CHARTA LEARNING · LESSON NOTES

Risk Capital and RAROC

FRM Part II

1 A story: which business earns its keep?

- Kestrel's board: which businesses earn their keep?
- Lending earns the most profit: $31.5m vs Wealth $11m
- But it also puts the most capital at risk
- Answer: measure the capital each unit puts at risk
- Then judge return per dollar of that capital: RAROC

IN THE LESSON

- Kestrel Bank's board asks a simple question.
- Which of our businesses earn their keep?
- The finance team brings a profit table.
- Corporate Lending made thirty one and a half million dollars last year, far more than the small Wealth business, which made eleven million.
- So Lending looks like the star.
- But a director asks a sharper question.
- How much capital did each business put at risk to earn that profit?
- Lending makes large loans, and a bad year could wipe out a great deal of capital.
- The answer is to measure the capital each unit puts at risk, and then to judge each unit by its return per dollar of that capital.
- That return is R A R O C.

2 Three kinds of capital

Regulatory, economic and risk capital answer different questions

Concept	What it is
Regulatory capital	Minimum set by rules such as Basel
Economic capital	Own estimate for unexpected loss
confidence, horizon	99.9% or 99.97% (AA), 1 year
Risk capital	The buffer for one unit or position
Expected loss	Covered by pricing and provisions

IN THE LESSON

- Three capital ideas are easy to confuse.
- Regulatory capital is the minimum a supervisor requires, set by rules such as the Basel framework.
- Economic capital is the bank's own estimate of the capital it needs to absorb unexpected losses, at a confidence level it chooses, over a horizon, usually one year, across credit, market and operational risk.
- The confidence level might be ninety nine point nine per cent, or ninety nine point nine seven per cent for a bank that targets a double A rating.
- Risk capital is that same buffer measured for one unit, one product or one position.
- Last, expected loss, the average loss, is covered by pricing and provisions, not by capital.

3 Risk capital: the gap above the average

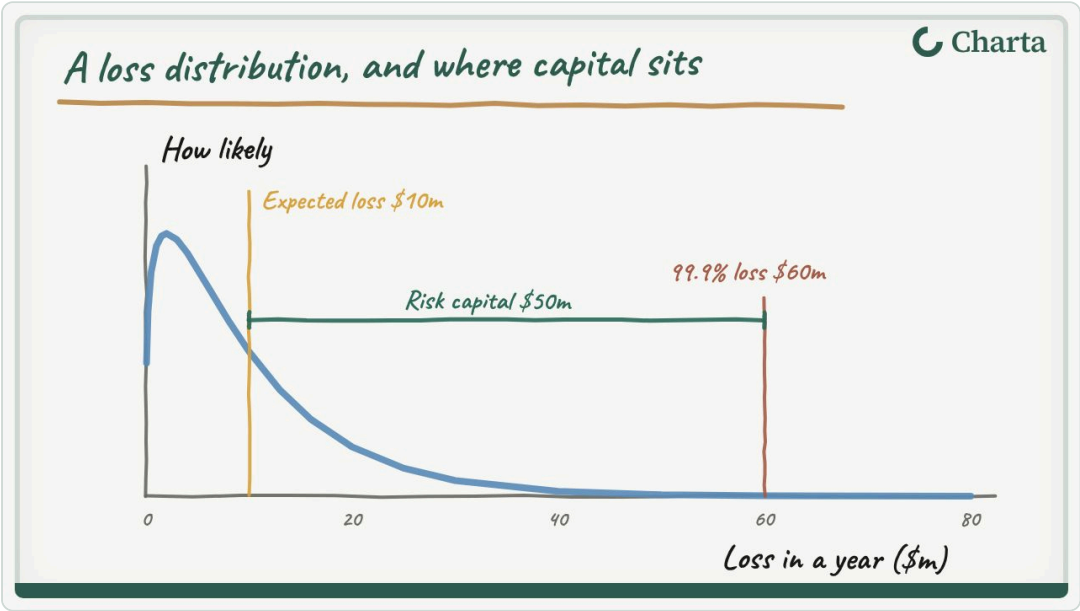
RC = Q − EL
Q: loss at 99.9% or 99.97%, over one year

Loss at the confidence level	Exceeded only rarely
Expected loss	Average loss, priced in
Risk capital	Cushion for unexpected loss

IN THE LESSON

- Here is how risk capital is measured.
- Write Q for the loss at the chosen confidence level, over one year.
- The level is often ninety nine point nine per cent, or ninety nine point nine seven per cent for a double A target.
- At ninety nine point nine per cent, Q is a loss so large that it is exceeded only one year in a thousand.
- Write E L for the expected loss, the average loss in a year.
- Risk capital, R C, is the difference: Q minus E L.
- Expected loss is subtracted because it is priced into loans and covered by provisions, a cost of doing business, not a surprise.
- Capital is only needed for the gap between a very bad year and an average year.
- That gap is the unexpected loss.

4 A loss distribution, and where capital sits



IN THE LESSON

- This chart shows the loss distribution of one of Kestrel's loan books.
- Along the bottom is the loss in a year, from zero up to eighty million dollars.
- Up the side is how likely each loss is.
- The blue curve is tall near the left, because most years bring small losses, with a long thin tail to the right for the rare very large ones.
- The first line marks the expected loss, ten million dollars, the average.
- The second line marks the loss at the ninety nine point nine per cent level, sixty million dollars.
- Only one year in a thousand is worse.
- The bracket between the two lines is the risk capital, fifty million dollars.

5 Example 1: risk capital for one loan book

Kestrel loan book: EL $10m; loss at 99.9% $60m; loss at 99.97% $70m

Risk capital at 99.9%	60 − 10	**$50m**
Risk capital at 99.97% (AA)	70 − 10	**$60m**
Wrong: hold Q in full	forgets EL is priced	**$60m**
Regulatory minimum	set by the rules	**$40m**

Economic and regulatory capital answer different questions

IN THE LESSON

- Now the numbers for that loan book.
- Its expected loss is ten million dollars a year.
- The loss at the ninety nine point nine per cent level is sixty million, so risk capital is sixty minus ten, fifty million.
- If Kestrel wants the safety of a double A rating, it uses ninety nine point nine seven per cent instead.
- The loss at that level is seventy million, so risk capital rises to sixty million.
- A common slip is to hold the whole sixty million loss as capital, forgetting that the expected ten million is already priced in.
- Meanwhile the regulatory minimum for the same book, set by the rules rather than by Kestrel's model, is forty million.
- Economic and regulatory capital answer different questions.

6 Why and how capital is apportioned

- Why: compare units on a risk-adjusted basis
- Also to price products and budget capital
- Stand-alone: the unit's capital as if alone
- Incremental: firm capital with the unit, minus without
- Contribution: splits the diversified total; adds up

IN THE LESSON

- Kestrel holds economic capital for the whole bank, but decisions are made in the units, so it apportions the capital to them.
- Why?
- First, so that units can be compared on a risk adjusted basis, profit per dollar of capital rather than profit alone.
- Second, so that loans and products can be priced to cover the capital they use, and capital can be budgeted between units.
- There are three main techniques.
- Stand alone capital is the unit's capital measured as if it were a separate firm.
- Incremental capital is the firm's capital with the unit, minus the firm's capital without it.
- Contribution, or covariance based, allocation splits the diversified firm total so that the pieces add up exactly.

7 Example 2: three techniques give three answers

Stand-alone capital: Lending $300m, Markets $200m. Firm-wide model: $400m

Stand-alone sum	300 + 200	**$500m**
Incremental: Lending	400 − 200	**$200m**
Incremental: Markets	400 − 300	**$100m**
Incremental sum	200 + 100	**$300m**
Contribution: L and M	adds to exactly 400	**262.5 + 137.5**

Stand-alone sums to too much; incremental to too little

IN THE LESSON

- Kestrel has two big units.
- Measured stand alone, Corporate Lending needs three hundred million dollars of capital and Markets needs two hundred million.
- Added up, that is five hundred million.
- But the firm wide model, which allows for the two rarely losing heavily in the same year, says four hundred million.
- Incremental capital for Lending is the firm's four hundred, minus the two hundred Markets would need alone, so two hundred million.
- For Markets it is four hundred minus three hundred, so one hundred.
- These add up to only three hundred.
- The contribution method, which we build later, gives two hundred and sixty two point five and one hundred and thirty seven point five, and these add to exactly four hundred.

8 The RAROC formula

RAROC = Risk-adjusted after-tax return ÷ EC
Return = (Revenue − Costs − EL + Return on EC) × (1 − tax)

Revenue	Interest margin and fees
Expected loss	Average loss, priced in
Return on economic capital	Earned on capital held safely
Economic capital	Capital at risk, not book equity

IN THE LESSON

- Now the measure itself.
- R A R O C, risk adjusted return on capital, measures the return a business earns per unit of risk capital.
- In its simplest form it is a ratio.
- On top is the risk adjusted, after tax return.
- Below is economic capital.
- The return is built in steps.
- Start with expected revenue, meaning interest margin and fees.
- Take away operating costs.
- Take away the expected loss, the average credit loss.
- Add the return earned on the economic capital itself.
- Then take away tax on the total.

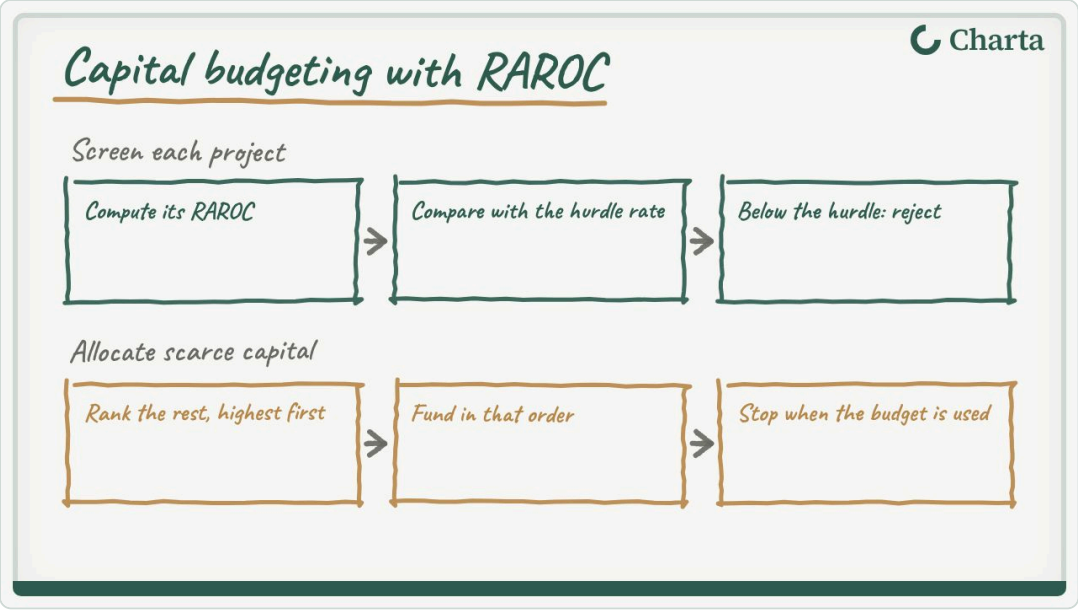
9 Inside the numerator and the denominator

- Numerator: revenue less costs and expected loss
- Plus the return on economic capital, then less tax
- Why: capital is held in safe assets, not borrowed
- Denominator: economic capital
- Not book equity, and not the loan's notional

IN THE LESSON

- Two parts of the formula need a closer look.
- In the numerator, revenue is reduced by costs and expected loss, the return on economic capital is added, and tax is taken off the total.
- Why add it?
- Because the capital is not borrowed.
- It is the shareholders' money, held in safe assets such as government bonds, and it earns something there, roughly the risk free rate.
- In the denominator sits economic capital, the risk capital this business needs.
- It is not the book equity the accountants show, and it is not the notional size of a loan.
- A big, very safe loan needs little capital, and a small risky one may need a lot.

10 Capital budgeting with RAROC



IN THE LESSON

- R A R O C drives capital budgeting, which is the decision of which projects get capital.
- First, screen each project.
- Compute its R A R O C.
- Compare it with the hurdle rate, which is the return shareholders require; we will see how to work it out later.
- A project below the hurdle is rejected, because it destroys value, however much profit it makes in dollars.
- Second, allocate scarce capital.
- Capital is limited, so rank the projects that pass by their R A R O C, from highest to lowest.
- Fund them in that order.
- Stop when the capital budget is used up.

11 Example 3: a capital budget

Budget $120m of economic capital; hurdle 14%. Four projects ask for capital

Project S	RAROC 11% < 14%	**Reject**
Project P: EC $40m	RAROC 22%, first	**Fund**
Project Q: EC $30m	RAROC 18%, second	**Fund**
Project R: EC $50m	RAROC 15%, third	**Fund**
Capital used	40 + 30 + 50	**$120m**

IN THE LESSON

- Kestrel has a capital budget of one hundred and twenty million dollars of economic capital, and a hurdle rate of fourteen per cent.
- Four projects ask for capital.
- Project S has an R A R O C of eleven per cent, below fourteen, so it is rejected at once.
- The other three pass, so we rank them.
- Project P earns twenty two per cent and needs forty million, so it is funded first.
- Project Q earns eighteen per cent and needs thirty million, so it is funded second.
- Project R earns fifteen per cent and needs fifty million, funded third.
- That uses forty plus thirty plus fifty, the whole one hundred and twenty million.

12 Mistakes to avoid: the wrong benchmark

- Trap: comparing with the unit's average RAROC
- Unit average 20%: R at 15% wrongly rejected
- Unit average 10%: a 12% project wrongly accepted
- The benchmark is always the hurdle rate, here 14%
- Rule: accept when RAROC is above the hurdle

IN THE LESSON

- The commonest error is to compare a project with the average R A R O C of its own unit instead of the hurdle rate.
- Suppose Project R sits in a unit whose average R A R O C is twenty per cent.
- A manager rejects R, at fifteen per cent, because it drags the average down.
- But fifteen per cent beats the fourteen per cent hurdle, so R adds value.
- Now the reverse.
- A unit averaging ten per cent accepts a twelve per cent project because it lifts the average, yet twelve is below the hurdle, so it destroys value.
- The benchmark is always the hurdle rate, here fourteen per cent.
- The exam point: R A R O C compares return with risk capital, and the rule is to accept when R A R O C is above the hurdle.

13 Example 4: RAROC for one loan

Loan $100m: margin 2%, fees $0.4m, costs $0.6m, PD 1%, LGD 40%, EC $6m

Revenue: margin plus fees	2% × 100m + 0.4m	**$2.4m**
Expected loss	1% × 40% × 100m	**$0.4m**
Return on EC at 4%	4% × 6m	**$0.24m**
After tax at 25%	(2.4−0.6−0.4+0.24) × 75%	**$1.23m**
RAROC	1.23 ÷ 6	**20.5%**

EC $6m: the loan's share of the portfolio's 99.9% loss, net of EL

IN THE LESSON

- Kestrel lends one hundred million dollars to Brennan Logistics at a margin of two per cent, plus fees of four hundred thousand dollars, so revenue is two point four million.
- Brennan's default probability is one per cent, and the loss given default is forty per cent.
- Expected loss is one per cent times forty per cent times one hundred million, four hundred thousand dollars.
- Economic capital is six million, credited with the four per cent risk free rate, two hundred and forty thousand dollars.
- Revenue, less costs of six hundred thousand, less expected loss, plus that credit, is one point six four million.
- After tax at twenty five per cent that is one point two three million.
- Divided by six million, R A R O C is twenty point five per cent.
- The six million is the loan's share of the portfolio's ninety nine point nine per cent loss, net of expected loss.

14 Reading the answer, and two slips

The Brennan loan again; Kestrel's hurdle rate is 14%

Meaning of 20.5%	per $1 of capital a year	**20.5 cents**
Against the hurdle	20.5% > 14%	**Accept**
Slip: forget EL	1.53 ÷ 6	**25.5%**
Slip: PD used for PD × LGD	EL $1m: 0.78 ÷ 6	**13.0%**

The PD slip flips the verdict from accept to reject

IN THE LESSON

- What does twenty point five per cent mean?
- For each dollar of capital put at risk, the Brennan loan earns about twenty point five cents a year, after expected losses and tax.
- Read it against the hurdle rate.
- Kestrel's hurdle is fourteen per cent, so the loan creates value and is accepted.
- Now two slips.
- Forget the expected loss, and the after tax return becomes one point five three million, an R A R O C of twenty five point five per cent, which flatters the loan.
- Use the default probability where P D times L G D belongs, and expected loss becomes a full one million.
- The return falls to point seven eight million, thirteen per cent, and the loan is wrongly rejected.

15 Example 5: RAROC for a portfolio of loans

20 loans like Brennan's. Portfolio EC is $80m, not 20 × $6m

Revenue less costs less EL	48 − 12 − 8	**$28.0m**
Return on EC at 4%	4% × 80m	**$3.2m**
After tax at 25%	31.2 × 75%	**$23.4m**
Portfolio RAROC	23.4 ÷ 80	**29.25%**
Stand-alone sum of EC	20 × 6	**$120m**

IN THE LESSON

- The same steps work for a portfolio of twenty loans just like Brennan's.
- Revenue is twenty times two point four, forty eight million.
- Costs are twelve million, and expected loss is eight million, since expected losses simply add.
- That leaves twenty eight million.
- The difference is the denominator: the loans do not all default together, so the portfolio's economic capital is eighty million, not twenty times six.
- The return on that capital at four per cent is three point two million, giving thirty one point two million before tax and twenty three point four million after tax.
- Divided by eighty, portfolio R A R O C is twenty nine point two five per cent.
- The stand alone sum of capital would be one hundred and twenty million, so diversification saved forty million.

16 Example 6: ranking business units

After-tax profit and allocated EC, $m (Lending, Markets: covariance shares). Hurdle 14%

Wealth	11 ÷ 50	**22%**
Markets	24.75 ÷ 137.5	**18%**
Corporate Lending	31.5 ÷ 262.5	**12%**
Ranking by profit instead	31.5 > 24.75 > 11	**Wrong order**

Lending earns the most dollars, yet sits below the hurdle

IN THE LESSON

- Now back to the board's question, with each unit's after tax profit and allocated economic capital.
- Lending and Markets carry their covariance shares of the firm's four hundred million.
- Wealth earns eleven million on fifty million of capital, an R A R O C of twenty two per cent.
- Markets earns twenty four point seven five million on one hundred and thirty seven point five million, eighteen per cent.
- Corporate Lending earns thirty one and a half million on two hundred and sixty two point five million, only twelve per cent.
- Sorted from highest to lowest, the ranking is Wealth, then Markets, then Lending.
- Ranking by profit gives the opposite order, with Lending first.
- That is the trap: do not rank by profit or by capital size.
- A large unit with a low R A R O C can be worse than a small unit with a high one, and here Lending is below the fourteen per cent hurdle.

17 How each choice can mislead

RAROC is only as good as its inputs: three judgement calls

Choice	How it can mislead
One-year horizon	Too short for illiquid positions
Through-the-cycle PD	Understates downturn losses
Point-in-time PD	Procyclical: capital swings
Defaults cluster	Tail fatter than averages
Higher confidence level	More EC, so lower RAROC

IN THE LESSON

- R A R O C looks precise, but it is only as good as its inputs, and three of them are judgement calls: the horizon, the default probability and the confidence level.
- A one year horizon may be too short for illiquid positions, which cannot be sold or hedged quickly, so capital looks too low and R A R O C too good.
- Default probabilities cause trouble too.
- Through the cycle averages understate losses in a downturn.
- Point in time estimates, which follow current conditions, are procyclical, so capital swings with the economy.
- And defaults cluster, so the tail of the loss distribution is fatter than averages suggest.
- Last, a higher confidence level, such as ninety nine point nine seven rather than ninety nine point nine per cent, raises economic capital and so lowers R A R O C.

18 Example 7: the confidence level flips the verdict

Brennan loan at 99.97% instead of 99.9%: EC rises from $6m to $12m

At 99.9%: RAROC	1.23 ÷ 6	**20.5%**
Return on EC at 99.97%	4% × 12m	**$0.48m**
After tax	(2.4−0.6−0.4+0.48) × 75%	**$1.41m**
At 99.97%: RAROC	1.41 ÷ 12	**11.75%**
Against the 14% hurdle	passes, then fails	**Flips**

IN THE LESSON

- At ninety nine point nine per cent, the Brennan loan needs six million of capital and earns an R A R O C of twenty point five per cent.
- Now Kestrel moves to ninety nine point nine seven per cent to match a double A target.
- Defaults cluster, so the tail is fat, and the model now asks for twelve million of capital.
- The return on capital rises to four hundred and eighty thousand dollars, so the after tax return becomes one point four one million.
- Divided by twelve million, R A R O C falls to eleven point seven five per cent.
- Against the fourteen per cent hurdle, the same loan passed at one confidence level and fails at the other.

19 Two further problems

- RAROC divides by total risk capital
- Shareholders price only the systematic part
- Fix: adjusted RAROC, using beta
- Diversification is hard to allocate to units

IN THE LESSON

- Two further problems go beyond the inputs.
- First, R A R O C divides the return by total risk capital, which covers all the risk in a project.
- But shareholders do not price all risk.
- They can diversify away the part that is special to one project, so they price only the systematic part, the risk that moves with the market.
- The fix is adjusted R A R O C, which uses the project's beta, and we meet it shortly.
- Second, diversification is hard to allocate.
- The firm needs less capital than the sum of its units, but there is no single right way to share that saving among them.

20 The hurdle rate

Hurdle = Rf + Beta × (Rm − Rf)
After-tax cost of equity, not the cost of debt

Risk-free rate	Return on a safe asset
Beta	Bank's equity beta
Market return	Return on the market
Market risk premium	Rm − Rf

IN THE LESSON

- The hurdle rate is the minimum R A R O C a project must earn to leave shareholders better off.
- In the standard treatment it is the after tax cost of equity, the return investors demand for bearing the risk of the bank's shares.
- The C A P M, the capital asset pricing model, gives it.
- Write R f for the risk free rate, beta for the bank's equity beta, and R m for the market return.
- The hurdle is the risk free rate, plus beta times the market risk premium, which is the market return minus the risk free rate.
- It is the required return on equity, not the cost of debt, nor the risk free rate.

21 Example 8: Kestrel's hurdle and value added

Kestrel: risk-free rate 4%, equity beta 1.25, market return 12%

Market risk premium	12% − 4%	**8%**
Hurdle rate	4% + 1.25 × 8%	**14%**
Brennan loan: RAROC 20.5%	above 14%	**Accept**
Value added: Brennan	(20.5% − 14%) × 6m	**$0.39m**
Value added: Lending at 12%	(12% − 14%) × 262.5m	**−$5.25m**

IN THE LESSON

- Kestrel's numbers are a risk free rate of four per cent, an equity beta of one point two five, and a market return of twelve per cent.
- The market risk premium is twelve minus four, eight per cent.
- The hurdle is four per cent plus one point two five times eight per cent, which is fourteen per cent.
- The decision rule: accept if R A R O C is above the hurdle, reject if below.
- The Brennan loan earns twenty point five per cent, so accept.
- The excess over the hurdle, times economic capital, is the value added: six point five per cent times six million, three hundred and ninety thousand dollars.
- Corporate Lending, at twelve per cent on two hundred and sixty two point five million, destroys five and a quarter million a year.

22 Mistakes to avoid: tax basis and stale inputs

Two traps: mixing tax bases, and using stale inputs

Project X: pre-tax RAROC	16% vs hurdle 14%	**Looks fine**
Project X: after tax at 25%	16% × 75%	**12%: reject**
Risk-free rate rises to 5.5%	5.5% + 1.25 × 8%	**Hurdle 15.5%**
Project R: RAROC 15%	passed at 14%	**Now fails**

IN THE LESSON

- Two mistakes recur.
- The first is mixing bases.
- The hurdle is an after tax return, so R A R O C must be after tax too.
- Project X shows a pre tax R A R O C of sixteen per cent, which seems to beat fourteen.
- After tax at twenty five per cent it is only twelve per cent, so it should be rejected.
- The second mistake is stale inputs.
- Suppose the risk free rate rises to five point five per cent while the market risk premium stays at eight per cent.
- The hurdle becomes five point five plus one point two five times eight, fifteen point five per cent.
- Project R, at fifteen per cent, passed yesterday's hurdle of fourteen.
- Today it fails.

23 Adjusted RAROC

Adjusted RAROC = (RAROC − Rf) ÷ Beta
Accept if above E(Rm) − Rf

RAROC	The project's RAROC
Risk-free rate	Return on a safe asset
Beta	Project's equity beta
Market risk premium	E(Rm) − Rf

IN THE LESSON

- Now the fix for systematic risk.
- Adjusted R A R O C uses the project's own equity beta, which measures how much the project's returns move with the market.
- Take the project's R A R O C.
- Subtract the risk free rate.
- Divide by beta.
- The result is the project's excess return per unit of beta.
- Accept the project if this is above the market risk premium, the expected market return minus the risk free rate.
- This is the same as requiring R A R O C to exceed the C A P M hurdle built with the project's own beta.
- So a low beta project can pass where a high beta project with the same R A R O C fails.

24 Example 9: same RAROC, different verdicts

Two projects, both RAROC 16%. Rf 4%, E(Rm) 12%, so premium 8%

Beta 1.0: adjusted RAROC	(16% − 4%) ÷ 1.0	**12%: accept**
Beta 1.8: adjusted RAROC	(16% − 4%) ÷ 1.8	**6.67%: reject**
CAPM hurdle, beta 1.0	4% + 1.0 × 8%	**12%**
CAPM hurdle, beta 1.8	4% + 1.8 × 8%	**18.4%**

Same verdicts: 16% beats 12%, but not 18.4%

IN THE LESSON

- Two projects each have an R A R O C of sixteen per cent.
- The risk free rate is four per cent and the expected market return twelve, so the premium is eight per cent.
- The low beta project has a beta of one.
- Its adjusted R A R O C is sixteen minus four, over one, twelve per cent, above eight, so accept.
- The high beta project has a beta of one point eight.
- Twelve over one point eight is about six point six seven per cent, below eight, so reject.
- The C A P M check agrees: with a beta of one the hurdle is twelve per cent, and with a beta of one point eight it is four plus fourteen point four, eighteen point four per cent.
- Sixteen beats twelve, but not eighteen point four.

25 Example 10: estimating beta first

Project T: RAROC 16%, correlation 0.6, vol 30%, market vol 15%; Rf 4%, E(Rm) 12%

Beta = corr × vol ÷ mkt vol	0.6 × 30% ÷ 15%	**1.2**
Adjusted RAROC	(16% − 4%) ÷ 1.2	**10%**
Market risk premium	12% − 4%	**8%**
Verdict	10% > 8%	**Accept**
Check: CAPM hurdle	4% + 1.2 × 8% = 13.6%	**16% > 13.6%**

IN THE LESSON

- Often beta must be estimated.
- It equals the correlation of the project with the market, times the project's volatility, divided by the market's volatility.
- Kestrel's Project T has an R A R O C of sixteen per cent, a correlation with the market of point six, a volatility of thirty per cent, and the market's volatility is fifteen per cent.
- The risk free rate is four per cent and the expected market return twelve.
- Beta is point six times thirty, divided by fifteen, which is one point two.
- Adjusted R A R O C is sixteen minus four, divided by one point two, ten per cent.
- The premium is twelve minus four, eight per cent.
- Ten is above it, so accept.
- As a check, the C A P M hurdle is four plus one point two times eight, thirteen point six per cent, and sixteen is above it.

26 Mistakes to avoid: three slips with beta

Project T again: RAROC 16%, beta 1.2, Rf 4%, E(Rm) 12%

Correct	(16% − 4%) ÷ 1.2	**10%**
Slip: skip Rf	16% ÷ 1.2	**13.3%**
Slip: multiply by beta	12% × 1.2	**14.4%**
Slip: compare with E(Rm)	10% < 12%	**Wrong reject**

Compare with the premium, 8%, not the market return

IN THE LESSON

- Project T shows three common slips.
- The correct answer is sixteen minus four, divided by one point two, ten per cent.
- The first slip skips the subtraction of the risk free rate: sixteen divided by one point two gives about thirteen point three per cent, too high.
- The second slip multiplies by beta instead of dividing: twelve times one point two gives fourteen point four per cent, also too high.
- The third slip compares the right answer with the wrong benchmark.
- Ten per cent against the market return of twelve per cent looks like a reject, but the correct benchmark is the premium, eight per cent.
- The exam point: adjusted R A R O C brings market risk into the decision.

27 Adding up risk capital with diversification

Capital = √(A^2 + B^2 + 2 × rho × A × B)
Benefit = A + B − Capital

A	Stand-alone capital of unit A
B	Stand-alone capital of unit B
Correlation, rho	Correlation of their losses
Diversification benefit	Shortfall below the plain sum

IN THE LESSON

- Back to diversification.
- The firm's economic capital is less than the sum of its units' stand alone capital, because losses rarely all arrive together.
- Simply adding the stand alone figures assumes perfect correlation, and overstates capital.
- With two units, write ay for the stand alone capital of the first and B for the second, and rho for the correlation of their losses.
- Under normal style scaling, firm capital is the square root of ay squared, plus B squared, plus two times rho times ay times B.
- If rho is one, this is just ay plus B.
- The diversification benefit is the shortfall: ay plus B, minus firm capital.
- The lower the correlation, the bigger the benefit.

28 Example 11: Kestrel's diversification benefit

Stand-alone: Lending A = $300m, Markets B = $200m. Correlation 0.25

Inside the root	90,000 + 40,000 + 30,000	**160,000**
Firm capital	√160,000	**$400m**
Benefit	300 + 200 − 400	**$100m**
Stress: correlation 0.75	√220,000	**$469m**
Benefit in stress	500 − 469	**$31m**

IN THE LESSON

- Lending needs three hundred million stand alone and Markets two hundred million, and the correlation of their losses is point two five.
- Inside the root: three hundred squared is ninety thousand, two hundred squared is forty thousand, and two times point two five times three hundred times two hundred is thirty thousand.
- The total is one hundred and sixty thousand, and its square root is four hundred million.
- The benefit is five hundred minus four hundred, one hundred million.
- In a crisis, correlations rise.
- At point seven five, the root of two hundred and twenty thousand is about four hundred and sixty nine million, and the benefit shrinks to about thirty one million, just when it is needed most.

29 Example 12: sharing the benefit out

Sharing Kestrel's $400m between Lending and Markets, $m

Incremental	200 + 100	**300: too little**
Pro rata to stand-alone	400 × 3/5 and 400 × 2/5	**240 + 160**
Covariance: Lending	(90,000 + 15,000) ÷ 400	**262.5**
Covariance: Markets	(40,000 + 15,000) ÷ 400	**137.5**
Covariance total	262.5 + 137.5	**400**

IN THE LESSON

- The harder problem is sharing the four hundred million back to the units.
- Incremental capital gives two hundred and one hundred, which add up to only three hundred, short of the total.
- Pro rata scaling shrinks each stand alone figure by the same proportion: four hundred times three fifths for Lending, two hundred and forty, and times two fifths for Markets, one hundred and sixty.
- The covariance method charges each unit for its own risk plus its share of the joint term.
- For Lending, ninety thousand plus fifteen thousand, divided by four hundred, two hundred and sixty two point five.
- For Markets, forty thousand plus fifteen thousand, over four hundred, one hundred and thirty seven point five.
- Together that is exactly four hundred.

30 Each technique and its weakness

No method is perfect: link each one to its weakness

Technique	Weakness
Stand-alone	Too much: assumes correlation 1
Incremental	Understates; pieces fall short
Pro rata	Ignores who really diversifies
Covariance	Moves when other units change
Any method	Correlations rise in stress

IN THE LESSON

- Link each technique to its weakness.
- Stand alone capital sums to too much, because adding the figures assumes the units are perfectly correlated.
- Incremental capital understates each unit, and the pieces do not add up to the firm total, as we saw: three hundred against four hundred.
- Pro rata scaling is simple, but it ignores which unit really diversifies the firm, so a unit that lowers firm risk gets no extra credit.
- Covariance, or marginal, allocation does add up to the total, but a unit's charge moves when other units change, even if the unit itself did nothing different.
- And under any method, correlations rise in stress, so the diversification benefit shrinks when it is needed most.

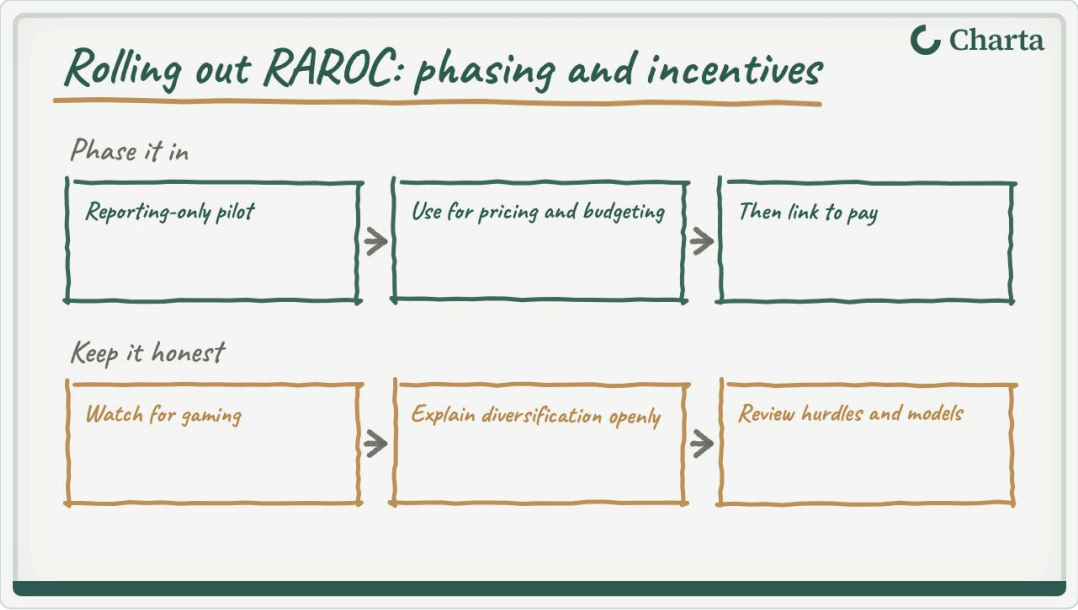
31 Rolling out RAROC: getting the basics right

- Visible senior management support
- Agree the method with business units early
- One definition: capital, confidence, horizon, hurdle
- Transparent assumptions
- Independent validation and back-testing by risk

IN THE LESSON

- Finally, how should Kestrel roll out an R A R O C method for allocating economic capital?
- Rollouts fail more often from organisation than from mathematics, so good practice is practical.
- First, secure visible support from senior management.
- Second, agree the methodology with the business units early, rather than imposing it on them.
- Third, use one consistent definition of capital, confidence level, horizon and hurdle rate across the bank, so that unit R A R O C figures can be compared.
- Fourth, make the assumptions transparent.
- Fifth, have the risk function validate the models independently and back test them, which means checking the predictions against what actually happened.

32 Rolling out RAROC: phasing and incentives



IN THE LESSON

- The second half of good practice is about use and incentives.
- Look at the boxes.
- Phase it in.
- Start with a reporting only pilot, so units see their numbers before anything rides on them.
- Then use the output for decisions, pricing and capital budgeting, as well as for judging performance.
- Only then link it to pay.
- Then keep it honest.
- Watch for gaming, such as units shifting into risks the model underestimates, which flatters their R A R O C.
- Explain allocated diversification benefits openly, so units understand why their charge changes.
- Review hurdle rates and models regularly.
- The exam point is that consistency, transparency, buy in and incentives matter as much as the formula.

33 Try three quick questions

1. Revenue $3m, costs $1m, EL $0.5m, EC $10m, Rf 4%, tax 25%. RAROC?
   Answer: (3 − 1 − 0.5 + 4% × 10) × 75% = 1.425; ÷ 10 = 14.25%.
2. Stand-alone $30m and $40m, correlation 0. Diversification benefit?
   Answer: Firm √(900 + 1,600) = $50m; benefit 70 − 50 = $20m.
3. RAROC 13%, beta 1.5, Rf 4%. Adjusted RAROC?
   Answer: (13% − 4%) ÷ 1.5 = 6%.

IN THE LESSON

- Three quick questions; pause before each answer.
- Question one.
- A loan has revenue of three million dollars, costs of one million, expected loss of half a million and capital of ten million.
- Risk free rate four per cent, tax twenty five per cent.
- What is R A R O C?
- The return on capital is four per cent of ten million, point four.
- Before tax, three minus one minus half plus point four is one point nine million, after tax one point four two five million, so fourteen point two five per cent.
- Question two.
- Two units need thirty and forty million stand alone, with zero correlation.
- What is the diversification benefit?
- Firm capital is the square root of nine hundred plus one thousand six hundred, fifty million, so the benefit is seventy minus fifty, twenty million.
- Question three.
- R A R O C is thirteen per cent, beta one point five, risk free rate four per cent.
- What is adjusted R A R O C?
- Nine over one point five, six per cent.