ӘЛЕУМЕТТІК-ЭКОНОМИКАЛЫҚ ЖӘНЕ ҚҰҚЫҚ ҒЫЛЫМДАРЫ
СОЦИАЛЬНО-ЭКОНОМИЧЕСКИЕ И ЮРИДИЧЕСКИЕ НАУКИ
SOCIO-ECONOMIC AND LEGAL SCIENCES

CENTRAL ASIAN SCIENTIFIC JOURNAL
ISSN 3135-3061
2026. No. 4 (32), Vol. 2. pp. 72–81
DOI: https://doi.org/10.5281/zenodo.24071365
Journal website: https://cajournal.kz

UDC 336.76

HOW OFTEN DOES THE VIX EXCEED THE VOLATILITY THAT FOLLOWS, AND WHEN DOES IT NOT? THE S&P 500, 1990-2026

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Abstract: The VIX index is the volatility of the S&P 500 that option prices imply for the next 30 days. This paper compares the VIX on each trading day from 2 January 1990 to 8 October 2026 (9,257 days) with the volatility the index actually showed over the next 21 trading days. The VIX was higher on 85.9% of days (95% interval 82.9-88.8%), by 4.10 points on average (3.48-4.73), also in samples without overlapping windows. Part of this gap would exist even without a risk premium, because the VIX is the square root of an expected variance; in variance terms the gap is also positive (113.6 percent squared, 67.3-159.8). The gap turned negative on 1,307 days, in runs that cluster around sharp market falls, as in February 2020 (VIX 15.6 on 20 February, realized 87.5 over the next month). Most large runs began at ordinary VIX levels, but in October-November 2008 the VIX was too low even at 40-70. The VIX on day t gave almost no warning of a negative window. There is no evidence of a calendar-month effect, although the test could detect only large differences. The median gap grows with the level of the VIX; the share of days on which the VIX was higher hardly changes.

Keywords: VIX; implied volatility; realized volatility; variance risk premium; S&P 500; financial crises.

1. Introduction

Buying a put option on a stock index works like buying insurance: the buyer pays now and is paid if the market falls. The price of that insurance depends on how much the market is expected to move. The Chicago Board Options Exchange (Cboe) introduced the VIX index in 1993, and since 2003 it has been calculated from S&P 500 option prices; it is often called the "fear index" [1, p. 1]. The VIX turns those prices into one number: the volatility of the index that the options imply for the next 30 days [1, p. 4], quoted as an annual percentage [1, p. 3]. A VIX of 20 means that option prices are consistent with the index moving by about 20% a year, or roughly 5.8% over a month.

If option prices contained no premium for risk, the squared VIX would on average equal the variance that actually follows. Research on the S&P 500 has found that it does not: the options market pays more for future variance than it later turns out to be worth, and this difference, the variance risk premium, is large and negative for the buyer of variance [2]; measured against the variance of the past month, the squared VIX is also almost always higher [3, p. 4477]. When she chose this topic, the author restated its question in her own words: "it seems interesting to me to find out why investors are willing to overpay for protection against a market

fall, and why in some periods this pattern stops working…" (translated from Russian).

This paper does not try to prove why investors pay the premium; the data used here cannot separate the explanations offered in the literature. It measures, with public data up to November 2026, how often and by how much the VIX has been above the volatility that followed, and it describes the periods when it was not.

Research questions. (1) On what share of trading days since 1990 was the VIX above the realized volatility of the next 21 trading days, and by how much?

(2) In which periods, and in which calendar months, did the gap turn negative, and what did those periods have in common? (3) Is the gap related to the level of the VIX?

2. Literature review

The original VIX of 1993 was based on at-the-money S&P 100 options. In 2003 Cboe changed it to a calculation over a wide range of S&P 500 put and call prices [1, p. 1] and rebuilt a history of the new VIX back to 1990 [1, p. 2]. The calculation targets a fixed 30-day horizon [1, p. 4]. Its square is therefore the market's price for the variance of the next month, and Bollerslev, Tauchen and Zhou use the squared VIX as their measure of the risk-neutral expected variance [3, p. 4476].

Carr and Wu compare such option-implied variance, which they call the synthetic variance swap rate, with the variance realized over the next 30 days, using options on five stock indexes and 35 stocks from January 1996 to February 2003 [2, p. 25]. They find that "the average risk premia on return variances are strongly negative for the S&P 500 and 100 indexes" [2, p. 3]. In their reading, buyers of variance "are willing to suffer a negative average excess return to hedge away upward movements in the index return variance" [2, p. 3]. The market beta of variance, which comes from the negative link between returns and volatility, explains only a small part of the premium, and the Fama-French factors do not explain it either [2, p. 3]. For their overlapping daily series they use Newey-West standard errors with 30 lags [2, p. 29, 32].

Bollerslev, Tauchen and Zhou define the variance risk premium as the squared VIX minus the variance realized over the previous month, measured from five-minute returns [3, p. 4475, 4477]. For 1990-2007 they report that this spread, measured against the past month rather than the next one, "is almost always positive" [3, p. 4477], and that a high premium predicts high stock returns over the following months, most strongly at the quarterly horizon [3, p. 4463]. Their model links the premium to time-varying economic uncertainty [3, p. 4463]. Bekaert and Hoerova split the squared VIX into the expected variance of returns and the variance premium, using daily data to 1 October 2010 [4, p. 6], and find that the premium predicts stock returns, while the expected variance is more closely linked to economic activity and financial instability [4, p. 1].

These studies measure the premium in variance terms, on samples that end between 2003 and 2010, and focus on its size and on what it predicts. That the

premium is positive on average and reverses in crises is therefore known; the contribution here is descriptive. This paper takes the simpler view a reader of the VIX would take: the VIX on one day against the volatility of the following month, in the same units, on every trading day to 2026. It asks less about prediction and more about the days on which the insurance turned out to be too cheap.

3. Data and method

Data. Daily closing values of the VIX come from the FRED database of the Federal Reserve Bank of St. Louis, which republishes the Cboe series VIXCLS [5]. The file was downloaded on 7 November 2026; it starts on 2 January 1990 and its last value is for 5 November 2026. Cboe's own history file could not be downloaded at the time of the study, so the FRED copy was checked against a second copy of the same index from Yahoo Finance [6]: on 9,279 common days the two agree to the cent on all but 13 days (largest difference on 6 February 2026, 17.76 against 20.37), and the main results are identical to two decimals with either copy. As a further check, the mean of VIXZ/12 on month ends of 1990-2007 in these data is 33.24, against the 33.23 that Bollerslev, Tauchen and Zhou report for the same years [3, p. 4478]. Daily closes of the S&P 500 price index come from Yahoo Finance [6], 2 January 1990 to 6 November 2026 (9,281 days). For 7 November

2016 to 5 November 2026, the period FRED covers, they match the official S&P Dow Jones Indices series in FRED within one cent on 2,506 of 2,513 days [7]; the largest difference is on 11 August 2021 (4,442.41 against 4,447.70) and does not change the results. The study uses published market data only; no people were involved.

Realized volatility. With S_t the closing value of the S&P 500 on day t and r_t $= \ln(S_t / S_{t-1})$ its daily log return, the realized volatility over the next 21 trading days, about one calendar month, is

$$RV_t = 100 \times \sqrt{[\ (252/21) \times (r^2_{t+1} + r^2_{t+2} + ... + r^2_{t+21})\ ]}$$

It is annualized and in percent, the same units as the VIX. As in Carr and Wu, realized variance is measured from day t forward over the same horizon as the option price [2, p. 27]. Squared returns are not demeaned, as is usual for variance contracts; using instead the sample variance of each window (mean removed, divided by 20, scaled to 21 returns) changes the results only slightly (Table 1). The gap on day t is $VIX_t - RV_t$ in volatility points. In variance terms it is $VIX^2_t - RV^2_t$, in percent squared per year. A positive gap means the options priced more movement than followed. Only S&P 500 trading days are used: VIX values for 34 days when the US stock market was closed are dropped, and three trading days with no VIX value (1 March 1991, 31 January 1997, 26 November 1997) are not used as day t. The first day t is 2 January 1990 and the last is 8 October 2026, the last day with 21 later trading days in the data: 9,257 days in all.

What the gap measures. The VIX is the square root of a price for variance, and the square root of an average is larger than the average of square roots. So even if the squared VIX were exactly the expected variance, with no premium at all, the VIX would on average be above the realized volatility that followed, and if realized volatility is right-skewed given what is known on day t, it would also be

above it on more than half of days. The gap in points and the share of days therefore describe how often and by how much the insurance went unused; the evidence of a premium is the gap in variance terms.

Overlapping windows. Neighbouring days share up to 20 of their 21 returns, and the gaps stay autocorrelated beyond that, so ordinary standard errors would be too small. Means and shares are therefore reported with Newey-West standard errors [8] with 63 lags (20 lags as a check). In addition, the share and the mean gap are recomputed on samples without overlap: every 21st trading day, for each of the 21 possible starting days (440 or 441 windows each), and the last trading day of each month (440 windows). The month-end sample is only nearly free of overlap, because a month with 19 or 20 trading days shares one or two returns with the next window, and neighbouring months are themselves correlated; its intervals use Newey-West standard errors with 6 lags. A day's calendar month is the month of day t; its window runs into the following month, so a month-end window describes the next month. The question about calendar months is tested on the month-end sample with a regression of the gap on month dummies (F-test with heteroskedasticity-robust HC1 standard errors, and with Newey-West standard errors with 6 lags).

Negative episodes. A negative episode is a run of consecutive trading days with a negative gap. For each day the paper also records the S&P 500 log return over the same 21-day window, the worst single day in it (log return), and the realized volatility of the previous 21 days. All return thresholds below are log returns.

The calculations were done in Python; the data files, scripts and results are described in the data availability statement.

4. Results

4.1 How often and by how much the VIX was higher

Over the 9,257 days the VIX averaged 19.43 and the realized volatility that followed averaged 15.33 (medians 17.57 and 12.93). The VIX was higher on 85.9% of days, and the gap averaged 4.10 points (Table 1). The median gap, 4.72 points, is larger than the mean because a few negative gaps were very large. In the middle of the distribution the realized volatility was about three quarters of the VIX (median ratio 0.73).

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Table 1. The VIX against the realized volatility of the next 21 trading days, 2 January 1990 - 8 October 2026 (9,257 days).

Measure	Value	95% interval
Days with VIX above realized volatility	85.9%	82.9-88.8%
Mean gap, VIX minus realized, points	4.10	3.48-4.73
Median gap, points	4.72	
Mean gap in variance terms, % squared	113.6	67.3-159.8
Every 21st day, 21 samples: share of windows	84.1-87.5%	
Every 21st day, 21 samples: mean gap	3.98-4.26	
Month ends (440): share of windows	84.3%	80.5-88.2%
Month ends (440): mean gap	4.06	3.29-4.83
Month ends (440): mean gap in variance terms	103.5	45.6-161.4
Window variance with the mean removed: share; gap	85.3%; 4.06	
20, 22 or 23-day windows: share; gap	85.7-86.0%; 4.06-4.12	
Yahoo Finance VIX instead of FRED: share; gap	85.9%; 4.10	

Note: own calculations from [5, 6]. Daily intervals are Newey-West with 63 lags (with 20 lags: 83.5-88.3% and 3.59-4.62); month-end intervals are Newey-West with 6 lags.

The headline does not depend on the overlapping windows. On every one of the 21 non-overlapping samples the VIX was higher in 84.1% to 87.5% of windows and the gap averaged 3.98 to 4.26 points; neither the length of the window nor removing the mean changes the picture.

The gap in points cannot be read as the premium itself, for the reason given in Section 3. The size of that effect has a ceiling, however: if the squared VIX had been exactly the expected variance, the VIX could have averaged at most the root mean square of realized volatility, 17.99, which is 2.66 points above its mean of

15.33. The VIX averaged 19.43, more than that. This comparison has no interval of its own; its formal version is the variance gap: in variance terms the squared VIX exceeded the realized variance by 113.6 percent squared per year on average (95% interval 67.3-159.8; on month ends 103.5, 45.6-161.4). This variance gap is the clearest evidence in the data that the insurance was, on average, priced above its later cost; it is wide because a few crisis months dominate squared numbers.

The VIX was higher on most days in every decade: on 92.4% of days in 1990-1999 (mean gap 5.44 points), 81.5% in 2000-2009 (3.35), 84.3% in 2010-

2019 (3.68) and 85.0% in 2020-2026 (3.84).

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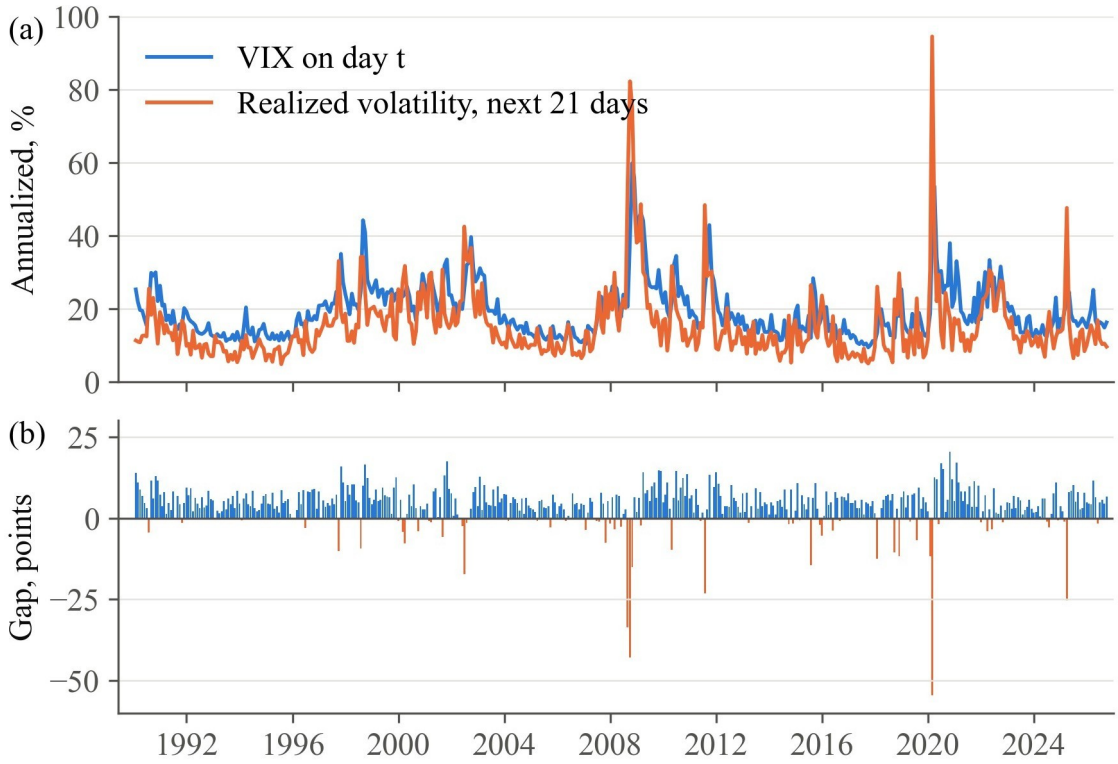


Figure 1. (a) The VIX on the last trading day of each month and the realized volatility of the S&P 500 over the next 21 trading days; (b) the gap between them, in points (orange: realized volatility was higher). Month ends only, so single days such as 20 February 2020 (Table 2) do not appear. Source: own calculations from [5, 6].

4.2 When the gap turned negative

The VIX was below the volatility that followed on 1,307 days (14.1%). These days form 181 runs; 58% of them last four days or less, and 17 last a month or more. On average the shortfall was larger than the excess (mean gap −6.46 points on negative days, +5.84 on positive ones), but the median shortfall was only

2.87 points against a median excess of 5.34: most misses were small and a few were very large. Added up over all days, the negative gaps take back 18% of the positive ones in volatility points and 36% in variance terms.

The largest negative gaps sit in a few short periods (Table 2, Figure 1), including the crises of 1997, 1998, 2008 and 2020 (the 1998 episode is the fourteenth largest and is not in the table). On 22 October 1997, during the Asian financial crisis, the VIX was 19.86 and the next 21 days realized 35.87. On 25 August 1998, during the Russian debt crisis, it was 30.33 against 43.26. In 2008 the run lasted 47 trading days, from 8 August, when the VIX was 20.66, to 14 October; on 16 September, the day after Lehman Brothers filed for bankruptcy, the VIX was 30.30 and the volatility that followed was 80.21. The largest gap of the whole sample came on 20 February 2020, at the start of the COVID-19 crash: the VIX was 15.56, and the next 21 days realized 87.52, a gap of almost 72 points.

Table 2. The twelve largest negative episodes: the day with the most negative gap in each.

Day t	VIX	Realized next 21 days	Gap	Window return, %	Worst day, %	VIX at run start
20.02.2020	15.56	87.52	−71.96	−38.1	−12.8	12.91
16.09.2008	30.30	80.21	−49.91	−29.0	−9.5	20.66
25.03.2025	17.15	48.25	−31.10	−5.2	−6.2	21.93

22.07.2011	17.52	45.85	−28.33	−18.0	−6.9	15.87
04.11.2008	47.73	74.80	−27.07	−17.4	−9.4	62.90
10.08.2015	12.23	30.81	−18.58	−8.0	−4.0	12.12
28.06.2002	25.40	42.56	−17.16	−9.2	−3.9	22.61
21.10.2008	53.11	69.68	−16.57	−16.9	−6.3	52.97
22.10.1997	19.86	35.87	−16.01	−1.0	−7.1	22.26
03.12.2018	16.44	31.80	−15.36	−9.7	−3.3	20.02
26.01.2018	11.08	25.74	−14.66	−4.6	−4.2	9.15
20.04.2022	20.32	34.90	−14.58	−13.4	−4.1	19.63

Note: one row per run of consecutive days with a negative gap; the twelve runs with the lowest minimum gap. Window return: log change of the S&P 500 from day t to 21 trading days later; worst day: the lowest daily log return in that window. Source: own calculations from [5, 6].

Ten of the twelve runs in Table 2 began with the VIX at or below 22.61, under its 75th percentile of 22.68. This is not a warning sign: 77% of all 181 runs began under that level, about as often as the VIX itself is there. The two exceptions are in October and November 2008, when the runs began at a VIX of 53-63; on the 27 negative days of those two months the VIX was between 39.8 and 70.0, and the market still moved more.

Most negative windows contain a sharp fall: 64% have either a fall of more than 5% over the window or a single day worse than −3%. On the median negative day, the S&P 500 lost 3.7% (log return) over the next 21 days, while on the median positive day it gained 1.7%. A fall of more than 5% happened in 39% of negative windows and in 3.8% of positive ones, and a single day worse than −3% happened in 55% and 6.8% of them. Seen from the other side, when the index fell by more than 10% (log) over the window (189 days), the gap was negative in 81% of cases. Even the 1997 window, whose total change was only −1.0%, contains a day of

−7.1%.

The VIX on day t gave almost no warning of these windows. The median VIX was 18.4 on negative days and 17.5 on positive days, and the VIX stood about 4 points above the volatility of the previous month in both groups (4.1 and 4.4). On the 9,233 days with a previous month available, the probability that a randomly chosen negative day had a higher VIX than a randomly chosen positive day is 0.52, where 0.5 means no signal; for the VIX minus the previous month's realized volatility it is 0.47, and for the five-day change in the VIX 0.53. The one weak signal is that when the VIX was below the previous month's realized volatility (1,036 days), 18.5% of windows were negative, against 13.6% otherwise. The difference came afterwards: during a negative window the VIX rose by a median

4.2 points, while during a positive window it fell by 0.6.

The same crises also produced some of the largest positive gaps. On 8 October 1998 the VIX was 45.74 and the next month realized 21.24. On 20 November 2008, when the VIX closed at 80.86, the month that followed realized 58.69, and on 16 March 2020, when it closed at its record of 82.69, the next month realized 63.59. On the day of each calendar year's highest VIX close, the VIX was above the volatility that followed in all 37 years (median gap 12.6 points; 2026 counts from January to 8 October). That day is known only afterwards, so this is not a test of buying protection at high VIX levels: among the 1% of days with the highest VIX (above 46.7; 70 of these 93 days fall between September 2008 and March 2009 and 20 in March-April 2020), the VIX was higher on only 67%. Relative to what followed, protection was therefore underpriced in the run-up to and the early part of most large falls, and in 2008 for weeks after the fall had begun; on the day of each year's highest VIX it was overpriced.

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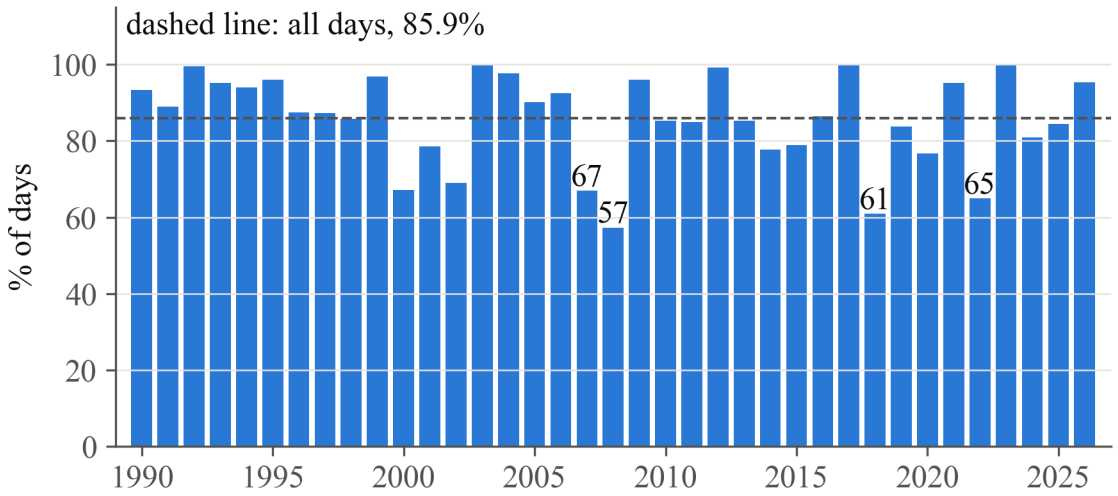


Figure 2. Share of trading days on which the VIX was above the realized volatility of the next 21 trading days, by year (2026: January to 8 October). The four lowest years are labelled. Source: own calculations from [5, 6].

By year (Figure 2), the gap was positive on every day in 2003, 2017 and 2023 and on fewer than 70% of days in 2000, 2002, 2007, 2008, 2018 and 2022. Only in 2008 was the average gap negative (−2.54 points, 57.3% of days positive).

Calendar months matter much less. The share of positive days ranges from 79.8% in February and 80.1% in July to 89.8% in June (89.4% in November), and the mean gap from 2.68 points in February to 5.41 in November. The low February mean comes from one year: in February 2020 (windows that run into the March crash) the gap averaged −51.9 points, and without that year February's mean gap is

4.18 points, close to the overall 4.10, although its share of positive days (82.0%) stays second lowest. In the month-end sample the month dummies are jointly not significant (HC1: $F = 0.75$, $p = 0.69$; Newey-West with 6 lags: $p = 0.49$; ordinary standard errors: $p = 0.66$). The test is weak, however: with about 37 years per month it could detect only differences of about 4 points, as large as the whole gap. So there is no evidence that the gap breaks in particular months of the year; in these data it breaks in particular episodes.

4.3 The gap and the level of the VIX

Table 3. The gap by the level of the VIX, 1990-2026.

VIX on day t	Days	VIX higher, %	Mean gap (95% interval)	Median gap	Median realized / VIX	Gap below −10, %
below 15	2,962	86.3	2.83 (2.29-3.36)	3.63	0.71	1.6
15-20	2,870	87.3	4.12 (3.53-4.72)	5.03	0.71	1.9
20-25	1,825	83.6	4.56 (3.55-5.56)	5.70	0.74	3.0
25-30	864	84.5	5.57 (4.36-6.77)	6.81	0.75	2.8
30-40	528	89.0	6.53 (3.93-9.13)	8.73	0.74	5.1
40 and above	208	78.4	5.78 (2.18-9.38)	8.44	0.82	12.0

Note: intervals are Newey-West with 63 lags on the days of each group taken in date order; days in a group are not always neighbours, so the intervals are approximate. Source: own calculations from [5, 6].

The median gap grows with the level of the VIX, from 3.63 points when the VIX was below 15 to 8.73 when it was between 30 and 40 (Table 3); a median regression on month ends gives a

slope of 0.19 points per VIX point (standard error 0.03). The mean gap rises from 2.83 to 6.53 and is 5.78 at 40 or more, but its straight-line slope is not robustly positive (see below). Measured in proportion, the picture hardly changes: the realized volatility was a median 71-82% of the VIX, and the VIX was higher on 83.6-89.0% of days in every group below 40. At a VIX of 40 or more the share is 78.4%, with a wide interval (65.7-91.0%) that includes the other groups. So a higher VIX meant a larger gap in points, but not a more reliable one. A gap below −10 points happened on 1.6% of days with a VIX below 15 and on 12.0% of days with a VIX of 40 or more (25 days: 19 in September-November 2008 and 6 in February-March 2020), but this mostly reflects the larger scale of everything at a high VIX: realized volatility above 1.5 times the VIX happened on 1.4-3.2% of days in the groups below 40 and on 5.3% at 40 or more.

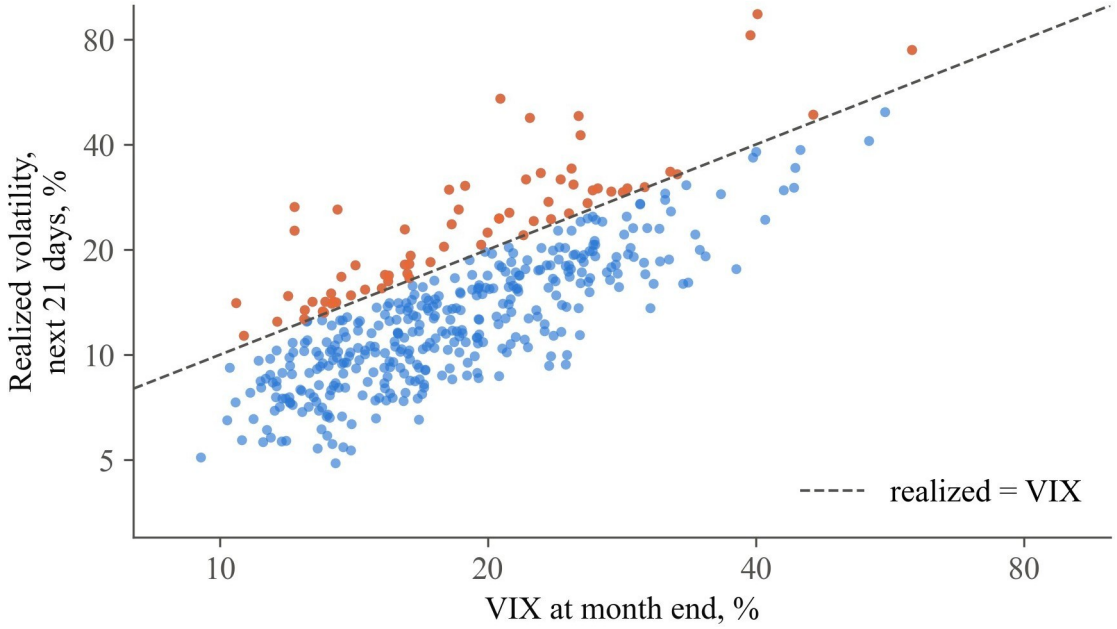


Figure 3. The VIX on the last trading day of each month and the realized volatility of the next 21 trading days, logarithmic scales. Blue points (371 of 440 months) lie below the dashed line, where the VIX was higher; orange points (69) lie above it. Source: own calculations from [5, 6].

A regression on all days gives RV = −1.72 + 0.877 × VIX (RZ = 0.52). A slope below one would mean that the mean gap grows with the VIX. The evidence for it is borderline: p = 0.025, 0.048 and 0.049 with 20, 42 and 63 lags and 0.055 with 126, and on the month-end sample the slope is 0.945 (heteroskedasticity-robust standard error 0.084, p = 0.51). The rank correlation between the VIX and the gap on month ends is 0.29 (p < 0.001), partly by construction, since the gap contains the VIX; it describes the median relation, in which realized volatility stays near three quarters of the VIX. Between the VIX and a negative month the rank correlation is 0.03 (p = 0.48). The VIX level therefore says something about the size of the gap and almost nothing about whether the next month will break it.

5. Discussion

The first part of the question, why investors overpay for protection, cannot be answered by these data, but they show what the payment buys. On average the VIX was about 4 points above the volatility that followed (median 4.7). On the minority of days when it was not, the window usually contained a sharp fall, and a few misses were very large: in variance terms they take back more than a third of all the excess. This is the pattern one would expect if option buyers pay a steady premium to be covered in exactly these episodes, the reading Carr and Wu give, although they also leave open that the market for variance risk is inefficient [2, p. 3]. It is also consistent with the model of Bollerslev, Tauchen and Zhou, in which the premium reflects time-varying economic uncertainty [3, p. 4463]. The data cannot choose between these readings, and a premium that buys insurance is not necessarily an overpayment.

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The second part, why the pattern sometimes stops working, can only be described. The gap turned negative mostly when a large fall arrived while the VIX

was at an ordinary level: in February 2020, from August 2008, in March-April 2025, in July-August 2011 and in August 2015. In each of these cases the VIX rose sharply during the window, but from a level that, on the day the window began, was below what followed. The exception is October-November 2008, when the VIX was already very high and realized volatility was higher still. On the day of each year's highest VIX close the VIX was above what followed. Thus the insurance looked too cheap mainly in the run-up to and the early part of the falls.

Several limitations apply. Realized volatility here is measured from daily closes rather than intraday data, so it misses moves within the day. The VIX covers 30 calendar days and the window 21 trading days, which is close but not identical; windows of 20 to 23 days give the same results. The gap in points and the share of days include the square-root effect described in Section 3, so only the variance gap measures the premium. Before 2003 the VIX values were recalculated by Cboe rather than published at the time [1, p. 2]. The Cboe file itself could not be downloaded; the FRED and Yahoo copies agree on all but 13 days, and one of these (6 February 2026) remains unresolved, without effect on the results. The month-end test has low power. Finally, the episodes are described, not explained: the labels used for them name the events of the time but do not prove what caused the moves.

6. Conclusion

From 1990 to 2026 the VIX was above the volatility of the S&P 500 over the next month on about 86% of trading days, by about 4 points on average and nearly 5 at the median, and this holds in every decade and in samples without overlapping windows. In variance terms the gap is also positive, which is the evidence of a premium. The gap turned negative mainly in short episodes when a sharp fall started while the VIX was at an ordinary level, as in 1997, 2008, 2011, 2015, 2018, 2020 and 2025, and in October-November 2008 even at a very high

VIX. There is no evidence that it depends on the calendar month. A higher VIX came with a larger median gap in points but not with a more reliable one. A next step would be to measure realized volatility from intraday data, and to check whether the same pattern holds for other markets with a volatility index.

Author contributions and use of AI tools

The author chose this direction on 31 October 2026 from five that her mentor offered on 30 October 2026, after naming it and one other as interesting. His message already contained the question (why the market almost always overpays for insurance, and in which months this breaks) and the headline figures recomputed here (86% of days, 4-5 points). She restated the question in her own words, quoted in the Introduction, as her motivation. Her mentor, Myrzabek Kurakbay, with a generative AI assistant (Claude, Anthropic), set the three research questions and the method, chose the literature, downloaded the data, wrote the analysis code, made the figures and wrote the text, including its interpretation. The author did not do the calculations. No number, quotation or

reference was produced by a language model without being checked by her mentor against the data or the source. The author read and approved the final text.

Data availability

All data are public [5, 6, 7]. The cleaned data, the analysis scripts (Python) and the results files are available from her mentor on request.

Conflicts of interest

The author declares no conflicts of interest. No funding was received.

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