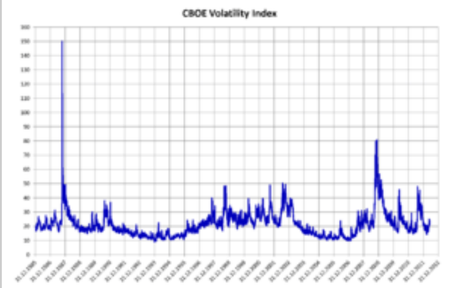
Volatility (finance)



The VIX

In finance, **volatility** is the degree of variation of a trading price series over time as measured by the standard deviation of returns.

Historic volatility is derived from time series of past market prices. An implied volatility is derived from the market price of a market traded derivative (in particular an option). The symbol σ is used for volatility, and corresponds to standard deviation, which should not be confused with the similarly named variance, which is instead the square, σ^2.

Volatility terminology

Volatility as described here refers to the **actual current** volatility of a financial instrument for a specified period (for example 30 days or 90 days). It is the volatility of a financial instrument based on historical prices over the specified period with the last observation the most recent price. This phrase is used particularly when it is wished to distinguish between the actual current volatility of an instrument.

- **actual historical volatility** which refers to the volatility of a financial instrument over a specified period but with the last observation on a date in the past
  - near synonymous is **realized volatility**, the square root of the realized variance, in turn calculated using the sum of squared returns divided by the number of observations.
- **actual future volatility** which refers to the volatility of a financial instrument over a specified period starting at the current time and ending at a future date (normally the expiry date of an option)
- **historical implied volatility** which refers to the implied volatility observed from historical prices of the financial instrument (normally options)
- **current implied volatility** which refers to the implied volatility observed from current prices of the financial instrument
- **future implied volatility** which refers to the implied volatility observed from future prices of the financial instrument

For a financial instrument whose price follows a Gaussian random walk, or Wiener process, the width of the distribution increases as time increases. This is because there is an increasing probability that the instrument's price will be farther away from the initial price as time increases. However, rather than increase linearly, the volatility increases with the square-root of time as time increases, because some fluctuations are expected to cancel each other out, so the most likely deviation after twice the time will not be twice the distance from zero.

Since observed price changes do not follow Gaussian distributions, others such as the Lévy distribution are often used.[1] These can capture attributes such as "fat tails". Volatility is a statistical measure of dispersion around the average of any random variable such as market parameters etc.

Volatility

Much research has been devoted to modeling and forecasting the volatility of financial returns, and yet few theoretical models explain how volatility comes to exist in the first place.

Roll (1984) shows that volatility is affected by market microstructure.[2] Glosten and Milgrom (1985) shows that at least one source of volatility can be explained by the liquidity provision process. When market makers infer the possibility of adverse selection, they adjust their trading ranges, which in turn increases the band of price oscillation.[3]

Volatility for investors

Investors care about volatility for seven reasons:

1. The wider the swings in an investment's price, the harder emotionally it is to not worry;
2. Price volatility of a trading instrument can define position sizing in a portfolio;
3. When certain cash flows from selling a security are needed at a specific future date, higher volatility means a greater chance of a shortfall;
4. Higher volatility of returns while saving for retirement results in a wider distribution of possible final portfolio values;
5. Higher volatility of return when retired gives withdrawals a larger permanent impact on the portfolio's value;
6. Price volatility presents opportunities to buy assets cheaply and sell when overpriced;
7. Volatility affects pricing of options, being a parameter of the Black–Scholes model.

In today's markets, it is also possible to trade volatility directly, through the use of derivative securities such as options and variance swaps. See Volatility arbitrage.

Volatility versus direction

Volatility does not measure the direction of price changes, merely their dispersion. This is because when calculating standard deviation (or variance), all differences are squared, so that negative and positive differences are combined into one quantity. Two instruments with different volatilities may have the same expected return, but the instrument with higher volatility will have larger swings in values over a given period of time.

For example, a lower volatility stock may have an expected (average) return of 7%, with annual volatility of 5%. This would indicate returns from approximately negative 3% to positive 17% most of the time (19 times out of 20, or 95% via a two standard deviation rule). A higher volatility stock, with the same expected return of 7% but with annual volatility of 20%, would indicate returns from approximately negative 33% to positive 47% most of the time (19 times out of 20, or 95%). These estimates assume a normal distribution; in reality stocks are found to be leptokurtotic.

Volatility over time

Although the Black Scholes equation assumes predictable constant volatility, this is not observed in real markets, and amongst the models are Emanuel Derman and Iraj Kani's[4] and Bruno Dupire's Local Volatility, Poisson Process where volatility jumps to new levels with a predictable frequency, and the increasingly popular Heston model of stochastic volatility.[5]

It is common knowledge that types of assets experience periods of high and low volatility. That is, during some periods, prices go up and down quickly, while during other times they barely move at all.[6]

Periods when prices fall quickly (a crash) are often followed by prices going down even more, or going up by an unusual amount. Also, a time when prices rise quickly (a possible bubble) may often be followed by prices going up even more, or going down by an unusual amount. The converse behavior, 'doldrums', can last for a long time as well. (Doldrums: stagnation: a state of inactivity (in business or art etc); "economic growth of less than 1% per year is considered to be economic stagnation" http://wordnetweb.princeton.edu /perl/webwn?s=doldrums)

Most typically, extreme movements do not appear 'out of nowhere'; they are presaged by larger movements than usual. This is termed autoregressive conditional heteroskedasticity. Of course, whether such large movements have the same direction, or the opposite, is more difficult to say. And an increase in volatility does not always presage a further increase—the volatility may simply go back down again.

Mathematical definition

For any fund that evolves randomly with time, the square of volatility is the variance of the sum of infinitely many instantaneous rates of return, each taken over the nonoverlapping, infinitesimal periods that make up a single unit of time.

Thus, "annualized" volatility σ is the standard deviation of an instrument's yearly logarithmic returns.[7]

The generalized volatility σ_T for time horizon T in years is expressed as:

$$\sigma_T = \sigma\sqrt{T}.$$

Therefore, if the daily logarithmic returns of a stock have a standard deviation of σ_{SD} and the time period of returns is P, the annualized volatility is

$$\sigma = \frac{\sigma_{SD}}{\sqrt{P}}.$$

A common assumption is that P = 1/252 (there are 252 trading days in any given year). Then, if $\sigma_{SD} = 0.01$ the annualized volatility is

$$\sigma_{\text{annual}} = \frac{0.01}{\sqrt{\frac{1}{252}}} = 0.01\sqrt{252} = 0.1587.$$

The monthly volatility (i.e., T = 1/12 of a year) would be

$$\sigma_{\text{monthly}} = 0.1587\sqrt{\frac{1}{12}} = 0.0458.$$

The formula used above to convert returns or volatility measures from one time period to another assume a particular underlying model or process. These formulas are accurate extrapolations of a random walk, or Wiener process, whose steps have finite variance. However, more generally, for natural stochastic processes, the precise relationship between volatility measures for different time periods is more complicated. Some use the Lévy stability exponent α to extrapolate natural processes:

$$\sigma_T = T^{1/\alpha}\sigma.$$

If α = 2 you get the Wiener process scaling relation, but some people believe α < 2 for financial activities such as stocks, indexes and so on. This was discovered by Benoît Mandelbrot, who looked at cotton prices and found that they followed a Lévy alpha-stable distribution with α = 1.7. (See New Scientist, 19 April 1997.)

Implied Volatility parametrisation

There exist several known parametrisation of the implied volatility surface, Schonbucher, SVI and gSVI.[8]

Crude volatility estimation

Using a simplification of the formulae above it is possible to estimate annualized volatility based solely on approximate observations. Suppose you notice that a market price index, which has a current value near 10,000, has moved about 100 points a day, on average, for many days. This would constitute a 1% daily movement, up or down.

To annualize this, you can use the "rule of 16", that is, multiply by 16 to get 16% as the annual volatility. The rationale for this is that 16 is the square root of 256, which is approximately the number of trading days in a year (252). This also uses the fact that the standard deviation of the sum of *n* independent variables (with equal standard deviations) is √n times the standard deviation of the individual variables.

Of course, the average magnitude of the observations is merely an approximation of the standard deviation of the market index. Assuming that the market index daily changes are normally distributed with mean zero and standard deviation σ, the expected value of the magnitude of the observations is √(2/π)σ = 0.798σ. The net effect is that this crude approach underestimates the true volatility by about 20%.

Estimate of compound annual growth rate (CAGR)

Consider the Taylor series:

$$\log(1+y) = y - \tfrac{1}{2}y^2 + \tfrac{1}{3}y^3 - \tfrac{1}{4}y^4 + \ldots$$

Taking only the first two terms one has:

$$\mathrm{CAGR} \approx \mathrm{AR} - \tfrac{1}{2}\sigma^2$$

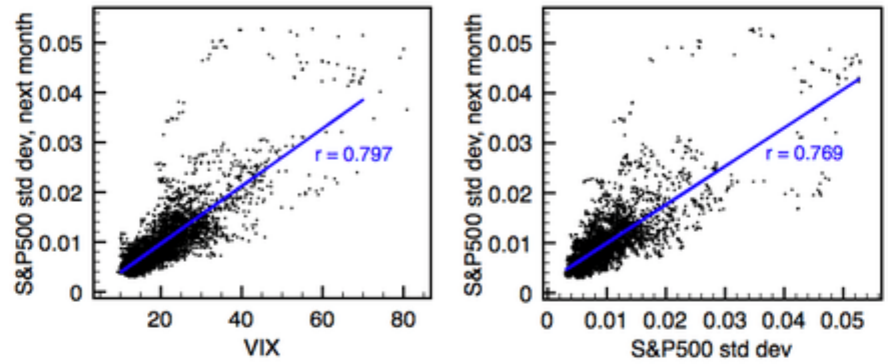
Realistically, most financial assets have negative skewness and leptokurtosis, so this formula tends to be over-optimistic. Some people use the formula:

$$\mathrm{CAGR} \approx \mathrm{AR} - \tfrac{1}{2}k\sigma^2$$

for a rough estimate, where *k* is an empirical factor (typically five to ten).

Criticisms of volatility forecasting models

Despite the sophisticated composition of most volatility forecasting models, critics claim that their predictive power is similar to that of plain-vanilla measures, such as simple past volatility [9][10] especially out-of-sample, where different data are used to estimate the models and to test them.[11] Other works have agreed, but claim critics failed to correctly implement the more complicated models.[12] Some practitioners and portfolio managers seem to completely ignore or dismiss volatility forecasting models. For example, Nassim Taleb famously titled one of his *Journal of Portfolio Management* papers "We Don't Quite Know What We are Talking About When We Talk About Volatility".[13] In a similar note, Emanuel Derman expressed his disillusion with the enormous supply of empirical models unsupported by theory.[14] He argues that, while "theories are attempts to uncover the hidden principles underpinning the world around us, as Albert Einstein did with his theory of relativity", we should remember that "models are metaphors -- analogies that describe one thing relative to another".



Performance of VIX (left) compared to past volatility (right) as 30-day volatility predictors, for the period of Jan 1990-Sep 2009. Volatility is measured as the standard deviation of S&P500 one-day returns over a month's period. The blue lines indicate linear regressions, resulting in the correlation coefficients *r* shown. Note that VIX has virtually the same predictive power as past volatility, insofar as the shown correlation coefficients are nearly identical.

Volatility Hedge Funds

Well known hedge fund managers with expertise in trading volatility include Paul Britton of Capstone Holdings Group,[15] Andrew Feldstein of Blue Mountain Capital Management,[16] and Nelson Saiers from Saiers Capital.[17]

See also

- Beta (finance)
- Derivative (finance)
- Financial economics
- IVX
- Risk
- VIX
- Volatility smile

References

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5. ↑ "Volatility". *wilmottwiki.com*.
6. ↑ "Taking Advantage Of Volatility Spikes With Credit Spreads".
7. ↑ "Calculating Historical Volatility: Step-by-Step Example" (PDF). 14 July 2011. Retrieved 15 July 2011.
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13. ↑ Goldstein, Daniel and Taleb, Nassim, (28 March 2007) "We Don't Quite Know What We are Talking About When We Talk About Volatility". *Journal of Portfolio Management* **33** (4), 2007.
14. ↑ Derman, Emanuel (2011): Models.Behaving.Badly: Why Confusing Illusion With Reality Can Lead to Disaster, on Wall Street and in Life", Ed. Free Press.
15. ↑ Devasabai, Kris (1 March 2010). "Interview with Paul Britton Founder CEO of Capstone". *Hedge Funds Review*. Retrieved 26 April 2013.
16. ↑ Schaefer, Steve (14 February 2013). "Blue Mountain's Andrew Feldstein: Three Ways to Play a More Volatile Steel Industry". *Forbes*. Retrieved 26 April 2013.
17. ↑ Creswell, Julie and Louise Story (17 March 2011). "Funds Find Opportunities in Volatility". *New York Times*. Retrieved 26 April 2013.

External links

- Graphical Comparison of Implied and Historical Volatility, video
- An introduction to volatility and how it can be calculated in excel, by Dr A. A. Kotzé
- Diebold, Francis X.; Hickman, Andrew; Inoue, Atsushi & Schuermannm, Til (1996) "Converting 1-Day Volatility to h-Day Volatility: Scaling by sqrt(h) is Worse than You Think"
- A short introduction to alternative mathematical concepts of volatility
- Volatility estimation from predicted return density Example based on Google daily return distribution using standard density function
- Research paper including excerpt from report entitled Identifying Rich and Cheap Volatility Excerpt from Enhanced Call Overwriting, a report by Ryan Renicker and Devapriya Mallick at Lehman Brothers (2005).

Further reading

1. Bartram, Söhnke M.; Brown, Gregory W.; Stulz, Rene M. (August 2012). "Why Are U.S. Stocks More Volatile?". *Journal of Finance*. **67** (4): 1329–1370. doi:10.1111/j.1540-6261.2012.01749.x.

Volatility	
Modelling volatility	Implied volatility · Volatility smile · Volatility clustering · Local volatility · Stochastic volatility · Jump-diffusion models · ARCH and GARCH

Trading volatility	Volatility arbitrage · Straddle · Volatility swap · IVX · VIX

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Types of markets	Primary market · Secondary market · Third market · Fourth market
Types of stocks	Common stock · Golden share · Preferred stock · Restricted stock · Tracking stock
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Participants	Broker-dealer · Day trader · Floor broker · Floor trader · Investor · Market maker · Proprietary trader · Quantitative analyst · Regulator · Stock trader
Exchanges	Electronic communication network · List of stock exchanges (Opening times) · Multilateral trading facility · Over-the-counter
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Patterns	**Chart**	Broadening top · Cup and handle · Double top and double bottom · Flag and pennant · Gap · Head and shoulders · Island reversal · Price channels · Triangle · Triple top and triple bottom · Wedge pattern

Indicators	Candlestick	Simple	Doji · Hammer · Hanging man · Inverted hammer · Marubozu · Shooting star · Spinning top
		Complex	Hikkake pattern · Morning star · Three Black Crows · Three white soldiers
	Support & resistance		Bottom · Fibonacci retracement · Pivot point (PP) · Top
	Trend		Average directional index (A.D.X.) · Commodity channel index (CCI) · Detrended price oscillator (DPO) · Know sure thing oscillator (KST) · Ichimoku Kinkō Hyō · Moving average convergence/divergence (MACD) · Mass index · Moving average (MA) · Parabolic SAR (SAR) · Smart money index (SMI) · Trend line · Trix · Vortex Indicator (VI)
	Momentum		Money flow index (MFI) · Relative strength index (RSI) · Stochastic oscillator · True strength index (TSI) · Ultimate oscillator · Williams %R (%R)
	Volume		Accumulation/distribution line · Ease of movement (EMV) · Force index (FI) · Negative volume index (NVI) · On-balance volume (OBV) · Put/call ratio (PCR) · Volume–price trend (VPT)
	Volatility		Average true range (ATR) · Bollinger Bands (BB) · Donchian channel · Keltner channel · CBOE Market Volatility Index (VIX) · Standard deviation (σ)
	Breadth		Advance–decline line (ADL) · Arms index (TRIN) · McClellan oscillator
	Other		Coppock curve · Ulcer index