How to Measure and Manage Risk

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What Is Risk?

- Wikipedia: "the possibility of something bad happening"
  - I have £10 for dinner, but have a 50% chance of losing it
- This is not what we mean by risk
  - Expected cash flow falls from £10 to £5
  - Everybody dislikes this
- We're focusing on risk *holding unchanged the expected (=average, mean) cash flow*
  - Do you prefer £5 for sure or a 50-50 split of 0 or £10?
- Risk-averse: prefer £5 for sure as *diminishing marginal utility*
- Risk-neutral: indifferent

Why Do We Care About Risk?

		Person	Company
Real	***Tangible***	Renovate a kitchen	Build a new factory
	Intangible	Attend university / this lecture	Increase parental leave
Financial		Buy shares	Buy back shares

- Investments all involve
  - Spending cash today
  - Receiving cash in the future
- Why can't you simply sum up the cash flows (calculate net cash)?
  - £1 today is worth more than £1 tomorrow due to the *time value of money*

Lecture 3: "How to Make Financial Decisions"

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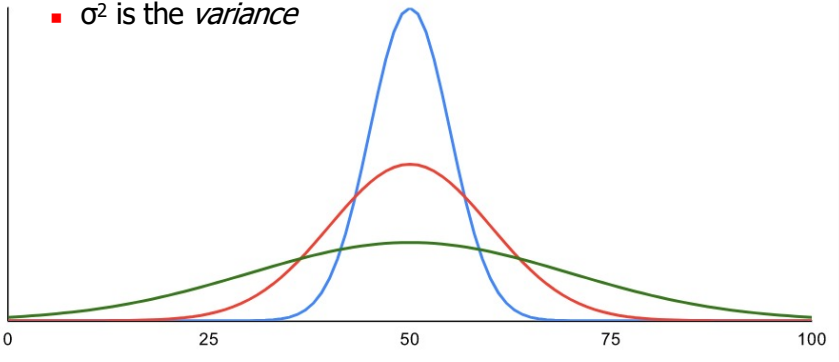
- Why can't you simply sum up the cash flows (calculate net cash)?
  - £1 today is worth more than £1 tomorrow due to the *time value of money*
  - A certain £1 is worth more than a risky £1
- These differences seem to depend on personal taste

How Do We Measure Risk?

- A certain £1 is worth one more than a risky £1
- How much more depends on *amount of risk* and *price of risk*
- Statistics 101: amount of risk is the *standard deviation* (σ)
  - σ^2 is the *variance*



Why Standard Deviation is the Wrong Measure of Risk

	Sun	Rain	Mean	Standard Deviation
Izy's Ice Cream	14	6	10	5.7
Carola's Coffee	9	9	9	0

- Which would you prefer? Seems to depend on your preferences for risk vs. return

Why Standard Deviation is the Wrong Measure of Risk

	Sun	Rain	Mean	Standard Deviation
Izy's Ice Cream	14	6	10	5.7
Carola's Coffee	9	9	9	0
Ursula's Umbrellas	8	12	10	2.8

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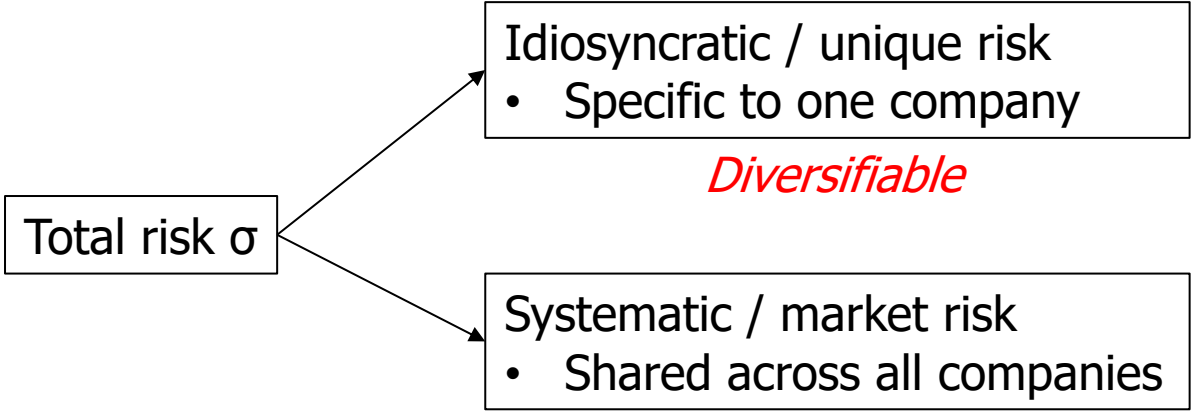
	Sun	Rain	Mean	Standard Deviation
Izy's Ice Cream	14	6	10	5.7
Carola's Coffee	9	9	9	0
Ursula's Umbrellas	8	12	10	2.8
1/3 of Izy and 2/3 of Ursula	10	10	10	0

- No-one holds Carola's Coffee, no matter how risk-averse they are

But Diversification Has Its Limits

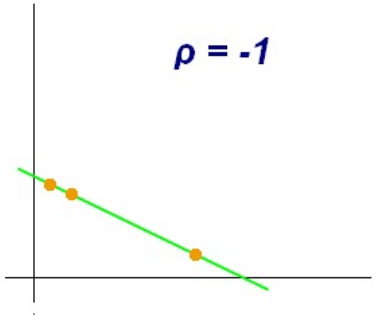
	Recession	Boom	Mean	Standard Deviation
Izy's Ice Cream	6	14	10	5.7
Carola's Coffee	7	13	9	4.2
Ursula's Umbrellas	8	12	10	2.8
1/3 of Izy and 2/3 of Ursula	7.3	12.7	10	3.8

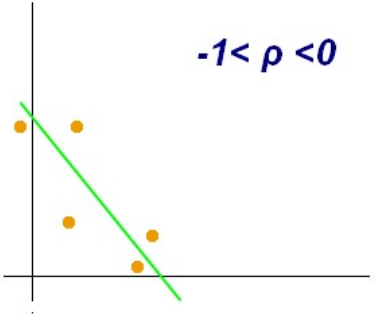
Two Types of Risk

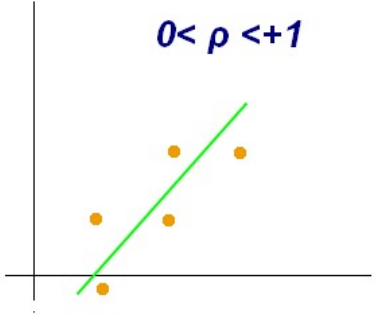


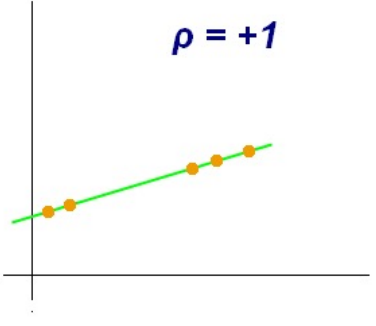
How To Measure Systematic Risk

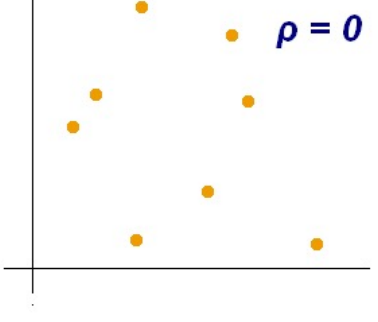
- Systematic / market risk is risk "shared with" the market (= "correlated with" the market)
  - Why? Because investors should diversify by holding the market portfolio (= portfolio of all risky assets)
- ρ is the *correlation coefficient*
  - ρ = +1: perfect positive correlation
  - ρ = -1: perfect negative correlation
  - ρ = 0: no correlation


ρ = -1


-1< ρ <0


0< ρ <+1


ρ = +1


ρ = 0

How To Measure Systematic Risk

- Covariance between stock 1 and the market m is

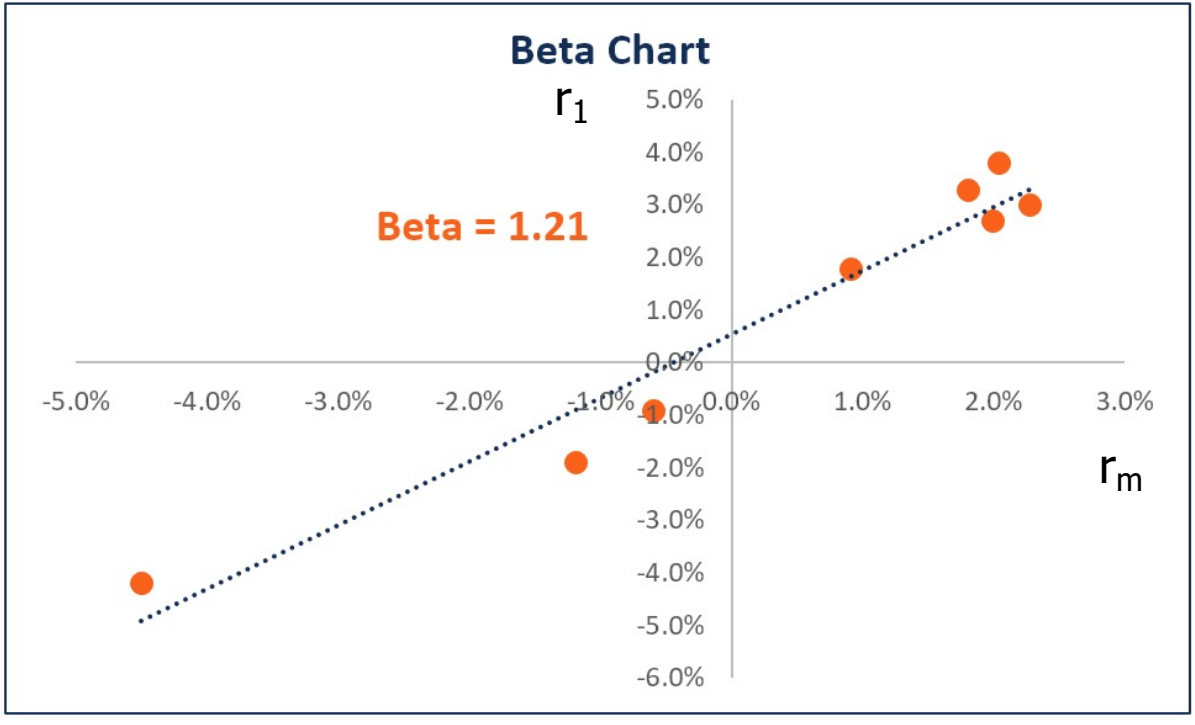
$$\sigma_{1m} = \rho_{1m}\sigma_1\sigma_m$$

- Systematic / market risk is measured by

$$\beta_1 = \frac{\sigma_{1m}}{\sigma_m^2} = \frac{Cov(r_1, r_m)}{Var(r_m)}$$

where r_1 = return on stock 1 and r_m = return on market

- β is the *regression coefficient*: slope of the best-fit line


Beta Chart
r1
Beta = 1.21
5.0%
4.0%
3.0%
2.0%
1.0%
0.0%
-1.0%
-2.0%
-3.0%
-4.0%
-5.0%
-6.0%
-5.0%
-4.0%
-3.0%
-2.0%
-1.0%
0.0%
1.0%
2.0%
3.0%
rm

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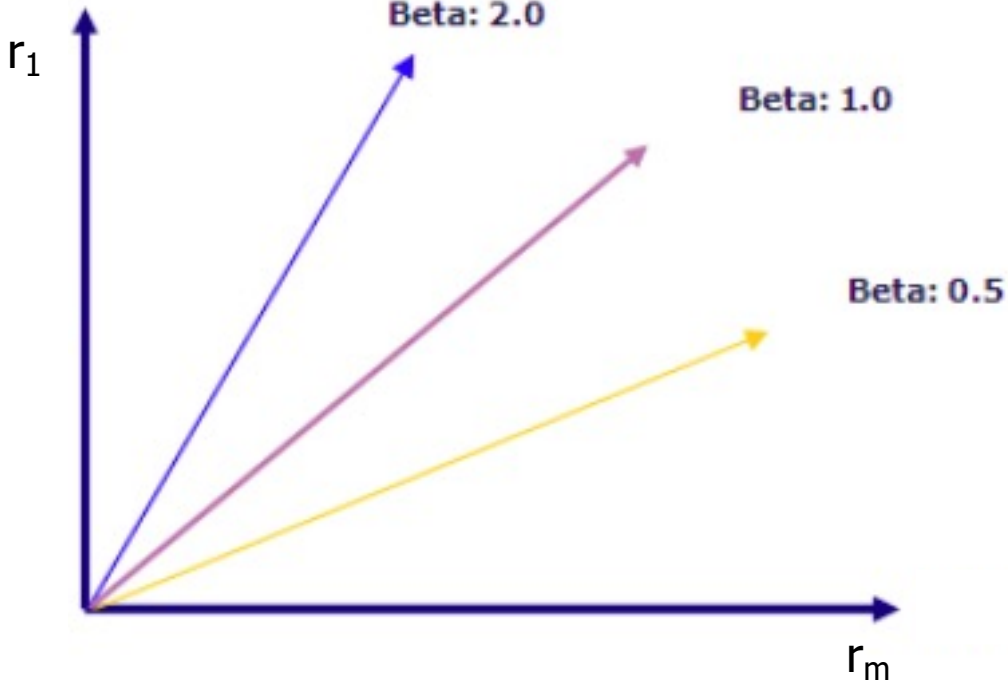
$$\beta_1 = \frac{\sigma_{1m}}{\sigma_m^2} = \frac{Cov(r_1, r_m)}{Var(r_m)}$$

where r_1 = return on stock 1 and r_m = return on market

- β is the *regression coefficient*: slope of the best-fit line
  - Measures how much r_1 rises when r_m rises by 1%
  - Unlike ρ, it is not bounded between -1 and 1


Beta: 2.0
Beta: 1.0
Beta: 0.5
r_1
r_m

What Determines Beta?

- $\beta > 1$: stock increases more than 1% when the market increases 1% (e.g. luxury goods)
- $0 < \beta < 1$: stock increases less than 1% when the market increases 1% (e.g. consumer goods / necessities)
- $\beta = 0$: stock is uncorrelated with the market
- $\beta < 0$: stock *decreases* when the market increases

The Relationship Between Risk and Return

- A certain £1 is worth one more than a risky £1
- How much more depends on *amount of risk* and *price of risk*
- Risk Premium = Amount of Risk × Price of Risk

$$r_1 - r_f = \beta_1(r_m - r_f)$$

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Risk premium

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Risk premium

Amount of risk

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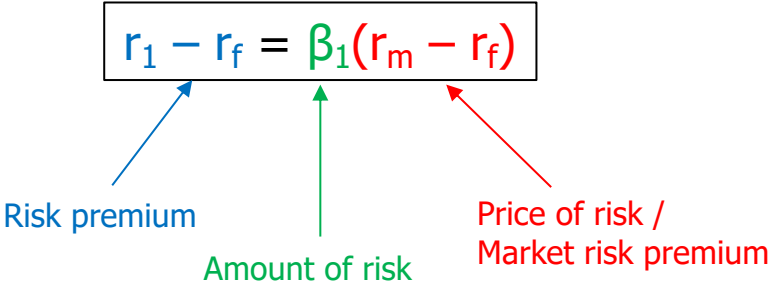

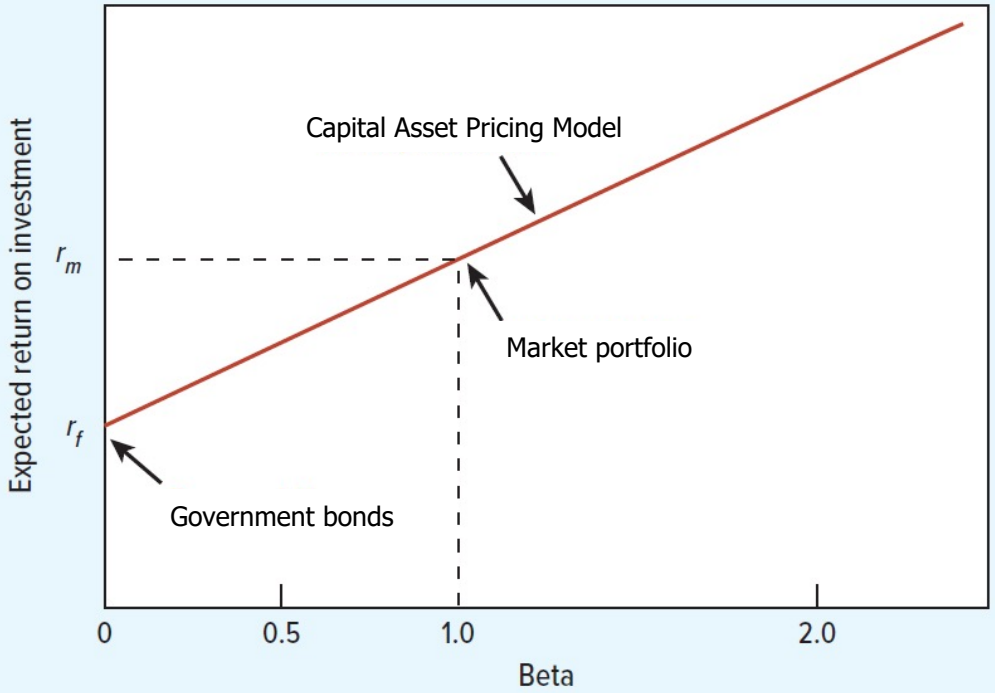
Capital Asset Pricing Model
Market portfolio
Government bonds
Expected return on investment
r_m
r_f
0
0.5
1.0
2.0
Beta

The Relationship Between Risk and Return

- A certain £1 is worth one more than a risky £1
- How much more depends on *amount of risk* and *price of risk*
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$$r_1 - r_f = \beta_1(r_m - r_f)$$

- This is the Capital Asset Pricing Model
- r_1 is the *cost of equity*, or discount rate for a stock
- None of this depends on preferences

Using the CAPM: Vodafone

$$r_V - r_f = \beta_V(r_m - r_f)$$

Using the CAPM: Vodafone

$$r_V - r_f = \beta_V(r_m - r_f)$$

	Vodafone	FTSE All-Share
30-Apr-21	136.8	3,983.85
29-Apr-21	135.48	3,977.04
28-Apr-21	135.14	3,979.39
27-Apr-21	135.04	3,970.50
26-Apr-21	134.34	3,983.59
23-Apr-21	133.58	3,965.16
22-Apr-21	134.1	3,965.04
21-Apr-21	132.84	3,935.64
20-Apr-21	131.48	3,920.05
19-Apr-21	135.28	3,996.65
16-Apr-21	135.18	4,006.76
15-Apr-21	133.34	3,988.72
14-Apr-21	134.12	3,964.67
13-Apr-21	134	3,939.31
12-Apr-21	134.82	3,933.89
09-Apr-21	134.64	3,949.51
08-Apr-21	136.46	3,960.97
07-Apr-21	136.64	3,931.53
06-Apr-21	134.62	3,897.81
01-Apr-21	133.66	3,849.24
31-Mar-21	131.88	3,831.05

	Vodafone	FTSE All-Share	rV	rM
30-Apr-21	136.8	3,983.85	0.97%	0.17%
29-Apr-21	135.48	3,977.04	0.25%	-0.06%
28-Apr-21	135.14	3,979.39	0.07%	0.22%
27-Apr-21	135.04	3,970.50	0.52%	-0.33%
26-Apr-21	134.34	3,983.59	0.57%	0.46%
23-Apr-21	133.58	3,965.16	-0.39%	0.00%
22-Apr-21	134.1	3,965.04	0.95%	0.75%
21-Apr-21	132.84	3,935.64	1.03%	0.40%
20-Apr-21	131.48	3,920.05	-2.81%	-1.92%
19-Apr-21	135.28	3,996.65	0.07%	-0.25%
16-Apr-21	135.18	4,006.76	1.38%	0.45%
15-Apr-21	133.34	3,988.72	-0.58%	0.61%
14-Apr-21	134.12	3,964.67	0.09%	0.64%
13-Apr-21	134	3,939.31	-0.61%	0.14%
12-Apr-21	134.82	3,933.89	0.13%	-0.40%
09-Apr-21	134.64	3,949.51	-1.33%	-0.29%
08-Apr-21	136.46	3,960.97	-0.13%	0.75%
07-Apr-21	136.64	3,931.53	1.50%	0.87%
06-Apr-21	134.62	3,897.81	0.72%	1.26%
01-Apr-21	133.66	3,849.24	1.35%	0.47%
31-Mar-21	131.88	3,831.05		

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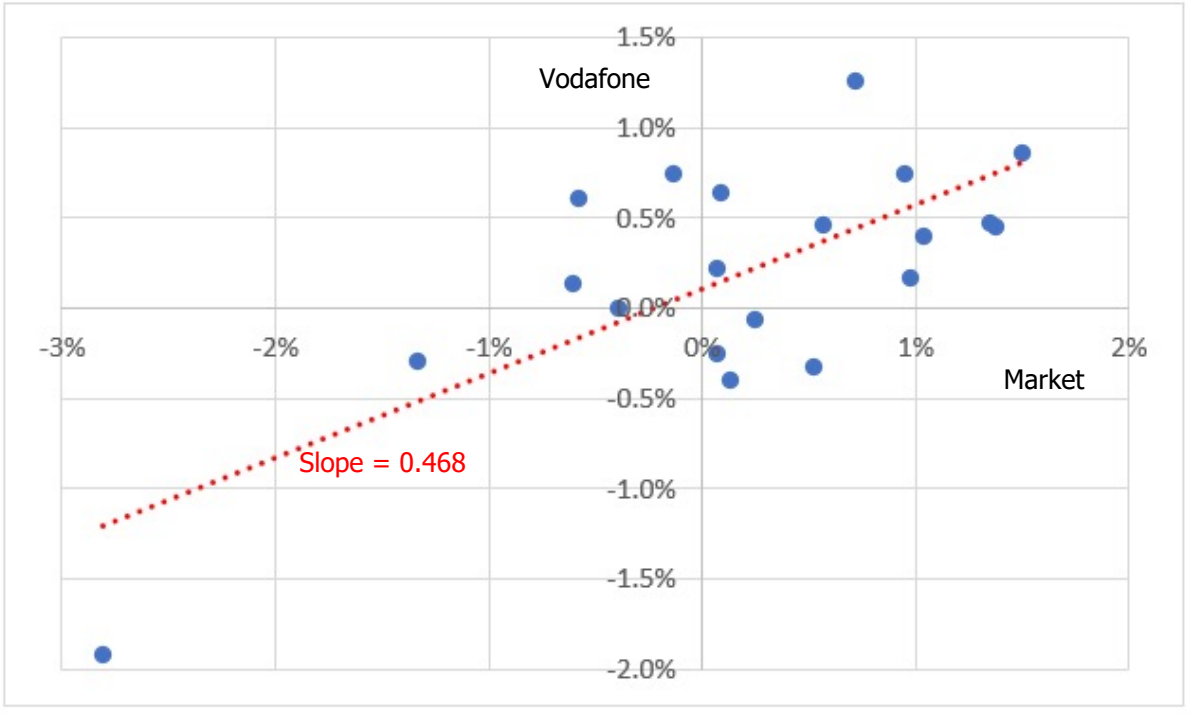
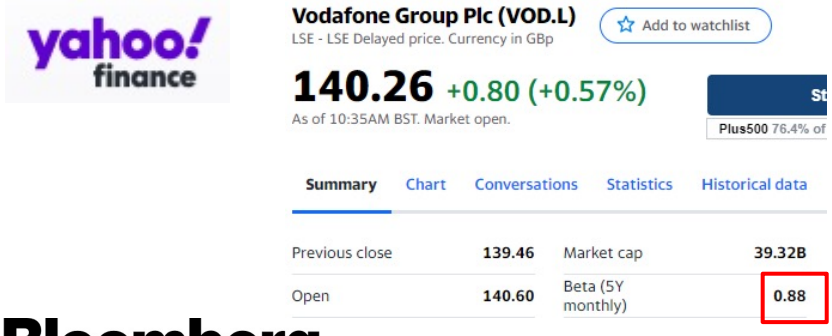
07-Apr-21	136.64	3,931.53	1.50%	0.87%
06-Apr-21	134.62	3,897.81	0.72%	1.26%
01-Apr-21	133.66	3,849.24	1.35%	0.47%
31-Mar-21	131.88	3,831.05		**0.468**

=SLOPE(Q3:Q22,P3:P22)


Vodafone
Market
Slope = 0.468
1.5%
1.0%
0.5%
0.0%
-0.5%
-1.0%
-1.5%
-2.0%
-3%
-2%
-1%
0%
1%
2%

Other Sources of Beta



Bloomberg

- If company is not publicly traded
  - Comparable company betas
  - Industry betas from Aswath Damodaran's website

Using the CAPM

$$r_V - r_f = \beta_V(r_m - r_f)$$

FINANCIAL TIMES

UK 10 year Gilt

UK10YG

YIELD	TODAY'S CHANGE
0.897	-0.002 / -0.22%

Using the CAPM

$$r_V - r_f = \beta_V(r_m - r_f)$$

	FTSE All Share	10 Year Gilt Yield	Market risk premium
2020	-9.82%	0.30%	-10.12%
2019	19.17%	0.93%	18.24%
2018	-9.47%	1.46%	-10.93%
2017	13.10%	1.24%	11.86%
2016	16.75%	1.30%	15.45%
2015	0.98%	1.90%	-0.92%
Average			**3.93%**

FTSE: https://siblisresearch.com/data/ftse-all-total-return-dividend/

Gilt: https://datahub.io/core/bond-yields-uk-10y

Using the CAPM

$$r_V - r_f = \beta_V(r_m - r_f)$$

- $r_V - 0.897\% = 0.88 \times 3.93\%$
- $r_V = 4.36\%$

- You should receive a 4.36% return for investing in Vodafone shares (compared to 0.897% for investing in government bonds)

The Importance of Risk Type

- A project pays £10 next year if successful, but there's a 50% chance it's unsuccessful
- Idiosyncratic: $V = \frac{5}{1.00897} = 4.96$
- Systematic, β=0.88: $V = \frac{5}{1.0436} = 4.79$

Using the CAPM: Caveats

- In $r_1 - r_f = \beta_1(r_m - r_f)$, the inputs should be forward-looking
- The past is a guide to the future, but an imperfect guide

Summary

- An investment is a claim to *risky* future cash flows
- Most people are risk-averse due to *diminishing marginal utility*
- The typical measure of risk is the *standard deviation* σ
  - But some risk is *idiosyncratic* and thus diversifiable
- Investors should only earn higher returns for non-diversifiable risk
  - Since investors should hold the market, non-diversifiable risk is *market risk*
- $\beta_1 = \frac{\sigma_{1m}}{\sigma_m^2} = \frac{Cov(r_1, r_m)}{Var(r_m)}$ measures market risk – how much the stock rises when the market rises
- The CAPM is $r_1 - r_f = \beta_1(r_m - r_f)$