CHARTA LEARNING · LESSON NOTES

Calculating and Applying VaR

FRM Part I

1 What a V a R number says

- What loss do we exceed one day in a hundred?
- Two choices: confidence level and horizon
- Ninety-nine per cent, one day: one bad day in a hundred
- V a R is a threshold, not the worst case

IN THE LESSON

- Start with the question V a R answers.
- Suppose you hold investments worth ten million dollars.
- You ask: over one day, what loss is so bad that I should only see it on one day in a hundred?
- If the answer is three hundred thousand dollars, then on ninety nine days out of a hundred you expect to lose less than that, or even make money.
- Notice what the number does not say.
- It does not say how bad the other one day could be.
- The two choices you make are the confidence level, here ninety nine per cent, and the horizon, here one day.
- The hard part is estimating the loss, and that is the rest of this lesson.

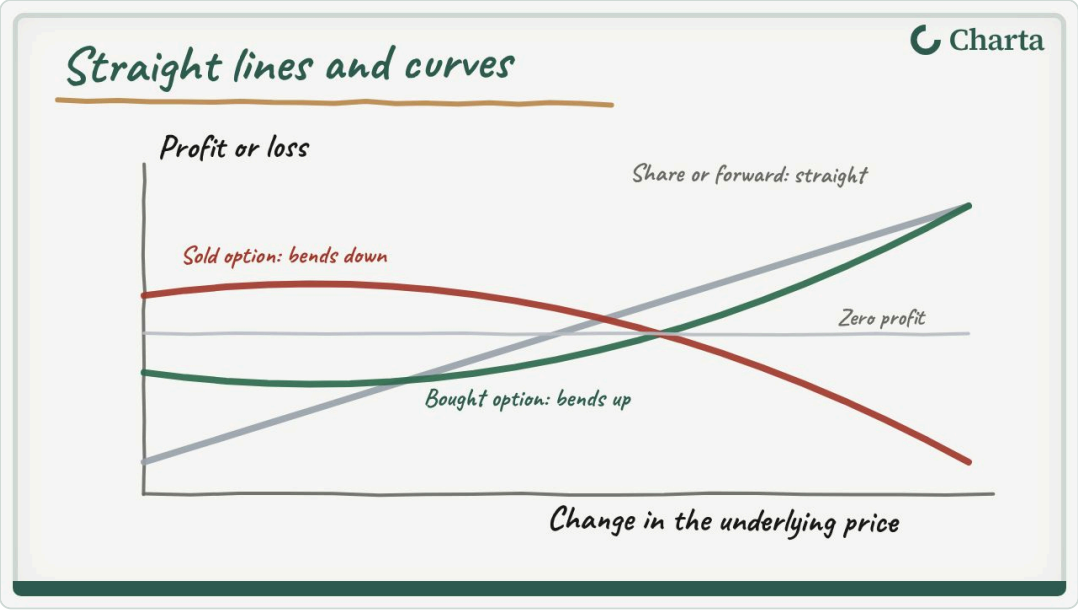
2 Linear and non-linear portfolios

- Risk factor: the market variable that drives value
- Linear: double the move, double the profit or loss
- Up and down moves give mirror-image results
- Non-linear: curved or kinked value, no simple scaling

IN THE LESSON

- Before measuring anything, we sort portfolios into two families.
- In a linear portfolio, the change in value is proportional to the move in the thing that drives it, which we call a risk factor.
- Double the market move and you double the profit or loss.
- A rise and a fall of equal size give mirror image results.
- In a non-linear portfolio, the value is a curved or bent function of the risk factor, so doubling the move does not double the result, and a rise and a fall are not mirror images.
- The test is the shape of the value line.
- Straight means linear.
- Curved or kinked means non-linear.

3 Straight lines and curves



IN THE LESSON

- Here is the picture.
- Across the bottom is the change in the underlying price, falling on the left and rising on the right.
- Up the side is the profit or loss on the position.
- The grey straight line is a holding of shares, or a forward contract.
- Every extra dollar of market move gives the same extra profit.
- The green curve is a bought option.
- When the market falls its loss is limited, and when the market rises it gains faster and faster, so the line bends upward.
- The red curve is a sold option, the mirror image: small gains when things are calm, and losses that speed up when the market moves.
- Bending is the signature of non-linearity.

4 Sorting positions by shape

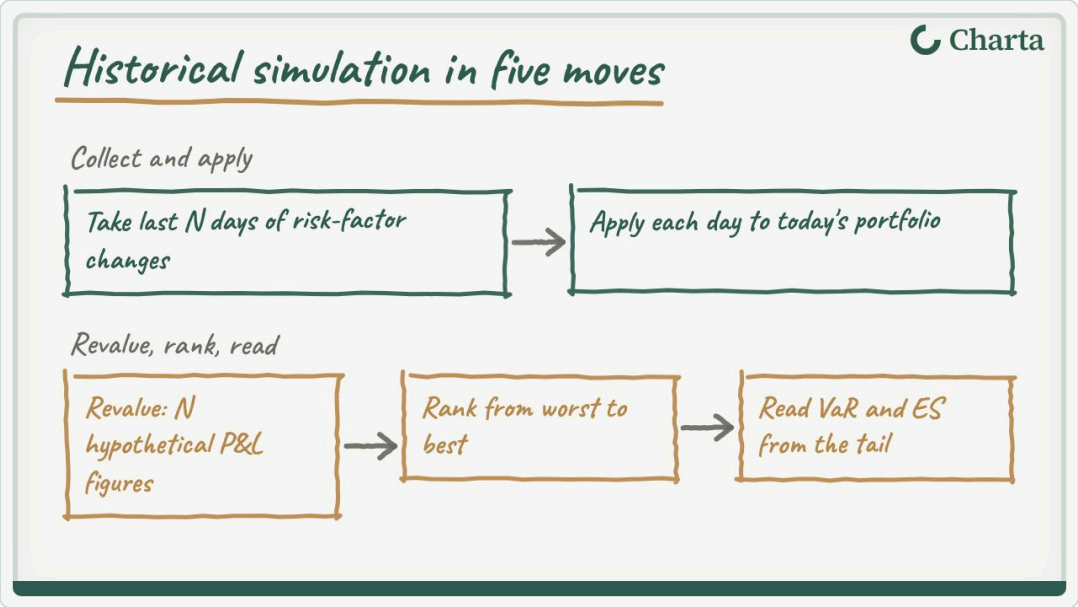
The shape of the value function decides, not the label

Position	Shape
Cash shares, currency	Linear
Futures and forwards	Linear
Options	Non-linear
Bonds against yield	Non-linear
Delta-neutral option book	Still non-linear

IN THE LESSON

- Now let's sort real positions.
- Shares are linear, because a one per cent rise in the price is a one per cent rise in your value.
- A currency position is linear in the exchange rate.
- Futures and forwards are linear too.
- A forward is worth the spot price minus the discounted delivery price, and that moves one for one with spot.
- Options are non-linear, because their payoff has a kink.
- So are bonds when measured against the yield, because the price curves as yields change.
- Two traps.
- Not every derivative is non-linear, forwards are not.
- And a book hedged to be delta neutral is not linear.
- Delta only gives the slope at today's price.

5 Historical simulation in five moves



IN THE LESSON

- Our first method is historical simulation, which simply replays the past on today's portfolio.
- First, collect the last N trading days, typically five hundred to one thousand.
- Second, for each of those days, write down how the risk factors moved: how much each share price, exchange rate or interest rate changed.
- Third, apply each day's moves to the portfolio you hold today.
- Fourth, revalue the whole portfolio under each set of moves, which gives N imaginary profit and loss figures.
- Fifth, rank them from worst to best and read off the answer.
- Notice the second step.
- We replay past changes in the risk factors, not past profits of the old portfolio.

6 Example 1: historical simulation

500 scenarios, $10m portfolio. Worst five losses: 412, 371, 338, 306, 295 ($ thousand)

Tail size	1% × 500 scenarios	**5**
99% VaR	fifth worst loss	**$295k**
Sum of worst five	412+371+338+306+295	**1,722**
Expected shortfall	1,722 ÷ 5	**$344.4k**

IN THE LESSON

- Let's use five hundred scenarios on a ten million dollar portfolio.
- After ranking, the five worst losses are, in thousands of dollars, four hundred twelve, three hundred seventy one, three hundred thirty eight, three hundred six, and two hundred ninety five.
- At ninety nine per cent confidence, one per cent of five hundred scenarios is five scenarios.
- So V a R is the loss at the fifth worst point, two hundred ninety five thousand dollars.
- Expected shortfall, E S, is the average of the losses in the tail.
- The mean of those five is one thousand seven hundred twenty two divided by five, or three hundred forty four point four thousand.
- E S is never smaller than V a R.

7 Strengths and weaknesses of replaying history

- No distribution assumed; full revaluation handles options
- All days weighted equally: slow to react to new volatility
- Only what is in the window can appear in the tail
- Use past risk-factor changes, not past P&L

IN THE LESSON

- What is good about this method?
- It needs no assumption that returns follow a bell curve, because the data speak for themselves.
- And because it revalues the portfolio in full each time, it handles options and other bent positions properly.
- What is less good?
- Every day in the window counts equally, so a calm stretch can bury a turbulent one, and the method reacts slowly when volatility changes.
- It can only show you what happened in the sample, so an event that is not in the window cannot appear.
- With five hundred days, the one per cent tail rests on just five observations, which is fragile.
- And remember the common error: use past changes in risk factors, never past profits.

8 The delta normal shortcut

- Replace the option by a straight line through today's price
- Delta: option value change per unit of move
- Equivalent position = delta × units × underlying price
- Assume normal returns, then value at risk as for shares

IN THE LESSON

- Revaluing everything is thorough but heavy.
- The delta normal approach is a quick shortcut for options.
- The idea is to replace the option by a straight line.
- Delta is the number that says how much the option's value changes for a small move in the underlying price.
- If delta is point six, a one dollar rise in the share lifts the option by about sixty cents.
- So for risk purposes, the option behaves like holding point six of a share.
- That stand-in is the equivalent position.
- We then assume the risk factors move with a bell shaped, normal distribution, and use the same recipe as for shares.
- The options have vanished, replaced by an equivalent exposure.

9 Delta normal V a R

VaR = z × σ × abs(δ) × position value

Confidence multiplier, z	2.326 at 99% confidence
Volatility, sigma	Volatility over the horizon
Delta	Absolute value: a put is negative
Position value	Units × underlying price

IN THE LESSON

- Here is the recipe for one underlying.
- V a R equals z times sigma times the absolute value of delta times the position value.
- The z is the confidence multiplier from the normal curve: two point three two six at ninety nine per cent.
- Sigma is the volatility of the underlying's return over your horizon.
- Delta times the position value is the equivalent exposure.
- We take the absolute value because a put option has a negative delta, yet its V a R is a positive loss number.
- And if your volatility is daily, multiply it by the square root of the number of days to reach a longer horizon.
- With several underlyings, combine the exposures using the covariance matrix.

10 Example 2: V a R of a put option position

10,000 puts on one share each. Share $50, delta −0.4, daily σ 2%, z = 2.326

Equivalent exposure	0.4 × 10,000 × $50	**$200,000**
One-day 99% VaR	2.326 × 0.02 × 200,000	**$9,304**
Ten-day VaR	9,304 × √10	**$29,422**
Trap: full notional	2.326 × 0.02 × 500,000	**$23,260**

IN THE LESSON

- Take ten thousand put options, each on one share.
- The share trades at fifty dollars, and the delta of each put is minus point four.
- The daily volatility of the share is two per cent.
- Step one, the equivalent exposure: point four times ten thousand times fifty is two hundred thousand dollars, using the absolute delta.
- Step two, the one day ninety nine per cent V a R: two point three two six times point zero two times two hundred thousand is nine thousand three hundred four dollars.
- Step three, for ten days multiply by the square root of ten, giving about twenty nine thousand four hundred twenty two.
- The trap is applying the formula to the full share value of five hundred thousand dollars, which gives twenty three thousand two hundred sixty.

11 Linear derivatives: forwards and futures

- Long forward = long share + borrow PV of price
- Exposure = the share position
- Short has the same V a R size as long
- Never use the delivery price or the margin as exposure

IN THE LESSON

- Now the easy case, derivatives that really are straight lines.
- A forward contract on a share that pays no dividend equals a long position in the share, plus borrowing the present value of the delivery price.
- The borrowing is a fixed amount that does not wobble with the market, so all the risk comes from the share.
- The exposure is therefore the share position, and the V a R is the same as for the share itself.
- A short forward has exactly the same V a R as a long one, because the loss distribution is just flipped.
- Be careful about what you use as exposure.
- It is never the delivery price, and never the margin you post.

12 Exposure of an index future

Exposure = contracts × multiplier × futures price
VaR = z × σ × exposure

Contracts and multiplier	Contracts × dollars per point
Futures price	Current futures price
Confidence multiplier, z	Confidence multiplier
Volatility, sigma	Volatility of the index return

IN THE LESSON

- For an equity index future, the exposure is the number of contracts, times the contract multiplier, times the futures price.
- The multiplier says how many dollars each index point is worth.
- Once you have the exposure, the rest is as before: V a R equals z times sigma times the exposure, where sigma is the volatility of the index return.
- For a currency forward, the exposure is the foreign amount, discounted at the foreign interest rate, then converted at the spot exchange rate.
- In a book with several positions, the signs of long and short enter the correlation term.
- A long and a short in assets that move together offset each other, which is the point of hedging.

13 Example 3: an index futures position

Long 20 contracts, multiplier $50 per point, futures price 4,000, daily σ 1.2%

Exposure	20 × 50 × 4,000	**$4,000,000**
Daily σ in dollars	1.2% × 4,000,000	**$48,000**
One-day 99% VaR	2.326 × 48,000	**$111,648**
Same size if short	sign flips, size same	**$111,648**

IN THE LESSON

- Let's say a fund is long twenty index futures.
- Each contract has a multiplier of fifty dollars per index point, and the futures price is four thousand.
- Step one, the exposure: twenty times fifty times four thousand is four million dollars.
- Step two, suppose the index has daily volatility of one point two per cent.
- The one day ninety nine per cent V a R is two point three two six times point zero one two times four million, which is one hundred eleven thousand six hundred forty eight dollars.
- If the fund were short the same twenty contracts, the V a R would be identical in size.
- And if the exchange asked for three hundred thousand dollars of margin, that figure plays no part in the calculation.

14 Example 4: a currency forward

Receive €1,000,000 in one year. Euro rate 3%, spot $1.10 per €, daily σ 0.7%

Discount at euro rate	€1,000,000 ÷ 1.03	**€970,874**
Convert at spot	€970,874 × 1.10	**$1,067,961**
Daily σ in dollars	0.7% × 1,067,961	**$7,476**
One-day 99% VaR	2.326 × 7,476	**$17,389**

IN THE LESSON

- Now a currency forward.
- A U S firm will receive one million euros in one year through a forward contract.
- The euro interest rate is three per cent, and today's spot rate is one dollar ten per euro.
- The exposure is the foreign amount discounted at the foreign rate: one million divided by one point zero three, which is about nine hundred seventy thousand eight hundred seventy four euros.
- Convert at spot, multiplying by one point one, and the exposure is about one million sixty seven thousand nine hundred sixty one dollars.
- With daily exchange rate volatility of point seven per cent, the one day ninety nine per cent V a R is two point three two six times point zero zero seven times the exposure, about seventeen thousand three hundred eighty nine dollars.

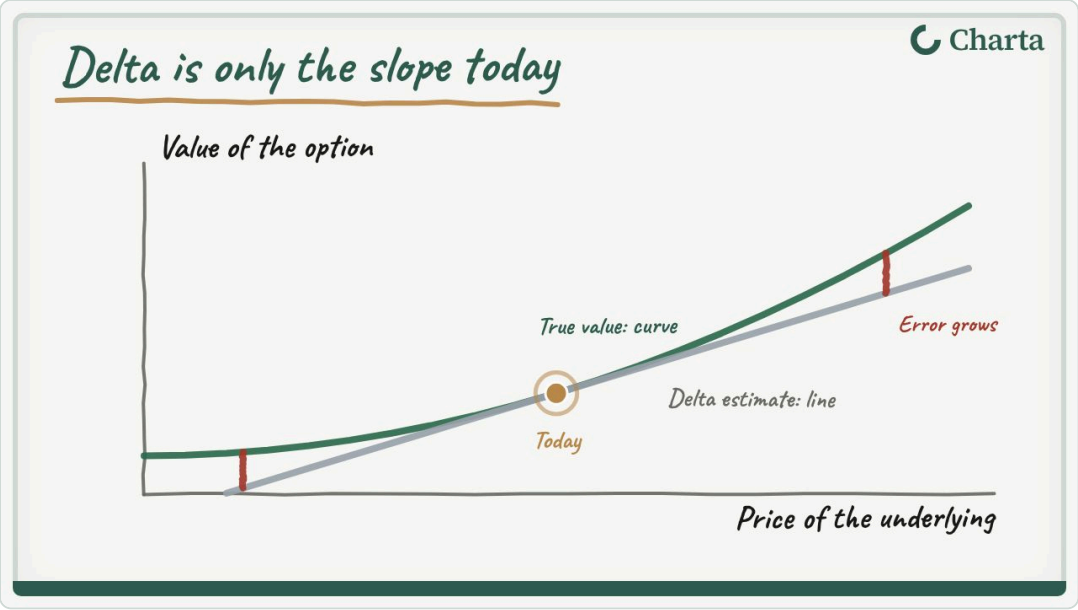
15 When delta normal breaks down

- Assumption 1: value is a straight line in the risk factor
- Assumption 2: risk factors are jointly normal
- Worst cases: large gamma, big moves, long horizons
- Short option books lose more than delta predicts

IN THE LESSON

- The delta normal method rests on two assumptions.
- First, that value changes are a straight line in the risk factors.
- Second, that the risk factors are jointly normal.
- When either fails, the answer can be badly wrong.
- The straight line fails when gamma is large, for example with options close to the strike price and near expiry.
- It fails for big market moves and for long horizons, because the line is only accurate close to today's price.
- It fails worst for a short option book, where the true loss is bigger than delta says.
- The second assumption fails because real returns have fat tails and skew, so extreme days come more often than the bell curve suggests.

16 Delta is only the slope today



IN THE LESSON

- Here is why.
- The green curve is the true value of a bought option as the underlying price changes.
- The dot marks today's price.
- Delta is the slope of the line that just touches the curve there, drawn in grey.
- Near the dot, line and curve are almost the same.
- But move away and they part company.
- The gap in red is the error, and it grows with the size of the move.
- For a bought option the curve lies above the line, so delta overstates the loss from a fall.
- For a sold option the picture is flipped: the true curve lies below the line, so the real loss is larger than the delta estimate says.

17 Adding the gamma term

Change in value ≈ δ × ΔS + ½ × Γ × (ΔS)²

Delta	Slope: what delta normal keeps
Gamma	How fast delta changes
Move in the underlying	Move in the underlying price

IN THE LESSON

- To see the missing piece, we add a second term.
- The change in the option's value is roughly delta times the move in the underlying, plus one half times gamma times the move squared.
- The first piece is what delta normal keeps.
- The second piece is the gamma term, which it throws away.
- Gamma measures how fast delta itself changes, in other words how bent the curve is.
- Because the move is squared, doubling the move quadruples the gamma term.
- A bought option has positive gamma, so the term helps.
- A sold option has negative gamma, so the term hurts, and it hurts more the bigger the move.

18 Example 5: a delta-neutral short option book

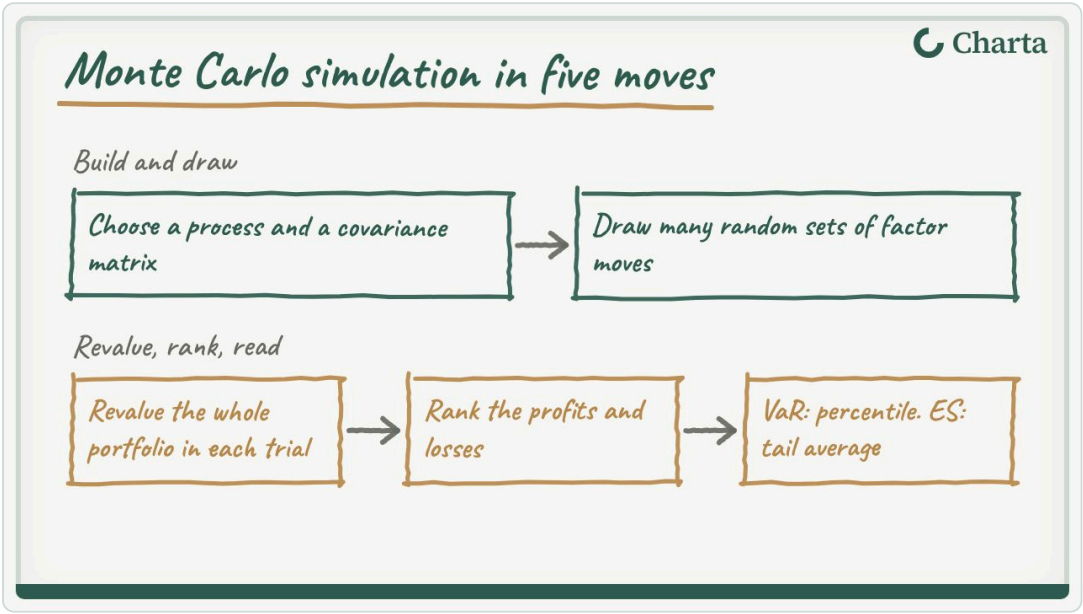
Net delta 0, gamma −30 per $ of price move. Delta normal reports VaR = 0

Delta effect, any move	0 × ΔS	**$0**
Gamma term, $10 move	½ × (−30) × 10²	**−$1,500**
Gamma term, $20 move	½ × (−30) × 20²	**−$6,000**
Delta normal VaR	|0| × z × σ × value	**$0**

IN THE LESSON

- A trader has sold options and hedged with shares, so the book has zero net delta.
- But the book's gamma is minus thirty per dollar, meaning delta shifts thirty units for each dollar of price move.
- A delta normal model sees zero delta, so it reports a V a R of zero.
- Now the share moves by ten dollars, up or down.
- The delta part is zero.
- The gamma term is half times minus thirty times ten squared, which is minus fifteen hundred dollars.
- Make the move twenty dollars, and the term is half times minus thirty times four hundred, minus six thousand dollars, four times as much for double the move.
- A book that looks riskless carries real risk.

19 Monte Carlo simulation in five moves



IN THE LESSON

- Our third method is Monte Carlo simulation.
- Instead of replaying the real past, it invents many possible futures.
- First, choose a model for how each risk factor moves, for instance geometric Brownian motion, which makes returns follow a bell curve around a steady drift, along with a covariance matrix to describe how the factors move together.
- Second, draw many random sets of factor moves, with the right correlations.
- Third, revalue the whole portfolio in each trial.
- Fourth, rank the resulting profits and losses.
- Fifth, V a R is the percentile of that simulated distribution, and E S is the average of the trials in the tail.
- Typically we use tens of thousands of trials.

20 Example 6: making draws correlated

Correlation ρ = 0.6. Independent normal draws: z_1 = 1.0 and z_2 = −0.5

Weight on second draw	$\sqrt{(1 - 0.6^2)} = \sqrt{0.64}$	**0.8**
Factor one	$x_1 = z_1$	**1.0**
Factor two	$0.6 \times 1.0 + 0.8 \times (-0.5)$	**0.2**
Rule	$x_2 = \rho z_1 + \sqrt{(1-\rho^2)} z_2$	

IN THE LESSON

- Random number generators give independent draws, but risk factors move together.
- The fix is to combine independent draws using what is called a Cholesky factorisation.
- For two factors with correlation rho, the first factor takes the first draw as it is.
- The second factor takes rho times the first draw, plus the square root of one minus rho squared, times the second draw.
- Say rho is point six.
- The square root of one minus point three six is point eight.
- Suppose the independent draws are one and minus point five.
- The first factor is one.
- The second is point six times one, plus point eight times minus point five, which is point two.
- The two now have the right correlation.

21 Monte Carlo: strong and weak

Powerful, but the answer is only as good as the model

Strength or weakness	Why
Strength: non-linear	Full revaluation each trial
Strength: flexible	Any distribution, paths, many factors
Weakness: slow	Heavy computation
Weakness: sampling error	Falls with √(trials) only
Weakness: model risk	Wrong process, wrong answer

IN THE LESSON

- Where is Monte Carlo strong?
- It revalues the whole portfolio in each trial, so it handles non-linear positions.
- It lets you choose non-normal distributions, positions where the payoff depends on the whole path of prices, and portfolios with many risk factors.
- Where is it weak?
- It needs heavy computation.
- It has sampling error, which shrinks only with the square root of the number of trials, so a hundred times more trials gives only ten times more accuracy.
- And it carries model risk: the answer is only as good as the assumed process and its parameters.
- Simulation does not remove the need for assumptions.
- It hides them inside the model.

22 When correlations break down

- Calm times: assets partly offset each other
- Crisis: correlations jump toward one
- Hedges can fail; diversification vanishes when needed
- Calm-period models understate stress losses

IN THE LESSON

- Delta normal and Monte Carlo both lean on correlations estimated in ordinary times.
- The trouble is that correlations are not fixed.
- In a crisis, the correlations between risky assets tend to jump sharply toward one, because investors sell everything at once.
- Some hedges stop working altogether.
- This is called correlation breakdown.
- Diversification, the free protection that comes from owning things that do not move together, disappears just when you need it most.
- A model fed with calm period correlations will therefore understate losses in stress.
- The risk is not that the numbers are rounded badly.
- The risk is that the relationship you measured was true only in good weather.

23 Two-asset V a R and correlation

VaR = z × sqrt(a² + b² + 2 × ρ × a × b)

Confidence multiplier, z	Confidence multiplier
Stand-alone dollar risks	Dollar standard deviation of each
Correlation, rho	Correlation between the two

IN THE LESSON

- For two assets with normal returns and zero average return, portfolio V a R is z times the square root of a squared, plus b squared, plus two times rho times a times b.
- Here a and b are the stand-alone dollar standard deviations of the two positions, and rho is the correlation.
- Look at the last term.
- When rho rises, that term grows, and V a R rises with it.
- When rho is one, the square root simplifies to a plus b, so V a R equals the sum of the two stand-alone V a Rs.
- That is the upper bound.
- Any correlation below one gives a smaller number, and that gap is the diversification benefit.

24 Example 7: calm against crisis

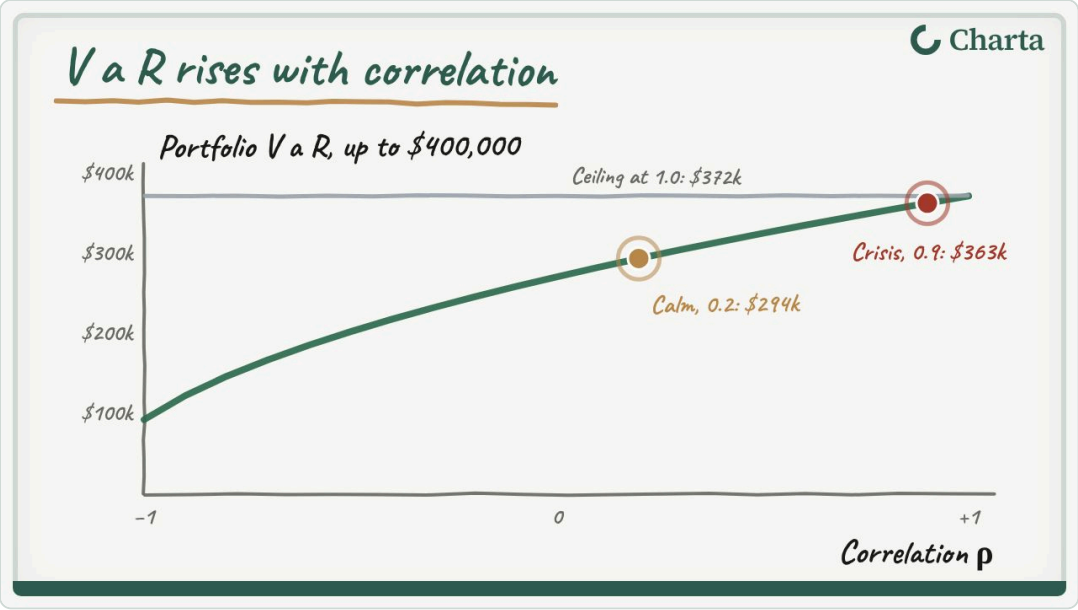
a = $100,000, b = $60,000, z = 2.326. Same positions, two correlations

Calm, ρ = 0.2	2.326 × √(1.6 × 10^{10})	**$294,218**
Crisis, ρ = 0.9	2.326 × √(2.44 × 10^{10})	**$363,333**
Upper bound, ρ = 1	2.326 × (100,000 + 60,000)	**$372,160**
Crisis is higher by	(363,333 − 294,218) ÷ 294,218	**23%**
Calm understated by	(363,333 − 294,218) ÷ 363,333	**19%**

IN THE LESSON

- Take two positions.
- Position A has a daily dollar standard deviation of one hundred thousand dollars, and position B sixty thousand.
- In calm markets the correlation is point two.
- Inside the root: ten billion, plus three point six billion, plus two times point two times six billion, which is two point four billion.
- The total is sixteen billion, and the root is about one hundred twenty six thousand four hundred ninety one.
- Times two point three two six gives about two hundred ninety four thousand two hundred eighteen dollars.
- In a crisis the correlation is point nine, and the V a R is about three hundred sixty three thousand three hundred thirty three.
- The crisis V a R is about twenty three per cent higher, so the calm model understated the loss by about nineteen per cent.

25 V a R rises with correlation



IN THE LESSON

- Here is the same pair of positions across every correlation.
- Along the bottom the correlation runs from minus one on the left to plus one on the right.
- Up the side is the portfolio V a R, on a scale up to four hundred thousand dollars.
- At minus one the positions largely offset and V a R is only about ninety three thousand dollars.
- As correlation rises, the curve climbs.
- The first dot is the calm estimate at point two.
- The second is the crisis case at point nine, already much higher.
- The curve flattens as it nears the top, where correlation of one gives the sum of the stand-alone figures, the grey ceiling.
- Diversification can never do worse than that line, but a crisis pushes you toward it.

26 How risk managers respond

- Stress correlations upward, toward one for risky assets
- Use crisis-period estimates alongside calm ones
- Keep the stressed correlation matrix consistent
- Never assume correlation is constant across regimes

IN THE LESSON

- What can a risk manager do?
- First, stress the correlations: rerun the V a R and E S with correlations pushed up, even to one for the assets most likely to move together.
- Second, use estimates from a crisis period, such as two thousand eight, instead of relying only on calm years.
- Third, keep the stressed matrix internally consistent.
- You cannot raise one correlation by hand and leave the rest, because the set of correlations must still be mathematically possible together.
- Fourth, remember that a higher correlation raises both V a R and expected shortfall.
- The error to avoid is simple: assuming that the correlation you measured last year will hold in every market regime.

27 V a R against worst-case analysis

- VaR: loss exceeded on one day, small chance
- Worst case: the worst loss over N days
- V a R is a threshold; worst case is about severity
- A daily 99% VaR is breached about once in 100 days

IN THE LESSON

- Our last topic compares V a R with worst case scenario analysis.
- They ask different questions.
- V a R asks: what loss will be exceeded with a small probability on a single day?
- Worst case analysis asks: over a longer period, say N days, how bad does the single worst loss get, and what is the distribution of that worst loss?
- That second question is closer to what keeps managers awake.
- Think of a daily V a R as the height of a flood wall that is overtopped one day in a hundred.
- Over a whole year, you will be overtopped some days, and the interesting question is how high the worst wave rises above the wall.

28 The worst loss over N days

Prob(worst loss over N days < x) = $F(x)^N$

Single-day loss distribution, F	Chance one day's loss is below x
Loss level, x	The loss level you test
Number of days, N	Number of independent days

IN THE LESSON

- Here is the key result.
- Suppose daily losses are independent, and write F of x for the chance that one day's loss is below x.
- The worst loss over N days is below x only if every one of the N days is below x.
- Because the days are independent, we multiply the chances, so the probability that the worst loss over N days stays below x is F of x, raised to the power N.
- With x set at the daily ninety nine per cent V a R, F of x is point nine nine.
- Raise point nine nine to a large power and it shrinks quickly.
- That is why, over a year, a breach of the daily V a R is almost certain.

29 Example 8: a year of trading days

Daily 99% VaR, 250 trading days, independent days

Expected breaches	250 × 1%	**2.5 days**
Chance of no breach	0.99^{250}	**0.081**
Chance of at least one	1 − 0.081	**0.919**
In words	about nine years in ten	**92%**

IN THE LESSON

- Take a daily ninety nine per cent V a R and a year of two hundred fifty trading days.
- On average the V a R is breached one per cent of the time, which is two point five days a year.
- Now ask: what is the chance of no breach at all?
- That is point nine nine raised to the power two hundred fifty, about point zero eight one.
- So the chance of at least one breach is one minus that, about point nine one nine, or ninety two per cent.
- In plain words, in most years the worst day will be worse than the V a R.
- A daily V a R is not the most you can lose, and the formula tells us how likely it is to be exceeded.

30 V a R and worst case side by side

Different questions, different answers

	VaR | Worst case
Horizon	One day | N days
Question	Threshold | Severity
Output	A loss level | A distribution
Tail loss size	Not given | Central focus
VaR mistake	Read as maximum loss

IN THE LESSON

- Let's set the two side by side.
- The question for V a R is how much we lose on a bad day that happens with a small, fixed probability.
- The question for worst case analysis is how bad is the worst day in a stretch of N days.
- V a R gives you a threshold, but it says nothing about how far beyond that threshold the losses go.
- Worst case analysis puts the focus on severity, and expected shortfall is a step in that direction because it averages the tail.
- Neither is the maximum possible loss.
- The classic mistake is to read V a R as the most you can lose, when it is really the least you lose on the bad days.

31 Recap: the main ideas

- Linear: straight value line. Options and bonds: curved
- Historical: replay past; Monte Carlo: simulate
- Delta normal: z × σ × |δ| × value; fails with gamma
- Correlation rises in crisis; V a R rises with it
- V a R is a threshold, not the maximum loss

IN THE LESSON

- Let's pull it together.
- Linear portfolios, with shares, currencies, futures and forwards, have a straight value line; options and bonds against yield are curved.
- Historical simulation replays past risk-factor changes on today's portfolio, then reads V a R and E S from the ranked results.
- Delta normal replaces an option by delta times its exposure, with V a R equal to z times sigma times the absolute exposure, and it breaks when gamma matters.
- Linear derivatives use their underlying exposure.
- Monte Carlo draws correlated random paths, strong but costly and model dependent.
- Correlations rise in crises, so V a R rises.
- And V a R is a threshold, not the worst case.

32 Try three quick questions

1. 500 scenarios, worst five losses $10m, 9m, 8m, 7m, 6m. 99% VaR and ES?
   Answer: VaR = fifth worst = $6m. ES = average = $8m.
2. Delta 0.5 on $40,000 of shares, daily σ 1%, z = 2.326. One-day VaR?
   Answer: 2.326 × 0.01 × 20,000 = $465.
3. Daily breach chance 1%. Chance of no breach in 100 days?
   Answer: $0.99^{100} \approx 0.366$, about 37%.

IN THE LESSON

- Now try three quick questions.
- Pause the video, think, then listen to the answer.
- Question one.
- Five hundred scenarios, and the five worst losses are ten, nine, eight, seven and six million dollars.
- What are the ninety nine per cent V a R and the expected shortfall?
- V a R is the fifth worst, six million, and E S is the average, eight million.
- Question two.
- A call option has a delta of point five on forty thousand dollars of shares, a daily volatility of one per cent, and z is two point three two six.
- What is the one day V a R?
- The exposure is twenty thousand, and two point three two six times point zero one times twenty thousand is about four hundred sixty five dollars.
- Question three.
- The daily V a R is breached with probability one per cent.
- What is the chance of no breach in one hundred days?
- Point nine nine to the power one hundred, about thirty seven per cent.