2027 CAIA® EXAM PREP

SchweserNotes™

Volatility and Complex Strategies, Universal Investment Considerations, and Emerging Topics

Level II Book 4

KAPLAN® SCHWESER

Book 4: Volatility and Complex Strategies, Universal Investment Considerations, and Emerging Topics

SchweserNotes™ 2027

CAIA Level II

KAPLAN SCHWESER

SCHWESERNOTES™ 2027 CAIA® LEVEL II BOOK 4: VOLATILITY AND COMPLEX STRATEGIES, UNIVERSAL INVESTMENT CONSIDERATIONS, AND EMERGING TOPICS

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Published in 2026 by Kaplan, Inc.

ISBN: 978-1-0788-5982-0

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Readings and Learning Objectives

TOPIC 8

CAIA Association. *CAIA Curriculum Level II Volume III*. Self-published, CAIA Association, 2026.

Reading 8.1: Volatility as a Factor Exposure

8.1.1: Demonstrate knowledge of measures of volatility.
Including:

- Understand differences between implied volatility and realized volatility.
- Identify limitations of realized volatility as a measure of dispersion.
- State the properties of realized volatility.

8.1.2: Demonstrate knowledge of volatility and the vegas, gammas, and thetas of options.
Including:

- Describe option vegas.
- Interpret the scaling of the vega of an option.
- Interpret and apply vega as an option for finite shifts.
- Understand how vega shifts as underlying variables change.
- Interpret option gammas.
- Understand the interrelationships between option vegas, gammas, and thetas.

8.1.3: Demonstrate knowledge of exposures to volatility as a factor.
Including:

- Contrast long volatility with short volatility.
- Understand distinctions between positive vega and long volatility exposures.
- Explain how volatility can be used to hedge risk.
- Understand volatility as an unobservable but unique risk factor.
- Understand how long volatility carries a negative risk premium.
- Explain how short volatility earns a positive risk premium.

8.1.4: Demonstrate knowledge of modeling volatility processes.
Including:

- Understand volatility processes with jump risk.
- Construct volatility processes and regime changes.
- Discuss reasons why volatility strategies recover.
- Identify reasons why volatility mean reversion cannot be arbitraged.

8.1.5: Demonstrate knowledge of implied volatility structures.
Including:

- Describe methods of computing implied volatility.
- Identify structures regarding implied volatility and moneyness.
- Identify an implied volatility surface.
- Explain key reasons for implied volatility structures and surfaces.
- Discuss reasons for high implied volatility and out-of-the-money puts.

Reading 8.2: Volatility, Correlation, and Dispersion Products and

Strategies

8.2.1: Demonstrate knowledge of common option strategies and their volatility exposures.
Including:

- Understand and apply theta as a measure of time decay in an option.
- Describe writing option straddles and strangles as short volatility strategies.
- Describe writing option butterflies and condors as short volatility strategies.

8.2.2: Demonstrate knowledge of volatility and delta-neutral portfolios with options, and advanced option-based volatility strategies.
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- State the general performance drivers of delta-neutral portfolios with options.
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8.2.3: Demonstrate knowledge on variance-based and volatility-based derivative products.
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- Describe derivative strategies that create payoffs driven by realized variance.
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- Describe the process of engineering VIX-related financial derivatives.
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8.2.4: Demonstrate knowledge of correlation swaps and dispersion trades.
Including:

- Understand and apply the mechanics of a correlation swap.
- Model the relationship between correlations, security volatility, and portfolio volatility.
- Understand motivations to correlation trading.
- Understand the basics of dispersion trades.

8.2.5: Demonstrate knowledge of commonalities of volatility, correlation, and dispersion trading.
Including:

- Understand the basics of volatility, correlation, and dispersion trading.

Reading 8.3: Structured Products

8.3.1: Demonstrate knowledge of structured products, types of wrappers, and the tax effects of wrappers.
Including:

- Describe equity-linked structured products.
- Describe the six types of wrappers as defined by BNP Paribas.
- Describe the tax effects of wrappers.
- Calculate the pre-tax and after-tax return of fully taxed investments.
- Calculate the after-tax return of tax-deferred wrappers.
- Calculate the after-tax return on a wrapper that offers both tax deduction and tax deferral.
- Identify investor motivations for including structured products in a portfolio.
- Discuss tax-related motivations for investors.

- Discuss the motivations of issuers of structured products.

8.3.2: Demonstrate knowledge of structured products with exotic option features.
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- Understand how simple call and put options can be combined to provide principal protection.
- Illustrate how a cash-and-call strategy is related to put-call parity.
- Identify path-dependent options and binary options.
- Describe and apply barrier, knock-in, and active options.
- Describe the characteristics of in versus out and up versus down barrier options.

8.3.3: Demonstrate knowledge of global structured product types and cases.
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- Discuss absolute return and principal protected absolute return barrier notes.
- Understand the components within a US-based structured product with multiple kinks.
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8.3.4: Demonstrate knowledge of structured product valuation.
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- Understand how a structured product can be valued using dynamic hedging.
- Discuss the advantages of the simulation approach over the PDE approach.
- Contrast the PDE approach and the building blocks approach.
- Explain the two principles of payoff diagram shapes and levels.
- Discuss the evidence on structured product prices.

Reading 8.4: Complexity and the Case of Cross-Border Real Estate Investing

8.4.1: Demonstrate knowledge of views regarding currency hedging for cross-border real estate investing.
Including:
- Understand the concept of cross-border return and calculate its total return.
- Identify key traditional currency risk assumptions of cross-border investing.
- Calculate the variance of an investor's total return viewed from the home currency.
- Understand and apply the role of the correlation coefficient in the volatility of dollar-based returns.
- Identify the financial instruments commonly used to hedge currency risk.
- Construct a natural hedge and identify its impact on currency risk.
- Explain the relationship between an investor's wealth and risk and currencies.

8.4.2: Demonstrate knowledge of fundamentals of currency risk and hedging in perfect markets.
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- Discuss currency risk and the law of one price with no currency hedging.
- Discuss currency risk and the law of one price with currency hedging.
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8.4.3: Demonstrate knowledge of currency risk and hedging within alternative investments.
Including:
- Define price stickiness and its relationship with asset values and expected future cash flows.
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- Understand levered assets in currency risk.

8.4.4: Demonstrate knowledge of access to foreign assets with futures and quanto futures.
Including:

- Define quanto future derivatives.
- Understand quanto futures contracts.
- Contrast futures-based strategies with direct cash investment in foreign assets.

8.4.5: Demonstrate knowledge of international real estate investing.
Including:

- Identify characteristics of international real estate markets.
- Discuss transaction costs and taxes in global real estate.
- Identify the factors that affect variation in the median time to sell a real estate property.
- Identify the benefits of international real estate investing.

8.4.6: Demonstrate knowledge of challenges in international real estate investing.
Including:

- Identify reasons why agency relationships are important in real estate investing.
- Understand relative inefficiencies in global real estate markets.
- Understand the role of information asymmetries in real estate investing.
- Understand the role of liquidity and transaction costs in real estate investing.
- Identify political, economic, and legal risks in international real estate investing.

Reading 8.5: Cryptocurrency Investing and Trading

8.5.1: Demonstrate knowledge of common investment styles used by liquid cryptocurrency.
Including:

- Understand portfolio strategies based on different market conditions.
- Contrast the different trading styles within the crypto markets.
- Analyze a trading plan used by an active crypto investor.

8.5.2: Demonstrate knowledge of common strategies used by liquid cryptocurrency funds.
Including:

- Contrast technical analysis, fundamental analysis, and macro-based analysis in cryptocurrency markets.
- Apply tokenomics to fundamental analysis-based crypto strategies.
- Identify tokenomic risk factors.

8.5.3: Demonstrate knowledge of common investment strategies and trading styles used by liquid cryptocurrency investors.
Including:

- Understand trading strategies used in cryptocurrency investing.
- Evaluate cryptocurrency markets using common cryptocurrency metrics and other risk and economic indicators.

8.5.4: Demonstrate knowledge of financial risk and risk management practices in cryptocurrency investing.
Including:

- Understand the historical risk profile of Bitcoin and other major crypto assets.
- Explain common crypto risk management metrics.
- Apply trading tactics, including take profit and stop-loss strategies.

8.5.5: Demonstrate knowledge of risk management practices in cryptocurrency investing investors.
Including:

- Understand how market manipulators affect the cryptocurrency markets.
- Identify the four phases of market manipulation.

- Distinguish between different types of market manipulation.
- Recommend risk management strategies to mitigate impacts of market manipulators.

TOPIC 9

CAIA Association. *CAIA Curriculum Level II Volume III*. Self-published, CAIA Association, 2026.

Reading 9.1: Global Regulation

9.1.1: Demonstrate knowledge of financial market regulation.
Including:

- Discuss principles of securities economic regulation.
- Understand the importance of regulation in some trading strategies.

9.1.2: Demonstrate knowledge of alternative investment regulation in the United States.
Including:

- Identify the main regulatory bodies and their jurisdictions.
- Identify regulatory frameworks and statutes within the United States.
- Understand regulation of private funds and why one must register as an investment advisor.
- Identify investment advisor obligations within private fund regulations.
- Understand the process of hedge fund registration in the United States.
- Understand the process of registering both private and public securities and how the Securities Act affects this process.
- Understand the exemptions from registration under the Investment Company Act.
- Identify the role of the chief compliance officer and compliance culture.
- Understand the importance of marketing material review.
- Identify the various SEC Exams.
- Identify reporting requirements.

9.1.3: Demonstrate knowledge of alternative investment regulation in Europe.
Including:

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- Understand regulatory frameworks within Europe.
- Identify requirements regarding registration and exemptions from those requirements within Europe.
- Understand disclosure requirements around the marketing of investment products.
- Identify formal requirements in risk management.
- Identify requirements around the reporting of regulations in Europe.
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- Understand how European regulations are enforced.
- Understand how non-EU managers may operate in Europe.

9.1.4: Demonstrate knowledge of alternative investment regulation in Asia.
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- Identify regulatory requirements and frameworks within Singapore.
- Identify regulatory requirements and frameworks within South Korea.
- Identify regulatory requirements and frameworks within Japan.
- Identify regulatory requirements and frameworks within Australia.

- Identify regulatory requirements and frameworks within India.
- Identify regulatory requirements and frameworks within China.

Reading 9.2: Geopolitics

9.2.1: Demonstrate knowledge of the various geopolitical paradigms embedded in an investment framework.

Including:

- Evaluate the role of geopolitical beta in long-term investments.
- Contrast the three potential starting systems of geopolitics.
- Contrast the three potential starting systems for politics.

9.2.2: Demonstrate knowledge of the role of geopolitics in investing while applying a constraint-based framework.

Including:

- Contrast the impact of geopolitical risk on public markets and private markets.
- Explain the constraint-based framework for geopolitical analysis.
- Identify the three pillars of the constraint-based framework.
- Distinguish between preferences and constraints.
- Identify material constraints.
- Understand the geopolitical risk premium and the impact on valuation and returns.

9.2.3: Demonstrate knowledge of the impact of geopolitics on private market valuations and return expectations.

Including:

- Discuss the challenges in generating geopolitical beta.
- State the three mistakes investors make when analyzing geopolitical events.
- Distinguish between geopolitical beta and geopolitical alpha.

9.2.4: Demonstrate knowledge of applying the 3×3 framework within an investment context.

Including:

- Construct a 3×3 diagram of the geopolitical and political future.

Reading 9.3: Sustainability and Alternative Investments

9.3.1: Demonstrate knowledge of sustainability in alternative investments.

Including:

- Understand the growth of sustainability principles in alternative assets.
- Understand how sustainability principles are incorporated by institutional investors.
- Identify and explain challenges in incorporating sustainability principles into the investment decision.

9.3.2: Demonstrate knowledge of how sustainability impacts natural resources as a real asset.

Including:

- Understand how environmental issues can impact investments in natural resources.
- Understand how social issues can impact investments in natural resources.
- Understand how governance issues can impact investments in natural resources.

9.3.3: Demonstrate knowledge of how sustainability impacts commodities as a real asset.

Including:

- Explain the role of speculators and speculation in pricing commodity derivatives.
- Understand the implication of changes in volatility on commodity speculation.
- Understand how sustainability factors can apply to direct investment in physical commodities.

9.3.4: Demonstrate knowledge of how sustainability impacts real estate as a real asset.

Including:

- Identify the impacts sustainability considerations can have on real estate development.
- Describe how sustainability considerations can impact the use of real estate.
- Explain how issues in sustainability can apply to the treatment of tenants, workers, and communities.
- Describe the influence of sustainability principles in recovery and disposal of real estate.
- Identify sustainability issues in refurbishment and retrofitting.
- Understand the processes of waste management, resource conservation, and recycling in relation to the demolition of real estate assets.
- Understand the process of land recovery and rehabilitation in real estate.

9.3.5: Demonstrate knowledge of how sustainability impacts infrastructure as a real asset.
Including:

- Assess the main sustainability factors related to infrastructure investments.
- Distinguish between sustainability priorities by infrastructure sector.

9.3.6: Demonstrate knowledge of how sustainability impacts hedge funds.
Including:

- Describe how sustainability principles guide hedge fund investment strategies.
- Describe how sustainability principles can guide hedge fund governance.
- Explain the relationship between sustainability principles and hedge fund transparency.
- Demonstrate knowledge of how sustainability interacts with hedge fund investment techniques and instruments.
- Understand the relationship between hedge fund strategies and underlying investments.
- Describe how hedge fund strategies are impacted by activism.
- Describe how hedge fund strategies are impacted by avoidance.

9.3.7: Demonstrate knowledge of how sustainability impacts private equity.
Including:

- Explain how partnership organizations can support sustainability, including within the GP-LP relationship.
- Describe how the private equity investment process can include sustainability principles.
- Understand the monitoring process and how it applies to sustainability.

Reading 9.4: Sustainability Analysis and Application

9.4.1: Demonstrate knowledge of the background of sustainability.
Including:

- Describe the history of sustainability.
- Explain the Global Reporting Initiative (GRI) Standards.
- Understand the relationship between social responsibility and evidence of stakeholder wealth within sustainability.

9.4.2: Demonstrate knowledge of how sustainability is rated and scored within an entity's operating procedures.
Including:

- Discuss sustainability-based ratings and scores as part of operating procedures.

9.4.3: Demonstrate knowledge of sustainability materiality and disclosure.
Including:

- Understand how the Global Reporting Initiative (GRI) governs sustainability materiality and sustainability disclosure.
- Explain KPMG's framework for materiality assessments.
- Interpret the sustainability materiality map.
- Discuss the measurement of sustainability materiality.

- State the three phases of the impact of adverse sustainability events.

9.4.4: Demonstrate knowledge of the role the United Nations (UN) has in sustainability issues.
Including:

- Identify the Six Principles for Responsible Investment (PRI).
- Explain Sustainable Development Goals (SDGs).

9.4.5: Demonstrate knowledge of fiduciary responsibilities and regulation within sustainability.
Including:

- Discuss fiduciary responsibilities within the US as they relate to sustainability.
- Discuss fiduciary responsibilities within Europe as they relate to sustainability.
- Discuss fiduciary responsibilities within Asia as they relate to sustainability.
- Discuss how asset managers approach sustainability compliance and risk management.

9.4.6: Demonstrate knowledge of methods of sustainability investing.
Including:

- Distinguish between negative and positive screening.
- Discuss engagement and proxy voting strategies.
- Describe impact investing in the context of their categories, the steps of implementation, and illiquid investments.

9.4.7: Demonstrate knowledge of market-based methods to address sustainability issues.
Including:

- Understand the background of externalities and markets.
- Discuss the Coase Theorem.

9.4.8: Demonstrate knowledge of special investment considerations as they apply to sustainability.
Including:

- Understand special consideration, cash flows, returns, and risk.
- Describe the case for special consideration of sustainability issues.
- Describe the case against special consideration of sustainability issues.

TOPIC 10

Burton, Elizabeth. “The First 100 Days: A CIO Blueprint.” Goldman Sachs Asset Management, Winter 2025.

Reading 10.1: The First 100 Days: A CIO Blueprint

10.1.1: Demonstrate knowledge of the early goals of a new CIO.
Including:

- Discuss the balance that is critical to find to be a successful CIO.
- Understand why it’s important to share your upcoming 100-day plan with the CEO (director).
- Discuss the key components to the foundation established over the initial 30-day period.
- Understand the risk assessment suggested as part of the new CIO’s preparations.
- Understand the components of the 31–60-day period necessary to become an expert in operations.
- Understand the key components of the 61–100-day period for the new CIO to consider.

Betermier, Sebastien, Eduard van Gelderen, and Barbara Zvan. *Direct Value Creation and Capture in the Pension*

Fund Industry: Five Examples. Working paper, National Pension Hub, Global Risk Institute, February 2024.

Reading 10.2: Direct Value Creation and Capture in the Pension Fund Industry: Five Examples

10.2.1: Demonstrate knowledge of direct value creation in the pension plan industry.

Including:

- Explain the four ways in which pension funds create and capture value.
- Explain the four primary sources of risk pension funds incur with in-house investment projects.
- Assess the OTPP acquisition of Cadillac Fairview.
- Assess the PSP acquisition of Mahi Pono.
- Assess the CDPQ development of the Réseau Express Métropolitain rail system.
- Assess the CPP acquisition of Antares Capital.
- Assess the value creation strategy employed by UPP.

"Value Creation in Private Equity," European Bank for Reconstruction and Development, April 2020.

Reading 10.3: Value Creation in Private Equity

10.3.1: Demonstrate knowledge of the relationship between Private Equity driven operational changes and investors returns.

Including:

- Explain private equity value creation plans (VCPs).
- Distinguish between operational improvements, top-line growth, governance engineering, financial engineering, and cash management.
- Discuss the variability of VCPs across deal type, fund ownership, growth strategy, and geographic focus.
- Discuss the relationship between action items and type of deal.
- Understand the factors influencing the likelihood that a PE firm successfully implements an action item.
- Determine which VCP combinations best predict higher returns and lower returns than average.
- Contrast predicted returns based on planned strategies versus achieved strategies.
- Evaluate the impact single strategies have on return outcomes.
- Assess the four company-level changes that correlate significantly with higher investor returns.

Brown, Gregory W., et al. *Scale, Scope, and Speed in Private Capital Funds.* Institute for Private Capital, UNC Kenan-Flagler Business School, Working Draft, March 2024.

Reading 10.4: Scale, Scope, and Speed in Private Capital Funds

10.4.1: Demonstrate knowledge of academic research outcomes related to private fund performance.

Including:

- Analyze the scale and historical growth in capital in private market strategies in relation to public markets.
- Understand the distribution of fund sizes across private markets and the impact this may have on forming conclusions about an average fund.
- Assess performance trends over time by strategy as measured by PME.

- Understand performance trends (as measured by PME) in relation to fund size.
- Understand performance dispersion (as measured by PME) across fund sizes.
- Understand performance trends (as measured by PME) across a series of fund launches by individual GPs as well as overall growth of the GP.
- Analyze performance trends (as measured by PME) in relation with the time-to-market of new funds.
- Identify conclusions derived from the regression analysis.
- Summarize the main conclusions of Scale, Scope, and Speed in Private Capital Funds.

Institutional Limited Partners Association. *Continuation Funds: Considerations for Limited Partners and General Partners.* May 2023.

Reading 10.5: Continuation Funds: Considerations for Limited Partners and General Partners

10.5.1: Demonstrate knowledge of guidance on best practices for use of continuation funds.
Including:

- Explain the economic and governance rationale for using continuation funds as an alternative to traditional exits, fund extensions, or co-investment structures.
- Describe the roles and responsibilities of General Partners, Limited Partners, and the LP Advisory Committee throughout a continuation fund transaction.
- Identify the key sources of conflicts of interest inherent in continuation fund transactions and the disclosure mechanisms recommended to address them.
- Summarize the recommended process, timing, and documentation standards that support informed roll-or-sell decisions by LPs.
- Assess the fairness and robustness of a continuation fund solicitation process by analyzing pricing validation methods, advisor roles, and LPAC conflict waivers.
- Construct an internal LP decision-making framework for continuation fund transactions.

Baz, Jamil, Lloyd Han, and Marc-Antoine Loo. “Three Models of the Liquidity Premium.” PIMCO, March 2024.

Reading 10.6: Three Models of the Liquidity Premium

10.6.1: Demonstrate knowledge of the illiquidity premium.
Including:

- Contrast the three distinct models of the liquidity premium and the economic intuition underlying each.
- Explain how investor skill, beliefs about alpha, and portfolio composition influence the magnitude of the liquidity premium demanded for illiquid investments.
- Assess whether the behavioral benefits of return smoothing justify a negative liquidity premium for certain investor types or portfolio contexts.
- Understand how return smoothing in private assets can mitigate behavioral biases such as market timing errors and excessive trading.

Lo, Andrew W., and Manish Singh (2023), “From ELIZA to ChatGPT: The Evolution of NLP and Financial

Applications,” *Journal of Portfolio Management*, June 2023.

Reading 10.7: From ELIZA to ChatGPT: The Evolution of NLP and Financial Applications

10.7.1: Demonstrate knowledge of natural language processing (NLP) and artificial intelligence (AI).
Including:

- Construct a timeline detailing the evolution of NLPs based on model complexity.
- Identify key milestones and advancements in NLP.
- Identify challenges and limitations associated with different generations of NLP models.
- Understand the different steps in the pipeline of a large language model.
- Contrast ChatGPT from other NLP models.
- Evaluate the limitations of ChatGPT and the implications they have in real-world applications.

10.7.2: Demonstrate knowledge of applications of NLP/AI in the finance industry.
Including:

- Apply NLP models to risk management.
- Describe how NLP models can be used in impact investing.
- Justify the use of NLP models by impact investors given the carbon footprint of these models.
- Identify the uses of NLP models in asset management.
- Evaluate the potential limitations of NLP in financial applications.

Costa, Andre, and Oswaldo Zapata. “Quantum Computing: An Introduction to Algorithms for Investors.” The Quantum Finance Boardroom. n.d.

Reading 10.8: Quantum Computing: An Introduction to Algorithms for Investors

10.8.1: Demonstrate knowledge of Quantum Computing in Finance.
Including:

- Explain the fundamental differences between classical computing and quantum computing, including qubits, superposition, and probabilistic measurement.
- Evaluate the conditions under which quantum-enhanced machine learning could offer meaningful advantages over classical machine learning in financial applications.
- Assess the investment implications of quantum computing across public and private markets.
- Construct an investment framework for evaluating quantum-related companies that integrates technological readiness, business-model viability, and strategic optionality.

The following is a review of the Volatility and Complex Strategies principles designed to address the learning objectives set forth by CAIA Association®. Cross-reference to CAIA Association Reading 8.1.

READING 8.1

VOLATILITY AS A FACTOR EXPOSURE

Topic 8

EXAM FOCUS

For the exam, be familiar with the products and strategies associated with changes in levels of asset volatilities and correlations. Be able to discuss the differences in the composition of implied return volatility and realized return volatility, and the various limitations and properties of realized volatility. Be prepared to apply vega formulas in approximating changes in value for options as well as explain how the curvature of gamma impacts option values. Focus on key concepts in applying volatility strategies that involve understanding long and short volatility and positive and negative correlation for various positions. Explain how jump risk and diffusion risk are measured and explain how alternative methods such as a mixture or regime-switching model are used to model volatility. Lastly, be able to discuss how volatility skew and option volatility surface graphs are used to better understand the impact of moneyness and maturity on implied risk premiums.

MEASURES OF VOLATILITY

LO 8.1.1: Demonstrate knowledge of measures of volatility.

Including:

Understand differences between implied volatility and realized volatility.
Identify limitations of realized volatility as a measure of dispersion.
State the properties of realized volatility.

Implied vs. Realized Volatility

Implied return volatility represents expected volatility going forward for the life of an option inferred from its option price and computed using market prices through an option pricing model. One example is the Black-Scholes option pricing model. This model assumes that the underlying asset follows a geometric Brownian motion (GBM), which has instantaneous asset returns that

- have an unchanging (constant) variance through time (homoskedastic),
- are normally distributed, and
- are uncorrelated through time.

Implied volatility typically is neither an accurate nor an unbiased estimate of realized volatility. An asset's **realized return volatility** is the actual variation that occurs over a specific time period. Implied volatilities differ from expected realized volatilities because risk premiums are associated and are reflected in implied volatility. In practice, observed returns are discrete, not continuous, and all three properties of a GBM process—constant variance, normally distributed returns, and returns that are uncorrelated through time—are typically violated.

Limitations of Realized Return Volatility

Realized return volatilities are only estimates, and therefore, assets with similar volatility estimates may experience very different actual returns. There are three limitations of realized volatility as a measure of dispersion.

Realized volatility does not define the return distribution's shape.

Even when assets have identical realized volatility, they could differ if their returns are trending, mean reverting, or exhibiting minimal autocorrelation.

Realized volatility does not indicate whether the dispersion of returns occurred near an underlying asset price or during a specific time period in the sample.

> **EXAMPLE: Realized volatilities**
>
> Suppose the following pairs of assets have the same realized volatility of returns but differ with respect to the three limitations of realized volatility as a measure of dispersion. **Identify** which of the three limitations the following cases represent.
>
> Case 1: Asset A returns had alternating signs and tended to mean-revert, while Asset B returns moved mostly in one direction.

> Case 2: Asset C experienced mostly average size returns, and Asset D experienced many very small returns and one large outlier return.
>
> Case 3: Asset E had low volatility for most of the sample period with a few very large shocks at the end of the sample period, and Asset F had a few very large shocks at the beginning followed by low volatility.
>
> **Answer:**
>
> Case 1 illustrates two assets with equal realized volatility can have return patterns that are very different, such as mean reverting and trending.
>
> Case 2 illustrates two assets may have the same realized volatility but very different return distribution shapes.
>
> Case 3 illustrates that equal realized volatility can occur even when the dispersion of returns occurred at very different time periods in the sample. The strategies used in those different cases would have very different results even if the underlying assets had the same realized return volatility. In addition, using daily, weekly, or monthly returns will change the characteristics of the returns.

Properties of Realized Volatility

The following six properties of realized volatility are common key factors in designing volatility arbitrage strategies and portfolio risk management.

- Realized volatility is nonconstant and exhibits behavior of slow mean reversion and clustering. Common trading strategies use generalized autoregressive conditional heteroskedasticity (GARCH) or regime-switching models.
- Realized volatility is normally low until a market shock, and then volatility rises for an extended time period.
- Realized volatility can exhibit large variability in the short term; however, in the long term, volatility levels are near long-term averages.
- Higher realized volatility is negatively correlated with risky asset returns because investor risk aversion increases at higher volatility levels.
- Equity market realized volatility is typically higher in bear markets and lower in bull markets. Higher volatility also results from decreases in the stock price (or index value), which increases leverage and risk. Therefore, there is a negative correlation between the equity value and volatility.

Realized equity volatility rises faster in bear markets and falls more slowly in bull markets.

OPTION VEGA, GAMMA, AND THETA

LO 8.1.2: Demonstrate knowledge of volatility and the vegas, gammas, and thetas of options.

Including:

- **Describe option vegas.**
- **Interpret the scaling of the vega of an option.**
- **Interpret and apply vega as an option for finite shifts.**
- **Understand how vega shifts as underlying variables change.**
- **Interpret option gammas.**
- **Understand the interrelationships between option vegas, gammas, and thetas.**

Option Vega

The sensitivity of an option's value to a change in the underlying asset's volatility, holding all other variables constant, is known as vega. Investors often view vega as the change in the price of a portfolio versus changes in expected volatility of the underlying asset. Understanding an option's vega plays an important role in risk management for portfolios. Many portfolio managers create option positions based on the levels of sensitivity versus changes in implied volatility or target vega levels while minimizing delta. Delta measures the change in option value versus a change in the value of the underlying asset.

The Black-Scholes option pricing model is used to define the equation for vega, *v*, for both call and put options as follows:

$$v = \frac{\partial p}{\partial \sigma} = SN'(d)\sqrt{T}$$



where:

p = put or call option value
σ = underlying asset volatility
S = underlying asset price
$N'(d)$ = probability density function for the normal distribution at d
T = time to expiration of the option

Vega is the first-order partial derivative of a call or put option's value with respect to the implied volatility of the underlying asset's returns, holding all other inputs constant. In practice, the formula is adjusted to scale the change based on a one-basis-point change in volatility as follows:

$$v = \frac{\partial p}{\partial \sigma} = SN'(d)\sqrt{T} / 100$$

Dividing vega by 100 is called *vega per basis point*.

> **EXAMPLE: Option vega**
>
> Suppose a portfolio manager holds a common stock that pays no dividends trading at a price of $40. A call option and a put option on the stock also exist that both expire in three months and have the same strike price. If the probability density function (N′(d)) for both options is 0.15, **calculate** vega and vega per basis point.
>
> **Answer:**
>
> The vega calculation is:
>
> $$v = \frac{\partial p}{\partial \sigma} = SN'(d)\sqrt{T} = \$40 \times 0.15 \times \sqrt{0.25} = \$3.00$$
>
> The vega per basis point can be calculated as:
>
> $$v = \frac{\partial p}{\partial \sigma} = SN'(d)\sqrt{T} \ / \ 100 = \$3.00 \ / \ 100 = \$0.03$$

In practice, vega measures the rate of change in an option's value with a basis point change in implied volatility. With a one-basis-point increase in implied volatility, the option price would increase by approximately $0.03.



PROFESSOR'S NOTE

Time, *T*, is measured on an annual basis when computing vega. Therefore, 3 months is measured as $\frac{3}{12}$ or 0.25 in the vega formula.

Vega as a Measure of Finite Shifts

The increase in option prices with changing volatility is a nonlinear process. Therefore, a one-basis-point increase in implied volatility does not equate to an exact $0.03 increase in option price at every level. The first derivative used in the vega computation provides a linear estimate of the change in price. Vega is only accurate for very small changes in volatility because it is a partial derivative, which measures the slope of a line tangent to the non-linear relationship between volatility and option price. Higher-order derivatives are used for estimating the change in price for a large shift in volatility. The following equation, based on the vega equation that was introduced previously,

uses vega for approximating the change in price as a first-order derivative (based on a linear relationship):

$$\Delta p \approx v\Delta\sigma$$

EXAMPLE: Calculating option value for small changes in implied volatility

Suppose an investor holds a long call option and a long put option on a common stock that does not pay dividends. Both options have three months to maturity and have the same strike price. The vega per basis point is $0.30 for both options. What will be the approximate change in value for both the put and call options given a −1 basis point change in implied volatility?

Answer:

The −1 change in implied volatility corresponds to a 1 basis point decline in volatility. The approximate change in price will be a decrease of $0.30 for each option and is computed as follows:

$$\Delta p \approx v\Delta\sigma = \$0.30(-1) = -\$0.30$$



PROFESSOR'S NOTE

Both the put and call options use the same formula for approximating a change in price based on vega.

Observations on Vega

Four principles are noted from observing the vega formula $v = \frac{\partial p}{\partial \sigma} = SN'(d)\sqrt{T}$.

Vega is positive for long calls and puts because all parameters on the right side of the equation are positive.

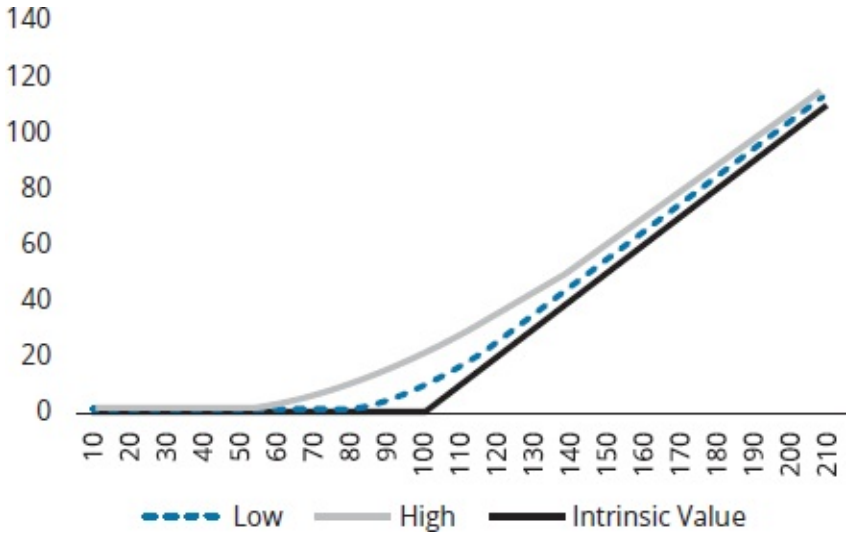
Vega must be equal for a call and put with the same time to maturity, strike price, and implied volatility, because vega is computed using the same formula for both options. Furthermore, based on the put-call parity formula of call − put = stock − bond, implied volatility is not included in the formula on the right side of the equation. Therefore, a long call and short put with the same underlying asset strike price and time to maturity have a net zero vega position where the vega of the call and put are equal.

As the time to expiration approaches zero, the option vega approaches zero.

As the value of the underlying asset gets closer to zero or infinity, the vega of an option gets closer to zero. The normal probability density approaches zero in both tails; therefore, the vega of deep-in-the-money and deep-out-of-the-money options approaches zero.

The last two observations are consistent with the relationship between the time value of call options and their moneyness. Figure 8.1A illustrates that call option prices increase, under the Black-Scholes model, with higher volatility or more time to maturity. The intrinsic value of the option is illustrated by the solid line. The *dashed curve* represents a *lower* level of volatility and time to maturity. The *gray curve* represents a *higher* level of volatility and time to maturity. Therefore, if everything else is held constant, option values will decrease (i.e., move to a lower curve) as they approach maturity and as time to maturity decreases.

Figure 8.1A: Call Option Values With High and Low Volatility Levels



Option Gamma

The second-order partial derivative of an option's value with respect to the value of the underlying asset is known as an option's gamma. Gamma is also the first-order partial derivative of delta with respect to the underlying asset value. The following formula is used to compute gamma using either the option's vega (v) or the probability density at d in the numerator, and a function of the underlying asset price, implied volatility, and time to expiration in the denominator:

$$\gamma = \frac{N'(d)}{S\sigma\sqrt{T}} = \frac{v}{(\sigma S^2 T)}$$

All parameters in the gamma formula are nonnegative. Therefore, a long call or long put will have both a positive vega and positive gamma. Short call and put options will have a negative gamma. An option's gamma represents the degree of curvature between the option value and the value of the underlying asset as illustrated by the two curves in Figure 8.1A. Both curves in Figure 8.1A have positive gamma, but the lower curve has a greater gamma, illustrated by its sharper curvature at the money. Both curves have less gamma the further out of the money or in the money the option is. Both curves have the highest gamma at the money.

Relationship Between Option Vega, Gamma, and Theta

The degree of curvature measured by gamma with respect to the underlying asset value results in increasing rates of returns for call options as the underlying asset increases in value and decreasing rates of losses for call options as the underlying stock price decreases. Similarly, put options experience increasing returns when the underlying stock price decreases in value and decreasing rates of losses when the underlying stock price increases. The asymmetric return characteristics of gamma are highly desirable, and gamma is the main reason that options sell for a premium that exceeds their intrinsic value.

Vega is very small for deep-in-the-money or deep-out-of-the-money options with near-zero gamma. Vega represents the sensitivity of changes in option prices to volatility. A higher gamma or curvature results in a higher vega as investors expect greater changes in option value with higher volatility.

Portfolios with large gamma are very desirable because they experience greater increases in value with large positive gains and smaller decreases in value with large movements of the underlying asset in the other direction. Portfolios with positive gamma tend to resemble a long call or put option.

Positive-gamma portfolios tend to be long options and therefore tend to have negative theta. A negative theta means the options on that asset will decline in value over time when an underlying asset experiences small price changes and implied volatility is very small. Thus, if the underlying asset is not expected to move in price, the value of the option decreases as it approaches maturity as a result of negative theta.

VOLATILITY AS A FACTOR

LO 8.1.3: Demonstrate knowledge of exposures to volatility as a factor.

Including:

- **Contrast long volatility with short volatility.**
- **Understand distinctions between positive vega and long volatility exposures.**
- **Explain how volatility can be used to hedge risk.**
- **Understand volatility as an unobservable but unique risk factor.**
- **Understand how long volatility carries a negative risk premium.**
- **Explain how short volatility earns a positive risk premium.**

Long vs. Short Volatility

An option or investment position has **short volatility** (short vol) when the investment returns are negatively correlated with the volatility level of a broad index (e.g., equity options relative to a broad equity market index). An option or investment position has **long volatility** (long vol) when the investment returns are positively correlated with the volatility level of the broad index. Long and short volatility are defined based on historical correlations with equity market indices.

A long (short) at-the-money call option is long (short) volatility with respect to the underlying asset's volatility. However, a deep-in-the money call option near maturity on an equity index has similar return behavior as the underlying equity index. The fifth property of realized volatility previously discussed states that an equity index value is negatively correlated with equity market volatility. Thus, a deep-in-the-money long call on an equity index is short volatility. This occurs because, when the equity index declines, the option's positive delta has a larger negative effect on the option's value than the offsetting positive-vega effect of the increase in volatility.

This illustrates that long call positions on equity markets are not always long volatility. Furthermore, many derivatives are designed to be either long or short volatility. Therefore, in addition to option exposures, the exposures to other products in the portfolio will determine whether the investment portfolio is long or short volatility.

Positive Vega vs. Long Volatility

An asset has positive vega if its price rises as implied volatility increases, assuming the other pricing inputs remain unchanged. Vega measures the sensitivity of changes to an option's value to changes in volatility of the

underlying asset, holding all else constant, including the underlying asset value. All long (short) option positions have positive (negative) vega.

There are important differences between positive vega and long vol. When an asset's returns are historically positively (negatively) correlated with volatility levels, it is long (short) volatility. An option's volatility exposure can be long or short depending on the option type and its moneyness. On the other hand, call options on equity indices that are deep in the money have positive vega but are short volatility because they are negatively correlated with the equity market index volatility.

Observed correlations are not the same as partial derivatives because observed correlations are calculated when everything else is not held constant and the underlying asset value is changing. Partial derivatives assume nothing else is changing.

Equity indices tend to fall with increased volatility. The vega of an equity index is zero and its returns are generated by delta. Thus, equity indices are short volatility because their returns are negatively correlated with equity market volatility.

Using Volatility to Hedge Risk

All previous discussions assumed static positions in assets, but we will now consider the effects of dynamic portfolio weighting strategies. Long positions in equities are short vol because their returns are negatively correlated with market volatility (higher volatility means lower asset returns). Volatility derivatives are used to hedge long positions in equity markets because the volatility derivatives are long volatility. Investors can hedge the market risk in traditional portfolios by establishing long exposure through volatility derivatives. Gains from long-volatility investments tend to offset losses on risky traditional assets during periods of financial-market crisis and rising volatility.

Volatility as a Unique Risk Factor

Volatility is a market-wide or macroeconomic factor that is one of the most important determinants driving asset returns. For that reason, multi-factor asset pricing models often include volatility.

Volatility is not immediately observable as a risk factor and is often estimated by *implied volatility* using liquid options (where asset volatility can be observed and