIX is forward looking; that is, it measures volatility that investors expect to see. It is not a backward-looking index to measure volatility that has been recently realized, as some commentators sometimes suggest. Conceptually, the VIX is like a bond's yield to maturity. Yield to maturity is the discount rate that equates a bond's price to the present value of its promised payments. As such, a bond's yield is *implied* by its current price and represents the expected *future* return of the bond over its remaining life. In the same manner, the level of the VIX is *implied* by the current prices of options on the S&P 500 Index and represents expected *future* stock market volatility over the next 30 calendar days.

VIX CALCULATION

The VIX was introduced by Whaley [1993]. The original index was based on the option prices of the S&P 100 Index (ticker symbol OEX), not the S&P 500 Index (ticker symbol SPX), for a very simple reason. At the time, OEX options were the most actively traded index options in the U.S., accounting for 75% of the total index option volume in 1992.[2] In contrast, the SPX option market was about one-fifth as active, accounting for only 16.1% of volume. Critical to the timeliness and usefulness of any implied volatility index, of which the VIX is only one, is that it must be based on prices from a deep and active index option market, such as the OEX. A second feature of the original VIX was that it was based on the prices of only eight at-the-money index calls and puts.[3] Again, this was reasonable because, of the option series available at the time, at-the-money options were by far the most actively traded. Options with exercise prices away from the current stock index level were less actively traded, frequently having stale price quotes and relatively wide bid–ask spreads. Including such quotes in the real-time computation of the VIX would have reduced its timeliness and accuracy.

Over the years since its inception, the structure of index option trading in the U.S. has changed in two fundamental ways. First, the SPX option market became the most active index option market in the U.S. SPX options currently trade about 12.7 times as frequently as OEX options.[4] Exactly why the trading volume shifted from one market to the other is unclear, but the fact that the S&P 500 Index is better known, futures contracts on the S&P 500 are actively traded, and S&P 500 option contracts are European-style (i.e., exercisable only at expiration) thus making them easier to value, are all contributing factors.[5] In contrast, by 2008, the average daily trading volume in OEX options was less than half its volume of 16 years earlier. Regardless of the reason(s) for the shift in market dominance, a timely and meaningful implied volatility index requires prices from an active underlying index option market. The OEX option market had been supplanted by the SPX option market and it was time for a change.

Second, trading motives of market participants in index option markets changed. In the early 1990s, both index calls and index puts had equally important roles in investor trading strategies. In 1992, trading volumes were balanced—OEX calls had an average daily trading volume of 120,475 and OEX puts had an average daily trading volume of 125,302. But over the ensuing years, the index option market has come to be dominated by portfolio insurers, who routinely buy out-of-the-money and at-the-money index puts for insurance purposes. The result was that during the first 10 months of 2008, the average daily volume of SPX puts was 909,748 contracts, over 72% more than the 525,460 average daily volume of SPX calls. Indeed, as Bollen and Whaley [2004] showed, the demand to buy out-of-the-money and at-the-money SPX puts is a key driver in the movement in SPX implied volatility measures, such as VIX.

On September 22, 2003, the CBOE changed the VIX calculation to account for both of these fundamental changes in index option market structure. First, they began to use SPX rather than OEX option prices. Second, they began to include out-of-the-money options in the index computation, because out-of-the-money put prices, in particular, contain important information regarding the demands for portfolio insurance and, hence, market volatility. Including additional option series also helps make the VIX less sensitive to any single option price, and hence less susceptible to manipulation.[6,7]

It is worth noting that the change from OEX option prices to SPX option prices had little to do with the return and risk properties of the indices themselves. For all intents and purposes, the S&P 100 and S&P 500 index portfolios are perfect substitutes.[8] Over the period January 1986 through October 2008, the mean daily returns of the S&P 100 and S&P 500 were nearly identical, 0.0263% and 0.0266%, respectively, and the standard deviations of S&P 100 daily returns was only slightly higher than the S&P 500 returns, 1.182% and 1.138%, respectively. The correlation between their daily returns was 0.9898. The near perfect correlation between the return series implies that, holding other factors constant, OEX and SPX options are equally effective from a risk management standpoint. Other factors are not constant, however. From the standpoint of maintaining the VIX as a timely and accurate reflection of expected stock market volatility, the critical consideration is the depth and liquidity of the index option market. The decision to turn to SPX option prices was warranted.

The VIX has been dubbed the "investor fear gauge." Although volatility technically means unexpected market moves either up or down, the S&P 500 index option market has become dominated by hedgers who buy index puts when they are concerned about a potential drop in the stock market. Buying insurance is nothing new. People routinely buy fire insurance as a means of insuring their home's value in the event of a fire. If the chance of a fire in your neighborhood rises, chances are that your insurance agent will charge more for coverage. The same is true for portfolio insurance. The more investors demand, the higher the price. VIX is an indicator that reflects the price of portfolio insurance.

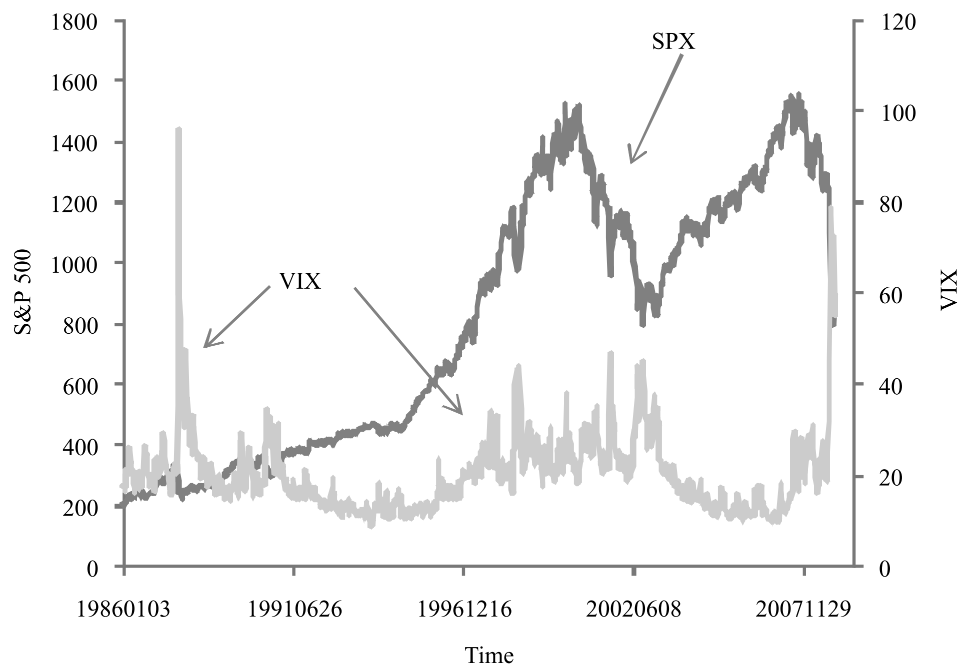
VIX HISTORY

Oftentimes individuals seek a precise meaning to an index level. The real benefit from an index, however, comes from comparing its current level to some historical benchmark(s). Consider, for example, the fact that, on October 24, 2008, the DJIA closed at 8,378.95. Which matters more—the fact that the level equals the sum of the prices of DJIA 30 stocks (1,052.00) divided by the index's current divisor (0.1255527090), or the fact that the DJIA exceeded 11,000 only a month earlier? Most people hone in on the latter and think about its relevance to their portfolio holdings.

Thus, to gauge the normal behavior of the VIX, we should look to its history.[9] Exhibit 1 shows week-ending levels of the S&P 500 Index and the VIX from the beginning of January 1986 through October 31, 2008. Several observations are noteworthy. Although not obvious from the weekly figure, the VIX reached its record-high level during the October 19, 1987, market crash. This was the only time the VIX ever exceeded a level of 100. By the week's end, the VIX had fallen to a level slightly below 90, but it continued to persist at abnormally high levels in the following weeks.

Another interesting phenomenon shown in Exhibit 1 is that the VIX frequently spikes upward in response to unexpected market and world events. The market crash in October 1987 is an example of such a spike, with other spikes of note occurring in October 1989, which was the "mini-crash" resulting from the UAL restructuring failure; in mid-1990 to mark when Iraq invaded Kuwait; and in early 1991 when United Nations forces attacked Iraq. And two sharp spikes occurred in October 1997 and in October 1998. The October 1997 spike followed a stock market sell-off in which the DJIA fell 555 points, and the October 1998 spike occurred during a period of general nervousness in the stock market. In the aftermath of each

EXHIBIT 1
S&P 500 and VIX Friday Closing Levels, January 3, 1986–October 31, 2008



spike, the VIX returned to more normal levels. The October 2008 spike will hopefully not be an exception.

Finally, although the weekly closing levels of the VIX and the S&P 500 Index, as illustrated in Exhibit 1, appear to spike in opposite directions, there are also times when a run-up in stock prices is accompanied by a run-up in volatility. In January 1999, for example, the VIX was rising (i.e., investors were becoming more nervous) while the level of the S&P 500 Index was rising. The same pattern appeared in the first two months of 1995, June and July 1997, and December 1999. Clearly, investors can become nervous even during market advances.

VIX IN RELATION TO THE STOCK MARKET

It is precisely because the VIX spikes during periods of market turmoil that it has come to be known as the "investor fear gauge." Two forces are at play. If expected market volatility increases (decreases), investors demand higher (lower) rates of return on stocks, so stock prices fall (rise). This suggests that the relation between the rate of change in the VIX should be proportional to the rate of return on the S&P 500 Index. But, the relation is more complicated. Earlier we argued and documented that increased demand to buy index puts affects the level of the VIX. Therefore, we should expect to find that the change in VIX rises at a higher absolute rate when the stock market falls, than when the market rises.

To test this proposition, we regressed the daily rate of change of the VIX, $RVIX_t$, the rate of change of the S&P 500 portfolio, $RSPX_t$, and the rate of change of the S&P 500 portfolio conditional on the market going down, and zero otherwise, $RSPX_t^-$; that is,

$$RVIX_t = \beta_0 + \beta_1 RSPX_t + \beta_2 RSPX_t^- + \varepsilon_t$$

If our proposition is true, the intercept term should not be significantly different from zero, and the slope coefficients should be significantly less than zero. As it turns out, our predictions are true. The estimated relation between the rate of change of VIX and the rate of change in SPX is

$$RVIX_t = -0.004 - 2.990 RSPX_t - 1.503 RSPX_t^-$$

where the number of observations used in the estimation is 5,753 and the regression R-squared is 55.7%. Except for the intercept, all regression coefficients are significantly different from zero at the 1% level.

The estimated intercept in the regression is –0.004, and the intercept is not significantly different from zero. This means that if the SPX does not change over the day, the rate of change in the VIX should be negligible. This outcome is not surprising. Although the value of stocks is expected to grow over time in order to compensate investors for putting their capital at risk, volatility is not expected to increase over time. Volatility tends to follow a mean-reverting process; in other words, when the VIX is high it tends to be pulled back down to its long-run mean, and when the VIX is too low it tends to be pulled back up. The estimated intercept reflects the absence of deterministic growth.

The estimated slope coefficients are both negative and significant, and clearly reflect not only the inverse relation between movements in the VIX and movements in the S&P 500, but also reflect the asymmetry of the movements brought about by portfolio insurance. The coefficients should be interpreted as follows. If the SPX rises by 100 basis points (bps), the VIX will fall by

$$RVIX_t = -2.990(0.01) = -2.99\%$$

and if the S&P 500 Index falls by 100 bps, the VIX will rise by

$$RVIX_t = -2.990(-0.01) - 1.503(-0.01) = 4.493\%$$

Because of the demand for portfolio insurance, the relation between the rates of change in the VIX and the SPX is asymmetric. The VIX is more a barometer of investors' fear of the downside than it is a barometer of investors' excitement (or greed) in a market rally. It is important to note, however, that this evidence merely documents correlation and is not intended to express causality.

NORMAL RANGE OF THE VIX

In addition to analyzing VIX levels, we can attempt to characterize what is normal and abnormal behavior for the index. Exhibit 2 does so in a probabilistic sense. Over the entire history of the VIX, its median daily closing level is 18.88. The VIX closed between 14.60 and 23.66 (a range of 9.06 index points) 50% of the time, between 12.04 and 29.14 (a range of 17.10 index points) 75% of the time, and between 11.30 and 37.22 (a range of 22.92 index points) 95% of the time. Exhibit 2 also shows a great deal of variation from year to year in what is considered normal behavior. In 1986, for example, the median daily closing level of the VIX was about 19.25. For that same year, the VIX closing levels were between 18.06 and 21.07 about 50% the time and between 16.92 and 24.24 about 90% of the time. The widest range experienced occurred in the first 10 months of 2008, with the VIX closing between 18.16 and 63.31 (a range of 45.15 index points) about 90% of the time. The second-widest range was in 1987, also a year encompassing a stock market crash; the 5% and 95% percentiles indicate that the range of daily VIX levels in 1987 was 16.64 to 54.11, or 3,474 bps.

An important way to judge market anxiety is to examine the persistence with which the VIX remains above certain extraordinary levels. Based on the data reported in Exhibit 2, we know that the chance of observing a VIX level above 34.22 is 5%. Suppose we re-examine the VIX history to count the number of consecutive days that the VIX has remained above a level of 34.22. Four periods of more than 20 days can be identified: October 16–December 22, 1987 (47 days); August 28–October 31, 2002 (46 days);

EXHIBIT 2

Normal Ranges for VIX Daily Levels, January 1986–October 2008

Year	No. of obs.	5.0%	10.0%	25.0%	50.0%	75.0%	90.0%	95.0%
Jan 1986–Oct 2008	5,754	11.30	12.04	14.60	18.88	23.66	29.14	34.22
1986	252	16.92	17.34	18.06	19.25	21.07	23.64	24.24
1987	253	16.64	17.28	20.85	22.66	26.81	46.25	54.11
1988	253	17.44	18.11	20.35	24.06	27.21	34.20	36.16
1989	252	15.51	15.90	16.47	17.30	18.22	20.60	22.59
1990	253	16.55	17.32	18.31	21.16	26.11	28.96	30.49
1991	251	14.99	15.29	16.02	17.29	19.13	21.87	24.46
1992	254	12.18	12.73	13.36	14.76	15.98	17.33	17.96
1993	251	10.43	10.92	11.40	12.27	13.03	14.05	14.38
1994	252	10.26	10.49	11.29	12.80	14.47	15.63	16.07
1995	252	10.71	11.00	11.51	12.29	13.18	13.80	14.15
1996	254	13.43	14.70	15.72	16.78	18.16	19.39	20.45
1997	253	19.92	20.17	21.11	22.20	24.64	27.80	30.36
1998	252	18.06	18.82	20.43	22.61	27.67	36.37	41.49
1999	252	19.70	20.73	22.39	24.29	26.59	28.73	30.34
2000	252	19.67	20.76	22.45	24.89	27.61	30.19	31.50
2001	248	21.80	22.37	23.85	26.24	30.64	34.20	36.34
2002	250	19.79	20.84	22.44	29.19	35.31	41.25	43.89
2003	252	16.45	16.78	18.96	21.21	26.92	34.77	35.80
2004	252	12.63	13.05	14.28	15.32	16.55	18.13	18.91
2005	252	10.75	11.08	11.66	12.52	13.64	14.83	15.58
2006	251	10.52	10.78	11.35	12.00	13.60	16.18	17.73
2007	251	10.34	10.97	13.11	16.33	21.65	25.24	26.48
2008*	212	18.16	19.45	21.14	23.79	27.55	45.24	63.31

*Note: *Through October 31, 2008.*

September 26–October 31, 2008 (26 days); and January 8–February 8, 1988 (22 days).

VIX PREDICTION OF FUTURE VOLATILITY

Unlike the DJIA, which only has meaning relative to its history, the VIX has a simple, probabilistic interpretation regarding the *expected range* of the rates of return on the S&P 500 Index level over the next 30 days. Exhibit 3 provides a quick-and-ready method for interpreting the level of the VIX.[10] Exhibit 3 can be used as follows. Assume that the current level of the VIX is 60. Reading up from 60 on the horizontal axis to the line labeled "50%," and then across to the vertical axis, we see that the expected range of S&P 500 returns over the next 30 days is about 11.5%. This means that, if the VIX is at 60, the chance is 50–50 that the rate of return on the S&P 500 Index will rise or fall by less than or more than 11.5% over the next 30 days. The lines labeled 75% and 95% offer different levels of probability for a given VIX level. At a VIX level of 60, the 75% (95%) line indicates that the expected range of S&P 500 returns over the next 30 days is about 20% (34%). In other words, if the VIX is at 60, the chance that the S&P will rise or fall by less than 20% (34%) over the next 30 days is 75% (95%). Conversely, at a VIX of 60, the chance that the S&P will rise or fall by more than 20% (34%) over the next 30 days is 25% (5%). The exhibit is intended to be a quick reference guide for interpreting the VIX. For those who want to be more precise, the lines are generated using the following relations:[11]

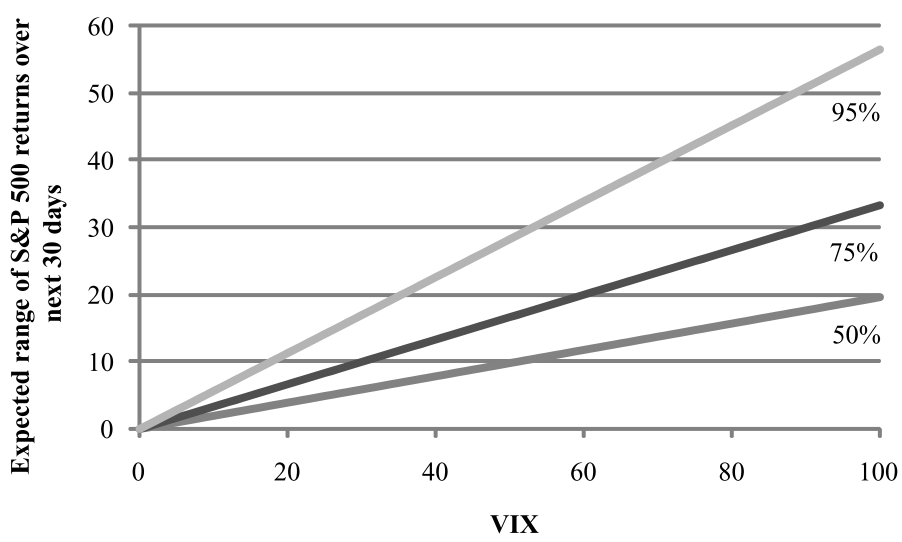
$$\text{Expected range at 50\%} = 0.1947 \times VIX$$
$$\text{Expected range at 75\%} = 0.3321 \times VIX$$
$$\text{Expected range at 50\%} = 0.5658 \times VIX$$

At a VIX level of 60, the exact values for the expected ranges are 11.68%, 19.92%, and 33.95%, respectively.

VIX PERFORMANCE AS A PREDICTOR

The obvious question about the prediction rule described in the previous section is "How well does it perform?" To answer this question, we performed a simple experiment. At the beginning of each of the 274 months in the sample period, the level of the VIX was recorded. Based on the level of the VIX at the beginning of each of these months, the 50%, 75%, and 95% expected ranges were computed using the formulas given in the previous section. The rate of return of the S&P 500 Index over each of the months was computed, and the number of times the return fell outside the range during the 274 months of the sample period was recorded. Of the 274 trials, 95, or 34.7% fell outside the 50% range; 20, or 7.3% fell outside the 75% range; and 3, or 1.1% fell outside the 95%

EXHIBIT 3
Expected Range of S&P 500 Returns for Next 30 Days Conditional on Current VIX Level



range. In other words, the VIX works reasonably well as a predictor of expected stock index movements.[12]

CREATION OF OTHER VOLATILITY INDICES

The VIX is not unique as a stock market volatility index, but is merely the first to have been introduced and therefore has a first-mover advantage. The methodology for computing the index is not unique to the prices of S&P 500 index options. It can be applied to any index option market. Indeed, the CBOE has already applied the methodology to create a volatility index for the NASDAQ 100 (VXN) and for the DJIA (VXD). The only important requisite is that the underlying index option market has deep and active trading across a broad range of exercise prices. Not surprisingly, the VIX has also attracted international imitators. The NYSE Euronext has applied the same methodology to index options listed on the AEX (an index of 25 stocks traded in Amsterdam), the BEL20 (an index of 20 Belgium stocks), the CAC40 (an index of 40 French stocks), and the FTSE 100 (an index of 100 stocks traded in the U.K.). Examining the co-movements of the volatility indices in different countries will undoubtedly be a subject of future research and discussion.

CONCLUSION

The VIX is a forward-looking index of the expected return volatility of the S&P 500 Index over the next 30 days and is implied from the prices of S&P 500 index options, which are predominantly used by the market as a means of insuring the value of stock portfolios. High levels of the VIX reflect investor anxiety regarding a potential drop in the stock market, just as high flood insurance premiums reflect homeowner anxiety about possible inclement weather. From the standpoint of an individual, both barometers can provide important pieces of information.

ENDNOTES

[1]A couple of recent quotes include "Now we're in uncharted territory…" in "Volatility: Measure Could Signal a Bottom" (*Philadelphia Inquirer*, November 1, 2008) and "The VIX is a self-fulfilling prophecy…" in "On Wall Street, Eyes Turn to the Fear Index" (*New York Times*, October 20, 2008).

[2]See Whaley [1993, p. 72].

[3]The details of the original index computation are provided in Whaley [1993, pp. 80–82].

[4]This exhibit is based on the first 10 months of trading in 2008.

[5]OEX options, however, are American-style and can be exercised at any time during the option's life.

[6]From the perspective of trading derivatives contracts on the VIX, the change in methodology also provided a means of passively replicating VIX futures contracts using SPX option contracts (see Carr and Madan [1998] and Demeterfi et al. [1999]), and provided market makers in VIX futures and options with a less expensive means of hedging their inventory, promoting narrower bid–ask spreads in the VIX futures and options markets.

[7]The details of the revised VIX computation are provided in CBOE [2003]. An Excel-based spreadsheet for computing the VIX is provided in Whaley [2006, pp. 553–562].

[8]Both the S&P 100 and the S&P 500 are market capitalization-weighted stock indices. As of October 31, 2008, all S&P 100 stocks were contained within the S&P 500 index portfolio and accounted for 62.46% of the S&P 500's total market capitalization. The 34 highest market-cap stocks in the S&P 500 are also the 34 highest market-cap stocks in the S&P 100. Of the 100 highest market-cap stocks in the S&P 500, 70 are from the S&P 100.

[9]The CBOE changed the composition of the VIX on September 22, 2003. From January 2, 1986, through September 19, 2003, the VIX was based on S&P 100 index option prices. Since September 22, 2003, the VIX has been based on S&P 500 index option prices. Because the S&P 100 and S&P 500 index portfolios are virtually perfect substitutes for each other, using the VIX history based on S&P 100 prices until September 22, 2003 (i.e., the cleaner, more accurate historical series), and then the VIX history based on SPX option prices is a sensible way to develop a full VIX history. Another, perhaps more accurate, approach is to attempt to address the scale difference in the volatilities of the two volatility series. Earlier, we showed that the daily standard deviation of the S&P 500 index was 0.011378 and the daily standard deviation of the S&P 100 index was 0.011822. The fact that the S&P 500 volatility is only 96.24% of the S&P 100 volatility reflects the fact that the S&P 500 has marginally lower risk. Consequently, we adjusted the pre-September 22, 2003, levels of the OEX option–based VIX to reflect this scale difference. To estimate the adjustment, we regressed the daily VIX based on SPX options prices on the daily VIX based on OEX option prices during the period September 22, 2003, through October 31, 2008, suppressing the intercept term in the regression. The estimated slope coefficient is 0.9727. To create the SPX option–based VIX prior to September 22, 2003, we simply scaled the OEX option–based VIX by a factor of 0.9727. With or without the adjustment, the qualitative interpretations of the VIX history are unaffected.

[10]The exhibit makes two simplifying assumptions: 1) the rate of return on the S&P 500 over the next 30 days is normally

distributed, and 2) the expected rate of return on the S&P 500 over the next 30 days is zero. Neither assumption is unreasonable.

[11]These relations are derived from the cumulative standard normal density function. A random number drawn from a unit normal distribution has a 50% chance of being within 0.6745 standard deviations of zero, a 75% chance of being within 1.1504 standard deviations of zero, and a 95% chance of being within 1.9600 standard deviations from zero. Because VIX is an annualized standard deviation, we scaled each of the coefficients by the square root of 12 to convert them to monthly volatilities (e.g., $0.6745/\sqrt{12} = 0.1947$).

[12]In fact, the range appears to be wide, given the empirical results. One possible explanation for this result is that investors pay more than the actuarial value for their portfolio insurance.

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