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EXAMINING ASSOCIATIONS BETWEEN ANNUAL MARKET VOLATILITY CONDITIONS AND EQUITY RETURNS USING HISTORICAL FINANCIAL MARKET DATA

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Abstract:

This analysis examines whether alternative summaries of market volatility yield consistent interpretations of annual equity performance, informing international debates on risk measurement. Published historical data provide 16 complete annual observations for the United States equity market from 2010 to 2025. Descriptive statistics, Pearson correlations, Spearman correlations, and exploratory exclusions of individual years compare annual mean, intraday peak, and intraday floor VIX with S&P 500 total returns. Mean VIX exhibits the strongest inverse Pearson association at negative 0.407, while peak VIX exhibits the strongest inverse Spearman association at negative 0.371. Both retain negative Pearson correlations under every individual year exclusion. Floor VIX displays a near zero rank association and changes Pearson direction when one influential year is excluded. Extreme volatility also coexists with positive annual returns, distinguishing episode intensity from completed annual performance. The contribution is a comparison showing that volatility summaries are not interchangeable and that interpretation depends on measurement and association criteria. These descriptive findings support separate reporting of average conditions and extremes, accompanied by sensitivity checks, without establishing causality or forecasting performance.

Key Words: Implied Volatility; Equity Returns; Risk Measurement; Rank Correlation; Sensitivity Analysis.

1. Introduction:

An extreme volatility episode and a poor investment year are different market outcomes. A sharp increase in implied volatility can coincide with substantial losses during part of a year while the completed annual return remains positive. This distinction matters when annual market assessments use average volatility, the highest observed volatility, or the lowest observed volatility as interchangeable descriptions of investment conditions. Each summary preserves different information about the same period. Understanding their relationships with annual equity returns therefore requires separating typical conditions from isolated extremes and distinguishing realised performance from expected compensation for risk. Asset pricing research provides competing reasons for volatility and returns to move together. An adverse revision to economic expectations can raise uncertainty and reduce equity valuations immediately. At the same time, greater exposure to risk can increase the compensation investors require for holding equities. Campbell et al. in 2018 incorporate stochastic volatility into an intertemporal asset pricing framework, demonstrating the relevance of volatility risk to changing investment opportunities and asset valuations. Martin in 2017 derives a lower bound on the equity premium from option prices. These contributions concern risk pricing and expected returns; they do not imply that a year with elevated implied volatility must deliver either a positive or negative realised return. The distinction between contemporaneous adjustment and subsequent compensation is central to interpreting annual market evidence.

Measurement further complicates this relationship. Bekaert and Hoerova in 2014 distinguish conditional stock market variance from the variance premium within squared VIX and document differences in their informational content. VIX consequently cannot be interpreted as an isolated measure of uncertainty or risk aversion. Annual aggregation introduces another distinction: the average of daily closing observations describes the level of implied volatility across the year, whereas an intraday maximum or minimum records an extreme that may be brief. Although all three summaries describe market volatility conditions, they need not display equivalent relationships with completed annual returns. The interpretation of extremes also requires separating the severity of perceived risk from the duration of market disruption. Bollerslev and Todorov in 2011 show that compensation for rare events accounts for a substantial share of equity and variance risk premia. Their findings establish the pricing relevance of extreme adverse outcomes, but an annual VIX maximum is not itself a tail risk premium or disaster probability. Similarly, an annual minimum identifies the calmest recorded observation without establishing that calm conditions persisted. Treating either extreme as a sufficient description of the annual investment environment can therefore obscure the distinction between an episode and the broader period containing it.

Evidence on volatility management reinforces the need for precise interpretation. Moreira and Muir in 2017 find that reducing portfolio exposure when volatility is high can improve performance because expected returns do not rise proportionately with volatility. Cederburg et al. in 2020 subsequently show that volatility management does not systematically outperform unmanaged portfolios in direct comparisons and identify instability that limits implementation. These findings address portfolio strategies rather than correlations between annual VIX summaries and annual market returns. Nevertheless, they demonstrate why a retrospective volatility relationship cannot automatically be translated into an investment rule. A descriptive comparison must first establish what its chosen measure represents and how sensitive the observed relationship is to influential periods. The reviewed evidence does not establish whether annual mean, intraday peak, and intraday floor VIX provide equivalent descriptions

of contemporaneous annual equity performance within the same observation window. The present contribution addresses this bounded measurement question. It compares the three summaries against one consistently defined outcome, using identical years and complementary association measures. The comparison does not introduce a new risk pricing mechanism. Instead, it examines whether conclusions about the volatility and return relationship depend on the annual summary selected, the distinction between linear and rank association, and the influence of individual years.

This analysis aims to determine how annual mean VIX, annual intraday peak VIX, and annual intraday floor VIX are associated with annual S&P 500 total returns. The central research question asks whether these three descriptions of volatility conditions yield a consistent direction and relative strength of association with realised annual performance. The specific objectives are to assess the relationship for each volatility measure, compare the conclusions obtained from Pearson and Spearman correlations, and examine whether the direction persists when individual years are excluded. These objectives concern descriptive association rather than causation, forecasting, or portfolio optimisation. The empirical setting is the United States equity market, observed through 16 complete calendar years from 2010 through 2025. The dataset combines published annual VIX summaries with annual S&P 500 total returns, including reinvested dividends. The unit of analysis is the calendar year. Descriptive statistics characterise the distributions, Pearson correlations summarise linear relationships, and Spearman correlations assess relationships in ranks. Exploratory recalculation after excluding each year evaluates dependence on individual observations. Using the same annual sample throughout makes differences across measures directly inspectable, although the small sample and contemporaneous timing restrict interpretation.

The findings show that the three volatility summaries are not interchangeable. Annual mean VIX displays the strongest inverse Pearson association with returns, while peak VIX displays the strongest inverse Spearman association. Both retain a negative Pearson direction under every individual year exclusion. The floor measure differs: its rank association is near zero, and its Pearson direction changes when one influential year is excluded. The contribution is therefore a distinction between a recurring sample direction and a relationship that depends on particular observations, rather than evidence of a universal volatility effect. These results inform the interpretation of market monitoring indicators. Average conditions and extremes should be reported separately because they describe different aspects of the annual return environment. Their international relevance lies in this measurement principle, not in assuming that coefficients estimated from United States observations apply to other markets. The analysis provides a transparent comparison that can guide equivalent assessments elsewhere while keeping conclusions tied to the observed measure, temporal horizon, and return definition.

2. Theory Conceptual Framework and Research Questions Development:

This analysis examines how annual market volatility conditions relate to annual S&P 500 total returns across 16 observations from 2010 to 2025. The theoretical foundation is intertemporal asset pricing, which connects equity valuations to expected cash flows, required compensation for risk, and changes in investment opportunities. Investors respond to these conditions through portfolio allocation and demand for protection, linking equity and option markets. Campbell et al. in 2018 incorporate stochastic volatility into an intertemporal asset pricing framework and establish the relevance of volatility risk to asset valuation. This provides a theoretical basis for examining volatility and returns together, without assuming that their contemporaneous annual association identifies a causal effect. Market volatility conditions are represented by three observed measures: annual mean VIX, annual intraday peak VIX, and annual intraday floor VIX. Annual S&P 500 total return, including reinvested dividends, is the outcome. These measures distinguish the average level of implied volatility from its highest and lowest observed values within each year. They remain separate explanatory measures rather than components of a constructed index. Importantly, VIX does not measure uncertainty independently of its market price. Bekaert and Hoerova in 2014 distinguish conditional stock market variance from the variance premium within squared VIX and show that these components carry different information. Consequently, an annual VIX measure cannot be interpreted as a direct observation of risk aversion or expected realized volatility alone.

Annual mean VIX captures the average level of implied volatility across daily closing observations. A higher mean can accompany repeated revisions to economic expectations, greater demand for protection, or increased compensation for bearing volatility risk. If adverse information raises required returns while expected cash flows remain unchanged, equity valuations can fall immediately. This mechanism suggests a negative contemporaneous association between average VIX and realized equity returns. However, higher required compensation can also increase expected subsequent returns. Drechsler and Yaron in 2011 demonstrate how uncertainty and the variance premium can generate return predictability, establishing why realized returns and expected compensation must be distinguished. Their findings motivate competing interpretations rather than a predetermined sign for the annual relationship examined here. The annual observation combines market declines, recoveries, and dividends within one calendar period. A year with elevated average VIX may therefore produce either a negative return or a positive return following recovery. Moreover, the average VIX and annual return cover the same period, so their association does not establish that volatility preceded the return. The first research question addresses the observable relationship without imposing a directional restriction.

RQ1: What direction and magnitude of association exist between annual mean VIX and annual S&P 500 total return during 2010 to 2025?

Annual intraday peak VIX captures the most extreme implied volatility observation within a year. Unlike the annual mean, the peak can reflect a brief episode of intense demand for protection. Its theoretical relevance concerns the pricing of severe adverse outcomes rather than the typical level of market uncertainty. Bollerslev and Todorov in 2011 find that compensation for rare events accounts for a substantial share of equity and variance risk premia. Their evidence supports examining extreme market conditions, although an annual VIX maximum is not itself an estimated disaster probability or tail risk premium. A high annual peak may accompany an abrupt equity market decline, creating a plausible negative contemporaneous association. Nevertheless, the maximum records intensity without measuring duration or subsequent recovery. Two years can reach similar peaks while differing substantially in how long stress persists and how equity prices evolve afterward. Annual peak VIX must therefore be

interpreted alongside average conditions, while retaining the possibility that a short volatility spike coexists with a positive annual return.

RQ2: What direction and magnitude of association exist between annual intraday peak VIX and annual S&P 500 total return during 2010 to 2025?

Annual intraday floor VIX identifies the lowest observed implied volatility value within each year. It describes the calmest recorded market condition, rather than the persistence of calm across the year. A low floor may accompany reduced demand for protection and greater willingness to hold equities. However, a single low observation cannot establish sustained investor confidence, increased leverage, or institutional risk taking. Those mechanisms remain theoretical interpretations rather than measured explanations. The relationship between low volatility and returns is also conditional on how risk compensation changes. Moreira and Muir in 2017 show that changes in volatility are not offset by proportional changes in expected returns and document gains from reducing portfolio exposure when volatility is high. This evidence challenges a simple assumption that greater volatility necessarily produces proportionately greater returns. For the annual floor, neither stronger equity demand during calm conditions nor lower required compensation determines the sign of the completed annual return.

RQ3: What direction and magnitude of association exist between annual intraday floor VIX and annual S&P 500 total return during 2010 to 2025?

The conceptual framework connects these three observed descriptions of market volatility conditions with annual equity returns through contemporaneous associations. The research questions guide descriptive comparisons and exploratory assessment of their distinct relationships with the outcome. Interpretation remains bounded by the small annual sample, shared information across the VIX measures, and the absence of within year event sequencing. Positive, negative, weak, and inconclusive associations are all admissible outcomes.

3. Data:

This analysis documents the provenance, coverage, and measurement of annual market volatility and equity return data. It establishes the analytical sample, reports completed consistency checks, and defines the descriptive comparisons supported by the available observations.

3.1 Data Sources, Population, and Sample Construction:

The dataset combines published annual VIX statistics from VIXChart.com with annual S&P 500 total returns from Slickcharts. The VIX observations comprise the annual average of daily closing values, the annual intraday maximum, and the annual intraday minimum. The equity observations measure annual returns including reinvested dividends. VIXChart.com attributes its underlying observations to Cboe daily historical data. Slickcharts provides the extracted return series. These websites are the extraction sources; the workbook does not establish that the annual summaries were independently reconstructed from original provider files. The workbook identifies these sources as V1 and R1, respectively. These identifiers are internal provenance keys rather than official series codes. Neither an extraction date nor a numbered source release is recorded in the supplied workbook. The observations therefore constitute an undated historical extract rather than a documented archival vintage. The workbook records no redistribution licence, so public accessibility is not treated as unrestricted permission to redistribute the underlying provider data.

The empirical setting is the United States equity market. The unit of analysis is the calendar year, and the observation period extends from 2010 through 2025. The resulting structure is one annual time series with 16 observations. The dataset does not contain individual companies, investor portfolios, or separate national markets. Its population boundary is the 16 calendar years within the specified period for the selected market measures, rather than all possible financial markets or assets. The accessible sampling frame consists of the published annual records for these years. All 16 years were retained because each contains the three VIX measures and the annual equity return. Selection is therefore complete within this defined frame rather than probabilistic sampling from a broader international population. The timing of the original eligibility decisions is not documented. The present verification retained the supplied period and all supplied observations without introducing additional exclusions.

Table 1: Sample construction

Stage	Market Units	Annual Observations	Rule or Verified Outcome
Eligible VIX records within scope	1	16	Annual mean, intraday peak, and intraday floor available
Eligible equity return records within scope	1	16	Annual S&P 500 total return available
Records matched by calendar year	1	16	Exact correspondence across the two source series
Duplicate year exclusions	0	0	No duplicate years detected
Missing measurement exclusions	0	0	All four analytical variables complete
Final descriptive sample	1	16	All years from 2010 through 2025 retained

The two source frames describe the same market years and are not added together to produce a sample of 32 observations. There are 16 matched annual records and 64 observed analytical measurements.

3.2 Data Integration, Cleaning, and Quality Assurance:

The annual source values were manually transcribed and consolidated by calendar year. The intended integration relationship is one VIX record to one equity return record for each year. Verification of the supplied workbook confirmed 16 distinct years, complete chronological coverage, and no unmatched years within the retained frame. No increase in observations resulted from integration. The annual measures were used at their published frequency. No daily observations were aggregated during the present analysis, and no fiscal year conversion or trading day realignment was performed. The annual VIX average is a period average, whereas the peak and floor are extrema observed within the period. The equity return is a change over the calendar

year that incorporates dividends. None of these measures represents an end of year monetary stock. Currency conversion, inflation adjustment, and rebasing were therefore not applied. All analytical fields contain numeric values. Missingness is zero for each variable and each retained year. No deletion, interpolation, imputation, or substitution of missing values with zero was required. Values retain the two decimal precisions supplied in the workbook. Negative equity returns remain valid observations and were retained.

A consistency check confirmed that the annual intraday floor does not exceed the annual mean and that the annual mean does not exceed the intraday peak in any observation. The year field contains neither repetitions nor gaps. These checks establish internal consistency but do not constitute independent verification against complete daily provider files. No numerical outlier threshold was imposed. Extreme observations were retained because large volatility movements and negative returns are substantively relevant to the research question. No winsorisation, trimming, or discretionary removal followed inspection of the descriptive results. This preserves the complete supplied frame while recognising that individual extreme years may influence summaries based on 16 observations. The historical extract does not document publication delays, revisions, or information available to investors at each observation date. Accordingly, the annual measures are treated as contemporaneous historical descriptions. They are not presented as information that could have supported a trading decision before the corresponding annual return occurred.

3.3 Variable Measurement, Construction, and Validation:

Market volatility conditions are operationalised through three observed VIX measures rather than an estimated latent construct. The annual mean represents average implied volatility conditions, the intraday peak represents the highest recorded intensity, and the intraday floor represents the lowest recorded intensity. These measures are related descriptions of one market indicator and are not combined into a composite score. Their interpretation requires a distinction between implied volatility and its underlying components. Bekaert and Hoerova in 2014 show that squared VIX contains both conditional variance and a variance premium. The available annual summaries do not separate these components. They therefore measure observed implied volatility conditions rather than independently identifying uncertainty, risk aversion, or compensation for volatility risk.

Table 2: Variable dictionary

Variable or Indicator	Analytical Role	Definition and Construction	Source and Identifier	Unit and Frequency	Transformation and Direction	Missing Value Rule	Coverage and Limitation
Calendar year	Temporal key	Published calendar year used for alignment	V1 and R1	Year, annual	No transformation	No missing years	2010 through 2025
Annual mean VIX	Explanatory measure	Published average of daily VIX closing values within the year	VIXChart.com, V1, Average column	VIX index points, annual	Untransformed; higher values indicate higher average implied volatility	No missing values; no imputation	Does not separate conditional variance from the variance premium
Annual intraday peak VIX	Explanatory measure	Published highest intraday VIX value within the year	VIXChart.com, V1, High column	VIX index points, annual	Untransformed; higher values indicate a higher observed peak	No missing values; no imputation	Does not measure stress duration or maximum closing VIX
Annual intraday floor VIX	Explanatory measure	Published lowest intraday VIX value within the year	VIXChart.com, V1, Low column	VIX index points, annual	Untransformed; higher values indicate a higher observed minimum	No missing values; no imputation	Does not establish persistent calm or sustained stress
Annual S&P 500 total return	Outcome	Published calendar year return including reinvested dividends	Slickcharts, R1, Total Return column	Percent, annual	Untransformed; higher values indicate stronger annual performance	No missing values; negative returns retained	Realised nominal return rather than expected or excess return

The return field stores percentage values directly. A value of 15.06 represents a return of 15.06 percent, rather than a decimal ratio of 15.06. Differences between return observations are expressed in percentage points. VIX observations remain index points and are not interpreted as realised equity returns. No logarithmic transformation, normalisation, interaction, moderator, control variable, or alternative outcome was constructed.

Table 3: Descriptive statistics

Variable	Valid Observations	Mean	Sample Standard Deviation	Median	Minimum	Maximum
Annual mean VIX	16	18.40	4.79	16.76	11.09	29.25
Annual intraday peak VIX	16	42.31	17.93	38.23	17.28	85.47
Annual intraday floor VIX	16	12.03	2.21	11.40	8.56	16.34
Annual S&P 500 total return, percent	16	14.98	13.89	16.94	Negative 18.11	32.39

The annual peak exhibits greater dispersion than the annual mean or floor. Its mean also exceeds its median, indicating sensitivity to unusually high observations. Annual equity returns span positive and negative outcomes, and their standard deviation is close to their arithmetic mean. The mean return describes the average annual observation and is not a compound investment growth rate. Validation remains appropriate to observed secondary measures. Internal ordering, completeness, numeric consistency, and temporal coverage were checked. No factor analysis or latent variable reliability assessment was applied.

3.4 Analytical Framework, Identification, and Reproducibility:

The implemented analysis is descriptive and exploratory. It summarises the observed annual distributions and calculates contemporaneous pairwise associations between each VIX measure and annual equity returns. Pearson correlations describe linear association, while Spearman correlations provide an exploratory comparison based on ranks. De Winter, Gosling, and Potter in 2016 demonstrate that the behaviour of these coefficients depends on distributional characteristics and sample size, supporting a distinction between linear and rank based summaries rather than treating them as interchangeable measures. Both calculations use the same 16 complete observations. No observations are lost through lags, differencing, controls, or estimator requirements. The

workbook records a proposed multiple regression specification, but the present descriptive analysis does not treat that proposal as a completed estimation. No regression coefficients, fixed effects, clustered standard errors, or causal effects are reported. The available variation is variation across calendar years within one market setting. Shared responses to economic news, simultaneous movement in option and equity markets, and aggregation within calendar years prevent identification of a causal volatility effect. Annual means, peaks, and floors also contain overlapping information. Their separate pairwise associations therefore do not establish independent contributions after conditioning on the other measures.

The Pearson and Spearman comparison was introduced during the present descriptive examination and is exploratory rather than documented as prespecified. It assesses sensitivity to ranking but does not resolve temporal dependence, omitted variables, measurement error, or the timing of market shocks. No significance threshold is used to select relationships for inclusion. This interpretation follows the distinction between statistical evidence and substantive importance emphasised by Wasserstein and Lazar in 2016. The supplied workbook preserves the analytical observations, variable definitions, source keys, and study design notes. These materials support reproduction of the reported summaries from the consolidated values. They do not establish complete reconstruction from original daily records. Peng in 2011 distinguishes reproducible computation from broader independent replication, a distinction relevant to this boundary. The remaining provenance limitations are the absent extraction date, absent source vintage, and absence of an archived construction script within the supplied workbook. Sandve et al. in 2013 emphasise preserving exact inputs and computational procedures. Accordingly, reproducibility here is bounded to the supplied annual extract, its stated definitions, and the calculations reported above.

4. Methods:

4.1 Research Design and Analytical Scope:

This analysis uses a descriptive observational design to examine contemporaneous associations between annual volatility conditions and annual equity performance. The analytical targets are the direction and magnitude of the sample relationships linking annual mean, intraday peak, and intraday floor VIX with annual S&P 500 total returns. The unit of analysis is the calendar year, with variation drawn from 16 observations covering 2010 through 2025. The design compares three descriptions of volatility conditions against the same outcome over an identical observation window. It distinguishes linear association from association in ranks and examines sensitivity to individual years. These comparisons address whether the interpretation of the volatility and return relationship changes with the selected summary measure. The relationships are unadjusted sample associations. They do not identify causal effects, independent predictor contributions, or forecasting performance. Volatility and equity returns can respond simultaneously to economic information, while annual aggregation combines market declines and recoveries within the same observation. Neither temporal precedence nor an exogenous source of variation is established.

4.2 Specification and Measurement Alignment:

Pearson correlation provides the baseline measure of linear association. For each volatility indicator, the coefficient is calculated using Equation 1.

$$r_j = \frac{\sum_{t=1}^{n}\left(x_{jt} - \bar{x}_j\right)\left(y_t - \bar{y}\right)}{\sqrt{\sum_{t=1}^{n}\left(x_{jt} - \bar{x}_j\right)^2 \sum_{t=1}^{n}(y_t - \bar{y})^2}}$$

Here, r_j is the Pearson correlation for indicator j; j identifies annual mean, intraday peak, or intraday floor VIX; tidentifies the calendar year; n is the number of matched observations; x_{jt} is the selected volatility measurement; $y_t$is annual S&P 500 total return; and $\bar{x}_j$and $\bar{y}$ are their respective sample means. Spearman correlation assesses whether the ordering of volatility observations corresponds to the ordering of annual returns. It is calculated as the Pearson correlation between ranks, as expressed in Equation 2.

$$\rho_j = \mathrm{Corr}\left[\mathrm{Rank}\left(x_j\right), \mathrm{Rank}(y)\right]$$

Here, ρ_j is the Spearman coefficient; Corrdenotes Pearson correlation; and Rankconverts the observations into ascending ranks, assigning average ranks to tied values. De Winter, Gosling, and Potter in 2016 demonstrate that Pearson and Spearman coefficients respond differently to distributional characteristics and sample size. Their comparison therefore informs the distinction between linear and rank relationships rather than treating either coefficient as universally preferable. The sample construction and measurement definitions follow Tables 1 and 2. All coefficients use the same 16 complete observations. Volatility measurements remain in index points, and returns remain in percentage units. No logarithms, standardisation, lags, controls, interactions, or composite scores are introduced. The coefficients are dimensionless and are not interpreted as percentage point changes in returns per volatility point.

4.3 Data Processing, Computation, and Reporting:

The consolidated workbook was read programmatically, and the year field was used to verify chronological coverage and uniqueness. Processing confirmed consecutive annual observations, numeric analytical fields, and complete coverage across the four measurements. The ordering of annual volatility summaries was checked by verifying that the floor did not exceed the mean and that the mean did not exceed the peak. Descriptive statistics comprise valid counts, arithmetic means, sample standard deviations, medians, minima, and maxima. Sample standard deviations use a denominator equal to the observation count reduced by one. These summaries characterise variation across annual observations; the arithmetic mean return is not interpreted as compound growth. Calculations were performed using Python 3.12.14, NumPy 2.3.5, and SciPy 1.17.0. NumPy supplied descriptive calculations, and SciPy functions pearsonr and spearmanr supplied the association coefficients. Each year receives equal weight. No random sampling, optimisation, or stochastic procedure is involved, so random seeds and convergence settings are inapplicable. Reported descriptive statistics are rounded to two decimal places and correlations to three decimal places. The analysis reports coefficients as finite sample descriptions. It does not use significance thresholds, confidence intervals, or independence-based probability statements. Wasserstein and Lazar in 2016 distinguish statistical significance from effect

magnitude and substantive importance. Accordingly, interpretation focuses on observed direction, magnitude, agreement across summaries, and sensitivity to sample composition.

4.4 Sensitivity, Reproducibility, and Interpretive Limits:

An exploratory sensitivity analysis evaluates dependence on individual years. For each volatility indicator, Pearson correlation is recalculated 16 times, excluding a different year in each calculation. Every reduced sample contains 15 observations. The analysis records the smallest and largest coefficient and whether its direction changes across exclusions. These calculations produce the sensitivity ranges reported in Table 6. The exclusion procedure evaluates influence rather than selecting a preferred sample. All years remain in the principal calculations. Changes across recalculations therefore reflect the omitted observation rather than altered definitions or transformations. The comparison between Pearson and Spearman coefficients provides a separate assessment of dependence on numerical distances versus ranks. These checks do not establish independence across years, remove confounding, or validate a predictive model. Directional persistence indicates stability under the specified exclusions, while differences in magnitude remain relevant. No residual diagnostics are reported because no regression model is estimated.

The workbook documents the consolidated observations, source keys, variable definitions, and analytical scope. Equations 1 and 2, the stated software functions, and the exclusion procedure specify how the reported calculations can be reproduced from those values. Complete reconstruction from original provider records remains bounded by the absent extraction date, source vintage, and archived construction script. Peng in 2011 distinguishes reproducible computation from broader independent replication, supporting this separation between reproducing calculations and independently rebuilding their inputs. The methodological contribution is a transparent application of established descriptive tools to a common sample. It enables comparison of three volatility summaries while preserving the distinction between observed association, sensitivity, prediction, and causation.

5. Findings:

This analysis evaluates the relationships between annual VIX conditions and annual S&P 500 total returns. The findings address average volatility, peak volatility, and the volatility floor across 16 calendar years. Descriptive correlations and exploratory sensitivity checks distinguish recurring patterns from relationships influenced by individual observations.

5.1 Sample Characteristics and Distributional Patterns:

The analytical sample contains 16 complete annual observations for the United States equity market from 2010 through 2025. All three volatility measures and the return outcome are observed in every year. No observations were excluded or imputed. Returns are expressed in percent, while volatility measures remain in VIX index points.

Table 4: Descriptive statistics for annual volatility conditions and equity returns

Measure	Observations	Mean	Standard Deviation	Median	Minimum	Maximum
Annual mean VIX	16	18.40	4.79	16.76	11.09	29.25
Annual intraday peak VIX	16	42.31	17.93	38.23	17.28	85.47
Annual intraday floor VIX	16	12.03	2.21	11.40	8.56	16.34
Annual S&P 500 total return, percent	16	14.98	13.89	16.94	Negative 18.11	32.39

Peak VIX exhibits substantially greater dispersion than average or minimum VIX. Its mean exceeds its median by 4.08 index points, compared with 1.64 points for annual mean VIX. Extreme intraday observations therefore contribute disproportionately to the distribution of annual peaks. This distinction matters because an annual maximum describes the intensity of a single extreme observation, whereas the annual mean incorporates conditions across daily closing observations. Equity returns were positive in 14 years and negative in two. The arithmetic mean return was 14.98 percent, while the median was 16.94 percent. The difference reflects the influence of adverse annual outcomes on average performance. These statistics describe realised calendar year returns rather than compound investment growth or expected returns. The three VIX measures also contain overlapping information. Annual mean VIX correlated positively with peak VIX at 0.632 and with floor VIX at 0.704. The peak and floor correlation was smaller at 0.142. Average conditions therefore shared variation with both extremes, while the extremes captured more distinct aspects of the annual volatility range. These relationships support treating the measures as related descriptions rather than interchangeable indicators. Bekaert and Hoerova in 2014 further establish that VIX combines information about conditional variance and the variance premium, limiting interpretation of these summaries as direct measures of a single economic mechanism.

5.2 Associations Addressing the Research Questions:

Table 5 reports Pearson correlations and Spearman rank correlations between each volatility measure and annual equity returns. Both calculations use the same 16 observations. The coefficients describe unadjusted contemporaneous relationships and do not measure return changes per VIX point.

Table 5: Contemporaneous associations with annual S&P 500 total returns

Research Question	Volatility Measure	Pearson Correlation	Spearman Correlation
RQ1	Annual mean VIX	Negative 0.407	Negative 0.326
RQ2	Annual intraday peak VIX	Negative 0.201	Negative 0.371
RQ3	Annual intraday floor VIX	Negative 0.285	Negative 0.065

For RQ1, annual mean VIX had the largest negative Pearson correlation with annual returns. The coefficient of negative 0.407 indicates that higher average implied volatility generally accompanied weaker annual equity performance within the observed sample. The Spearman coefficient remained negative at 0.326 in magnitude, indicating that the direction also appeared in the ordering of observations rather than solely in their numerical distances. This relationship does not establish that elevated volatility consistently produces a negative annual return. In 2020, annual mean VIX reached its sample maximum of 29.25, yet the

annual equity return was positive at 18.40 percent. In 2022, a lower annual mean VIX of 25.64 coincided with a return of negative 18.11 percent. Average implied volatility therefore distinguished broad market conditions without determining the sign or magnitude of completed annual performance. Campbell et al. in 2018 provide a theoretical basis for this distinction by incorporating volatility risk and changing investment opportunities into intertemporal asset pricing. For RQ2, annual peak VIX had a Pearson correlation of negative 0.201 with annual returns. Its Spearman correlation was more negative at 0.371 in magnitude. The contrast indicates that the ordering of annual peaks displayed a clearer inverse relationship with returns than their numerical magnitudes did. It does not establish a threshold effect or a nonlinear response.

The largest peak, 85.47 in 2020, occurred alongside a positive annual return. Likewise, peak VIX reached 65.73 in 2024 while annual equity returns were positive at 25.02 percent. Extreme intraday volatility therefore coexisted with strong completed annual performance in these observations. Annual peak intensity alone did not distinguish years with negative returns from years containing a volatility episode followed by sufficient recovery. For RQ3, annual floor VIX had a Pearson correlation of negative 0.285, but its Spearman correlation was close to zero at negative 0.065. The inverse relationship was therefore weak in the ranking of years. The numerical distances between particular observations contributed more to the Pearson result than a consistently ordered relationship across the sample. De Winter, Gosling, and Potter in 2016 explain why Pearson and Spearman coefficients can differ across distributions, supporting separate interpretation of these results. The lowest floor, 8.56 in 2017, accompanied a positive return of 21.83 percent. The highest floor, 16.34 in 2022, accompanied the sample minimum return of negative 18.11 percent. Although these endpoints align with an inverse relationship, the near zero rank correlation shows that this ordering did not extend consistently across the remaining years.

5.3 Sensitivity to Individual Years:

An exploratory sensitivity analysis recalculated each Pearson correlation after excluding one year at a time. Each calculation retained 15 observations. The resulting ranges assess dependence on individual years without changing variable definitions or removing observations from the main sample.

Table 6: Ranges of Pearson correlations after excluding individual years

Volatility Measure	Lowest Correlation	Highest Correlation	Direction Across All Exclusions
Annual mean VIX	Negative 0.562	Negative 0.214	Negative throughout
Annual intraday peak VIX	Negative 0.318	Negative 0.111	Negative throughout
Annual intraday floor VIX	Negative 0.494	Positive 0.070	Direction changes

The mean VIX association remained negative under every exclusion. Removing 2020 strengthened the correlation to negative 0.562, while removing 2022 weakened it to negative 0.214. These results show that the direction persisted, but its magnitude depended partly on years combining unusual volatility and return outcomes. The peak VIX association also remained negative throughout. Its correlation ranged from negative 0.318 after excluding 2020 to negative 0.111 after excluding 2013. This directional persistence supports a recurring inverse sample pattern, although the relationship remained smaller than the mean VIX association under the corresponding most influential exclusions. The floor VIX association was less stable. Excluding 2022 changed its Pearson correlation to positive 0.070, whereas excluding 2018 produced a correlation of negative 0.494. Combined with the near zero Spearman result, this sensitivity prevents a stable directional conclusion about the annual volatility floor.

5.4 Empirical Resolution:

RQ1 is resolved descriptively by an inverse association between annual mean VIX and annual equity returns that persists across rankings and individual year exclusions. RQ2 identifies a smaller inverse linear association for peak VIX, with a stronger relationship in ranks and a negative direction under every exclusion. RQ3 identifies no stable directional pattern for floor VIX because its rank association is near zero and its Pearson correlation changes sign when one influential year is removed. The findings distinguish average volatility conditions from isolated extremes. They do not establish that higher volatility earns proportionately higher annual returns, a distinction consistent with the evidence on volatility and expected compensation reported by Moreira and Muir in 2017. The results remain descriptive rather than causal or predictive. Their interpretation rests on magnitude, consistency, and sensitivity rather than a significance threshold, consistent with Wasserstein and Lazar in 2016.

6. Discussion:

Market fear and annual investment performance are not interchangeable signals. Table 5 shows that average VIX conditions have a stronger inverse linear association with annual equity returns than either annual extreme, while Table 6 shows that this direction survives every individual year exclusion. The contribution is the comparison of average, peak, and floor measures under identical temporal coverage, which reveals that their apparent informational value depends on how volatility is summarised. This distinction qualifies interpretations that treat any elevated volatility observation as equivalent evidence about completed annual performance. Martin in 2017 derives information about expected market returns from option prices, whereas the present analysis examines realised contemporaneous returns. Its negative associations therefore do not contradict positive compensation for bearing risk; they demonstrate why expected compensation and realised annual outcomes require separate interpretation. The empirical contribution concerns measurement and temporal alignment rather than a newly identified causal relationship. The coexistence of extreme volatility and positive annual returns changes how the peak measure should be interpreted. Tables 4 and 5 show that the largest observed volatility episode did not correspond to the weakest annual performance. A maximum records intensity without identifying duration, recovery, or the sequence of market adjustments. Wachter in 2013 develops a model in which changing disaster probabilities influence volatility and expected compensation, providing a theoretical explanation for why perceived danger need not translate mechanically into a negative completed annual return. The present observations are compatible with that distinction but do not identify disaster probabilities or investor responses. Their additional insight is narrower: an annual volatility peak cannot represent the full annual return environment. This shifts interpretation from treating peaks as sufficient summaries toward recognising the information lost when an extreme observation substitutes for conditions across the year.

The comparison also reveals that no volatility measure dominates across every descriptive criterion. In Table 5, annual mean VIX has the strongest Pearson association, but peak VIX has the strongest Spearman association. Average conditions therefore display the clearer linear relationship, while peak intensity displays the clearer relationship in ranks. The volatility floor performs differently: its near zero rank correlation and changing direction under individual year exclusions in Table 6 provide little basis for a stable directional interpretation. These contrasts refine the empirical meaning of indicator relevance without assigning causal shares to overlapping measures. Zhou in 2018 shows that the predictive content of variance risk premia depends on the horizon and asset examined. Although variance risk premia differ from the VIX summaries used here, that literature reinforces the importance of matching the measure and temporal horizon to the question. The contribution is a demonstrated dependence of the descriptive conclusion on both the volatility summary and the association statistic. Sensitivity to individual years exposes a practical constraint on interpreting annual market indicators. Table 6 distinguishes a recurring negative direction for average and peak VIX from an unstable direction for the floor. Directional persistence nevertheless does not establish stable magnitude, forecast accuracy, or an implementable allocation rule. Cederburg et al. in 2020 find that volatility management does not systematically outperform unmanaged portfolios and identify instability as an obstacle to translating retrospective relationships into investment performance. The present findings address a different empirical object, but sharpen the same distinction between an observed association and a decision rule. For market monitoring, the evidence supports reporting average conditions and extremes separately, together with sensitivity to influential years. It does not support replacing a broader investment assessment with a single annual VIX threshold. The advance is an explicit separation of descriptive persistence from operational reliability.

The international relevance lies in this measurement distinction rather than an untested claim that the United States coefficients apply elsewhere. Tables 5 and 6 show that even within one market and one observation period, conclusions change across volatility summaries and sensitivity checks. Londoño and Zhou in 2017 distinguish the information carried by currency and equity variance risk premia across forecasting horizons, illustrating why related risk indicators need not convey equivalent information across markets. Their evidence concerns different constructs and outcomes, so the present correlations neither replicate nor overturn those international results. Instead, this analysis contributes a bounded comparison that international applications can examine using consistent definitions: whether average conditions, extreme intensity, or the annual floor provides the more stable description of realised performance. Decision makers should distinguish these summaries before transferring interpretations across assets or jurisdictions. The resulting theoretical refinement is that the relationship between volatility and returns must specify the observed measure, return concept, temporal horizon, and sensitivity of the association.

7. Conclusion and Implications:

Market stress can intensify without determining how an investment year ends. This analysis shows that average conditions, extreme episodes, and the calmest observations provide different descriptions of annual performance. The first two retain inverse associations across individual year exclusions, whereas the third depends more heavily on particular observations. The contribution is a comparison demonstrating that both the selected summary and the association statistic shape conclusions about market conditions. This finding refines interpretation of risk pricing frameworks by separating realised contemporaneous performance from expected compensation for bearing uncertainty. It does not identify causal pathways or establish an investment rule. For managers, the evidence supports reporting typical conditions and extremes separately, accompanied by sensitivity checks before assigning strategic importance to an observed relationship. For supervisory monitoring, it supports contextual reporting that distinguishes episode intensity from completed annual outcomes, without prescribing intervention thresholds. Operationally, analytical routines should preserve consistent observation periods, distinguish linear relationships from rankings, and disclose dependence on influential years. These practices could improve the clarity of risk communication for institutions and investors. International relevance lies in the transferable comparison approach rather than universal coefficients: equivalent assessments can examine whether indicator interpretation remains stable across markets before informing allocation or resilience decisions.

The annual sample provides a starting point for examining how temporal aggregation shapes market interpretation. Monthly and daily observations could distinguish stress duration, recovery, and event sequencing that annual summaries conceal. Comparisons across countries and market structures could assess whether the observed differences persist under alternative institutional conditions. Archived provider data with documented extraction dates would strengthen reproducibility. Prospective evaluation could establish whether descriptive associations contain useful forecasting information, while designs incorporating measured economic channels could investigate causal explanations. These extensions would assess transferability and practical usefulness without treating the present associations as established mechanisms or policy effects.

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