Module 8

Risk, Return, and the CAPM

FINE 3010, Financial Management

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Goals

- **Module 7** left two questions open,
  - What is risk?
  - How is the opportunity cost of an investment (which we use as the discount rate) related to risk?

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  - How is the opportunity cost of an investment (which we use as the discount rate) related to risk?
- This module answers both,
  - **Part 1**, returns and risk premiums
  - **Part 2**, return volatility and portfolio diversification
  - **Part 3**, beta, the risk that actually matters
  - **Part 4**, CAPM, the relationship between beta and expected return
  - **Part 5**, from expected return to discount rate

Module 8, Part 1

Returns and Risk Premiums

Return

Recall from **Module 4**

- **Return**, percentage growth of an asset's value over some period of time

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- Suppose Oracle's stock price was \$100 at the beginning of 2024 and \$180 at the end of 2024. What was the return for 2024?

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$$\text{Return} = \frac{\$180 - \$100}{\$100} = 80\%$$

Expected Returns

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- E.g., a 50% chance of a 10% return and a 50% chance of a 0% return give $E[R_i] = 0.5 \times 10\% + 0.5 \times 0\% = 5\%$

Example, Expected Returns

- You want the expected return of a stock over the next year. Three things might happen,
  - A recession, 20% chance, the stock returns -10%
  - A normal year, 50% chance, the stock returns 5%
  - A boom, 30% chance, the stock returns 15%

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  - A normal year, 50% chance, the stock returns 5%
  - A boom, 30% chance, the stock returns 15%
- Solution, the expected return is

$$E[R_i] = 0.2 \times (-10\%) + 0.5 \times 5\% + 0.3 \times 15\% = 5\%$$

Portfolio

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Its stock portfolio on June 30, 2026 ($20.2 billion),

Company	Business	Weight
Sandisk	Memory chips	28%
Micron	Memory chips	28%
Bloom Energy	Fuel cells	9%
TSMC	Chip maker	6%
Nebius	AI cloud	6%
CoreWeave	AI cloud	4%
Other holdings		19%
Total		100%

Source, SEC Form 13F, filed August 14, 2026

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$$R_P = w_1 \times R_1 + w_2 \times R_2 + \cdots + w_S \times R_S$$

- The expected portfolio return is likewise a weighted average of the securities' expected returns,

$$E[R_P] = w_1 \times E[R_1] + w_2 \times E[R_2] + \cdots + w_S \times E[R_S]$$

Example, Portfolio Returns

- One year ago, you bought two stocks for \$500 each, \$1,000 in total
- One stock returned 30% during the year, the other -10%
- What is your portfolio return over the year?

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- Solution, you invested $500/1{,}000 = 50\%$ in each stock, so the weights are 50% each,

$$R_P = w_1 \times R_1 + w_2 \times R_2 = 0.5 \times 30\% + 0.5 \times (-10\%) = 10\%$$

Example, Expected Portfolio Returns

- You want the expected return of your portfolio over the next year. You hold two stocks, 50% of your money in each
- The first stock's expected return is 5%, the second's is 9%
- What is your portfolio's expected return over the next year?

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- What is your portfolio's expected return over the next year?

- Solution, the expected portfolio return is

$$E[R_P] = w_1 \times E[R_1] + w_2 \times E[R_2] = 0.5 \times 5\% + 0.5 \times 9\% = 7\%$$

The Risk-Free Rate and Market Returns

- $r_{f,t}$, the **risk-free rate** as of time t
  - The return from an investment with no risk, i.e., return is the same in every scenario
  - In practice, the interest rate on Treasury bills (short-term U.S. government debt)

The Risk-Free Rate and Market Returns

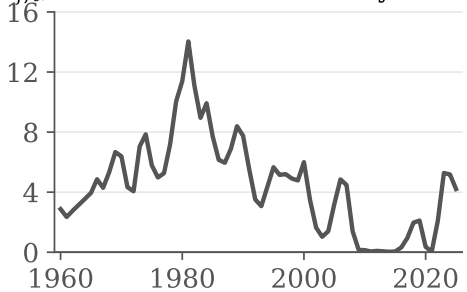
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- $R_{\text{mkt},t}$, the return on the market portfolio in period t
  - **Market portfolio**, the (theoretical) portfolio of all investable assets in the economy, weighted by market capitalization
  - In practice, represented by a broad market index such as the S&P 500

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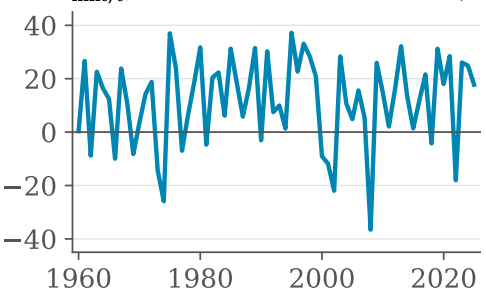
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- $E[R_{\text{mkt}}]$, the **expected return** on the market portfolio

The Risk-Free Rate and Market Returns over Time

$r_{f,t}$, interest rate on Treasury bills (%)

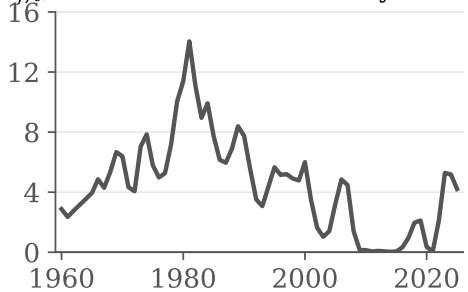


$R_{\text{mkt},t}$, return on the S&P 500 (%)

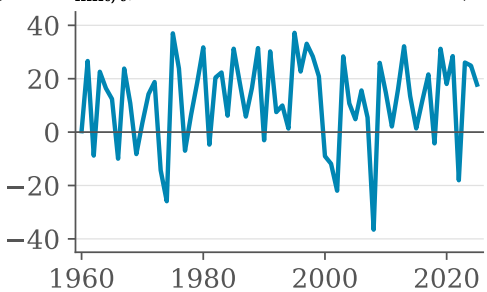


The Risk-Free Rate and Market Returns over Time

$r_{f,t}$, interest rate on Treasury bills (%)



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- $r_{f,t}$ and $R_{\text{mkt},t}$ can be different at different t

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Treasury bills	3.4%	0%

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Treasury bills	3.4%	0%
Investment-grade corporate bonds	6.9%	3.5%
Stocks	11.9%	8.5%

Risk Premiums

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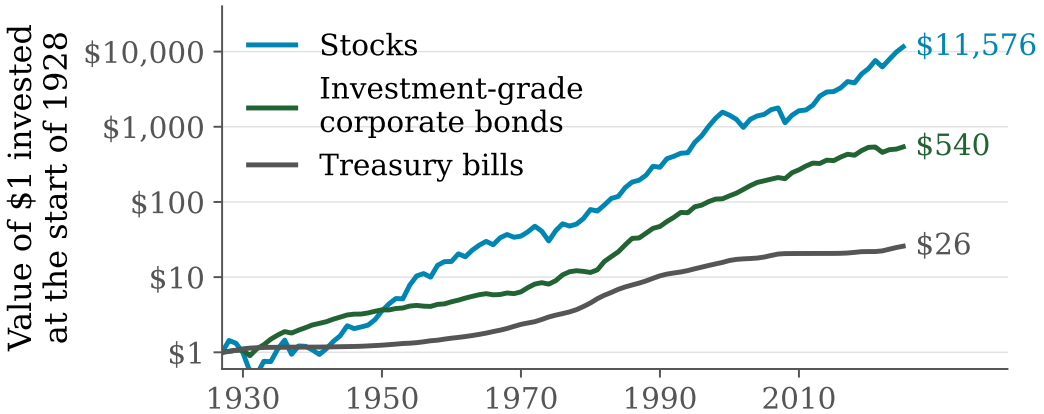
Risk Premiums

- **Risk premium**, the "extra" expected return you earn on an investment above the risk-free rate,

$$E[R_i] = r_f + \text{Risk premium}_i$$

- Investment-grade corporate bonds have historically earned an average risk premium of 3.5% over Treasury bills
- Stocks have historically earned an average risk premium of 8.5% over Treasury bills, the **equity premium**

Returns over Time for Stocks, Bonds, and Treasury Bills



Recap of Part 1

- **Return**, percentage growth of an asset's value over some period of time

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- **Return**, percentage growth of an asset's value over some period of time
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- **Portfolio return**, the weighted average of the securities' returns
- $E[R_i] = r_f + \text{Risk premium}_i$, riskier assets have higher expected returns
- **Equity premium**, about 8.5% over Treasury bills

Module 8, Part 2

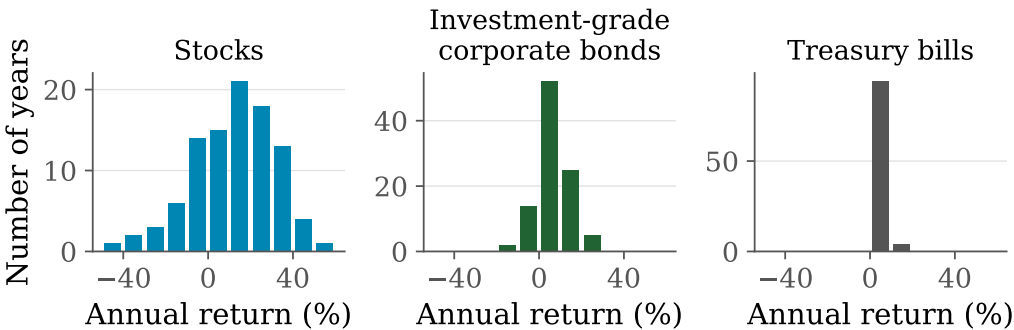
Return Volatility and Portfolio Diversification

Equity Premium Has Been High, but What about Volatility?

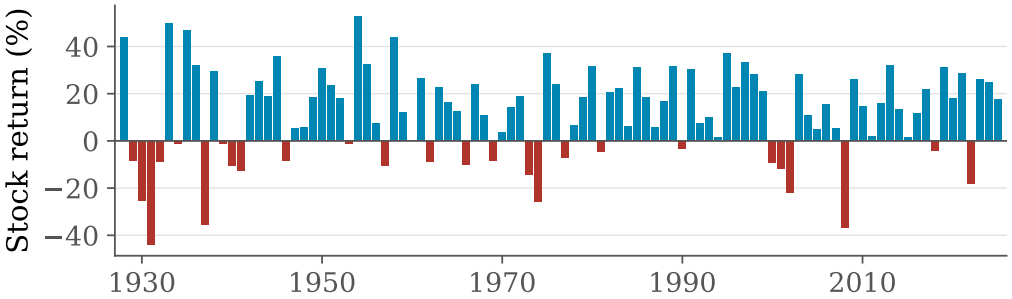
- How volatile are portfolios of stocks vs. bonds vs. Treasury bills?

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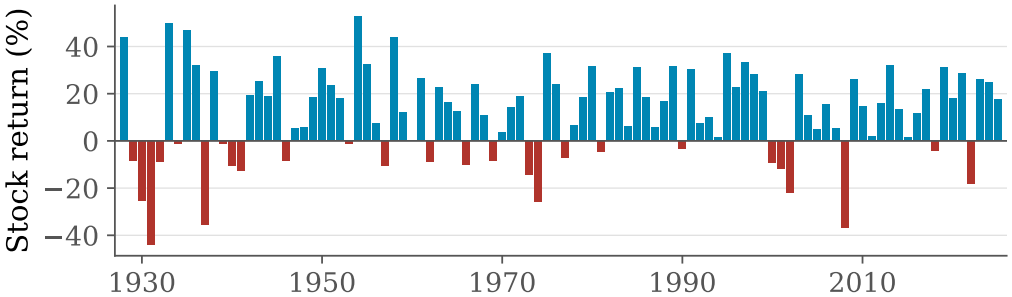
- How volatile are portfolios of stocks vs. bonds vs. Treasury bills?
- Consider the variation in annual returns, 1928–2025, how many years fell in each range,



Stock Market Returns over Time

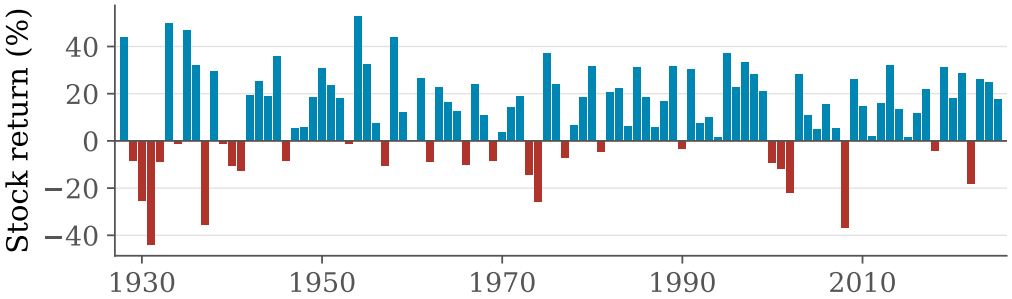


Stock Market Returns over Time



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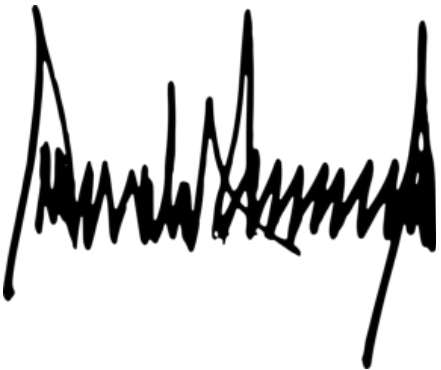
Stock Market Returns over Time



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- Individual stocks are even more volatile, around 50% of stock-years have negative returns

Discuss, Do They Look Alike?

US President Donald Trump's Signature

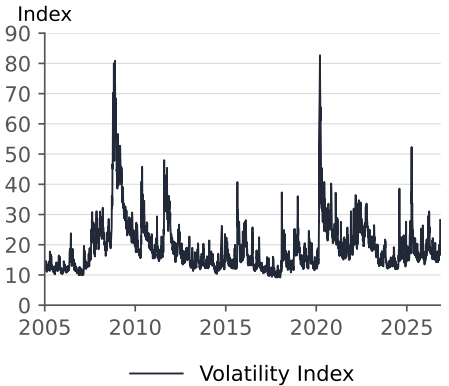


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US Stock Volatility Index (VIX)



Measuring Volatility, Variance and Standard Deviation

- **Variance**, the average squared deviation from the average return, in four steps,
  1. Compute the average return

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- **Standard deviation**, the square root of the variance,

$$\text{Standard deviation} = \sqrt{\text{Variance}}$$

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Year	Return
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3	10%
4	−5%
5	5%
6	20%

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- Your returns over six years are 5%, 25%, 10%, −5%, 5%, and 20%. What is the standard deviation of returns?

Year	Return	Deviation from average	Squared deviation
1	5%	−5%	0.0025
2	25%	15%	0.0225
3	10%	0%	0.0000
4	−5%	−15%	0.0225
5	5%	−5%	0.0025
6	20%	10%	0.0100
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6	20%	10%	0.0100
Average	10%	Variance (average of squared deviations)	0.0100

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6	20%	10%	0.0100
Average	10%	Variance (average of squared deviations)	0.0100
		Standard deviation (square root)	10%

Standard Deviation of Treasury Bills vs. Bonds vs. Stocks

Portfolio	Standard deviation (%), 1928–2025
Treasury bills	3.0

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Stocks	19.4

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- The standard deviation of an individual stock is typically much higher than that of the index

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Stock	Since	Standard deviation of annual returns (%)
Tesla	2011	201.4
Amazon	1998	186.9
Apple	1981	65.1
Microsoft	1987	41.9
McDonald's	1967	41.3

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S&P 500	**1928**	**19.4**

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- This is where diversification will help!

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Example, Portfolio Diversification

- Next year, one of three scenarios happens with equal likelihood, a recession, normal times, or a boom

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- Next year, one of three scenarios happens with equal likelihood, a recession, normal times, or a boom
- You consider two stocks, stock A (does relatively better in a boom) and stock B (does relatively better in a recession),

Scenario	Probability	Stock A (%)	Stock B (%)
Recession	1/3	−8	+20
Normal	1/3	+5	+3
Boom	1/3	+18	−20

Example, Portfolio Diversification

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- As investors, we love expected return but hate volatility (standard deviation)
- So we want a high expected return for a low standard deviation
- Then how should we invest?

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Stock A	Return
Recession	-8%
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Stock A	Return
Recession	-8%
Normal	5%
Boom	18%
$E[R_A]$	5%

Stock B	Return
Recession	20%
Normal	3%
Boom	-20%
$E[R_B]$	1%

Example, Portfolio Diversification

- What are the expected return and the volatility if we invest in one stock?

Stock A	Return	Deviation from $E[R_A]$
Recession	-8%	-13%
Normal	5%	0%
Boom	18%	13%
$E[R_A]$	5%	

Stock B	Return	Deviation from $E[R_B]$
Recession	20%	19%
Normal	3%	2%
Boom	-20%	-21%
$E[R_B]$	1%	

Example, Portfolio Diversification

- What are the expected return and the volatility if we invest in one stock?

Stock A	Return	Deviation from $E[R_A]$	Squared deviation
Recession	-8%	-13%	0.0169
Normal	5%	0%	0.0000
Boom	18%	13%	0.0169
$E[R_A]$	5%		

Stock B	Return	Deviation from $E[R_B]$	Squared deviation
Recession	20%	19%	0.0361
Normal	3%	2%	0.0004
Boom	-20%	-21%	0.0441
$E[R_B]$	1%		

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Normal	5%	0%	0.0000
Boom	18%	13%	0.0169
$E[R_A]$	5%	Variance	0.0113

Stock B	Return	Deviation from $E[R_B]$	Squared deviation
Recession	20%	19%	0.0361
Normal	3%	2%	0.0004
Boom	-20%	-21%	0.0441
$E[R_B]$	1%	Variance	0.0269

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Normal	5%	0%	0.0000
Boom	18%	13%	0.0169
$E[R_A]$	5%	Variance	0.0113
		Std. dev.	10.6%

Stock B	Return	Deviation from $E[R_B]$	Squared deviation
Recession	20%	19%	0.0361
Normal	3%	2%	0.0004
Boom	-20%	-21%	0.0441
$E[R_B]$	1%	Variance	0.0269
		Std. dev.	16.4%

Example, Portfolio Diversification

- What are the expected return and the volatility if we invest in one stock?

Stock A	Return	Deviation from $E[R_A]$	Squared deviation
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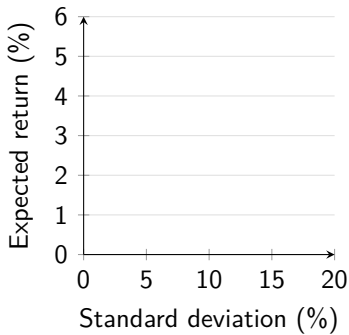
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- $E[R]$ / std. dev., stock A $5/10.6 = 0.47$, stock B $1/16.4 = 0.06$
- Stock A looks better as a stand-alone investment on this metric

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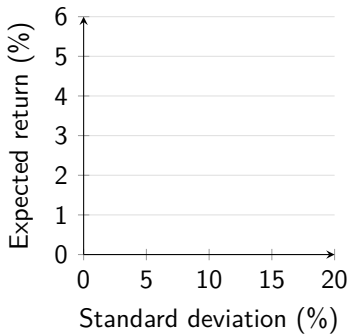
Portfolio	
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Stock B weight	
Recession	
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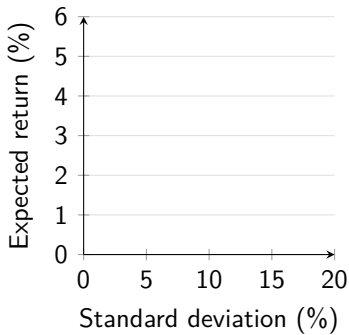
Portfolio	1
Stock A weight	100%
Stock B weight	
Recession	
Normal	
Boom	
$E[R]$	
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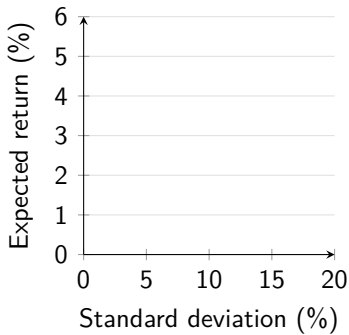
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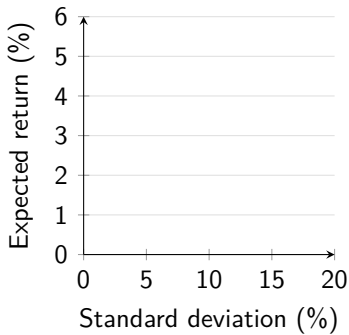
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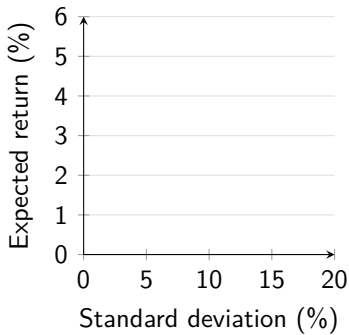
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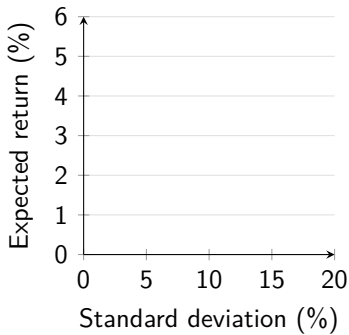
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Std. dev.	
$E[R]$ / std. dev.	



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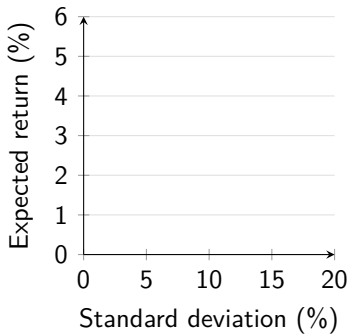
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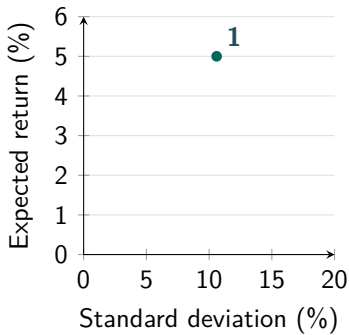
Portfolio	1
Stock A weight	100%
Stock B weight	0%
Recession	−8%
Normal	5%
Boom	18%
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$E[R]$ / std. dev.	



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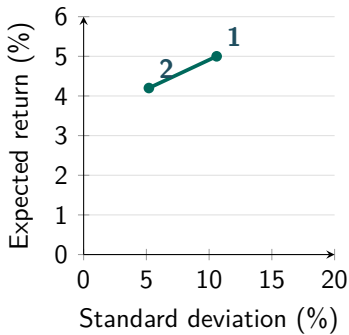
Portfolio	1
Stock A weight	100%
Stock B weight	0%
Recession	−8%
Normal	5%
Boom	18%
$E[R]$	5.0%
Std. dev.	10.6%
$E[R]$ / std. dev.	0.47



Example, Portfolio Diversification

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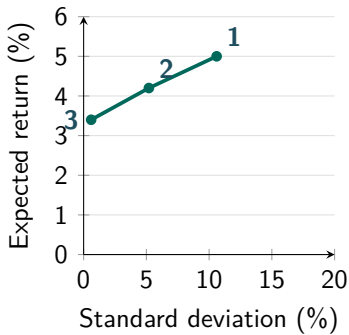
Portfolio	1	2
Stock A weight	100%	80%
Stock B weight	0%	20%
Recession	−8%	−2%
Normal	5%	5%
Boom	18%	10%
$E[R]$	5.0%	4.2%
Std. dev.	10.6%	5.2%
$E[R]$ / std. dev.	0.47	0.80



Example, Portfolio Diversification

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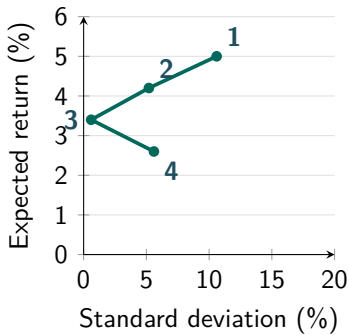
Portfolio	1	2	3
Stock A weight	100%	80%	60%
Stock B weight	0%	20%	40%
Recession	−8%	−2%	3%
Normal	5%	5%	4%
Boom	18%	10%	3%
$E[R]$	5.0%	4.2%	3.4%
Std. dev.	10.6%	5.2%	0.6%
$E[R]$ / std. dev.	0.47	0.80	5.77



Example, Portfolio Diversification

- What if we mixed the two stocks with different weights?

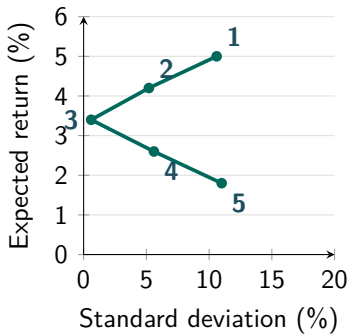
Portfolio	1	2	3	4
Stock A weight	100%	80%	60%	40%
Stock B weight	0%	20%	40%	60%
Recession	−8%	−2%	3%	9%
Normal	5%	5%	4%	4%
Boom	18%	10%	3%	−5%
$E[R]$	5.0%	4.2%	3.4%	2.6%
Std. dev.	10.6%	5.2%	0.6%	5.6%
$E[R]$ / std. dev.	0.47	0.80	5.77	0.46



Example, Portfolio Diversification

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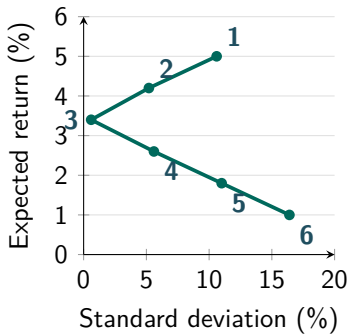
Portfolio	1	2	3	4	5
Stock A weight	100%	80%	60%	40%	20%
Stock B weight	0%	20%	40%	60%	80%
Recession	−8%	−2%	3%	9%	14%
Normal	5%	5%	4%	4%	3%
Boom	18%	10%	3%	−5%	−12%
$E[R]$	5.0%	4.2%	3.4%	2.6%	1.8%
Std. dev.	10.6%	5.2%	0.6%	5.6%	11.0%
$E[R]$ / std. dev.	0.47	0.80	5.77	0.46	0.16



Example, Portfolio Diversification

- What if we mixed the two stocks with different weights?

Portfolio	1	2	3	4	5	6
Stock A weight	100%	80%	60%	40%	20%	0%
Stock B weight	0%	20%	40%	60%	80%	100%
Recession	−8%	−2%	3%	9%	14%	20%
Normal	5%	5%	4%	4%	3%	3%
Boom	18%	10%	3%	−5%	−12%	−20%
$E[R]$	5.0%	4.2%	3.4%	2.6%	1.8%	1.0%
Std. dev.	10.6%	5.2%	0.6%	5.6%	11.0%	16.4%
$E[R]$ / std. dev.	0.47	0.80	5.77	0.46	0.16	0.06



Portfolio Diversification

- What is the standard deviation of the portfolio?

$$\text{StdDev}[R_P] \neq w_A \,\text{StdDev}[R_A] + w_B \,\text{StdDev}[R_B]$$

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- **Diversification**, spreading the money in a portfolio across many securities rather than one
- Diversification typically makes the standard deviation of a portfolio lower than the weighted average of the standard deviations of the stocks in it,

$$\textbf{StdDev}[R_P] < w_A \,\text{StdDev}[R_A] + w_B \,\text{StdDev}[R_B]$$

Simulation with AI

- An economy with N companies, each producing a product

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  - Something bad hits the whole economy, like a pandemic (10% chance each year), every stock return falls by 30 points

Simulating an Investor's Return

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- Now the investor splits the money equally across 2 companies, then 5, 10, 30, 100. Does the standard deviation fall? To zero?

What Is the End Game of Portfolio Diversification?

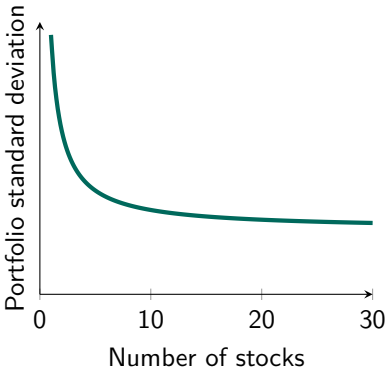
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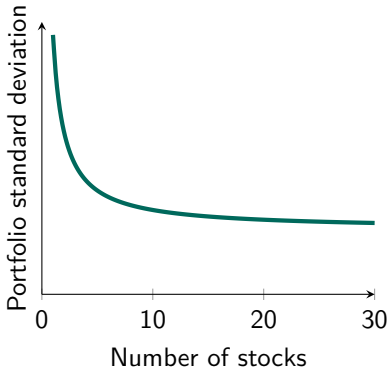
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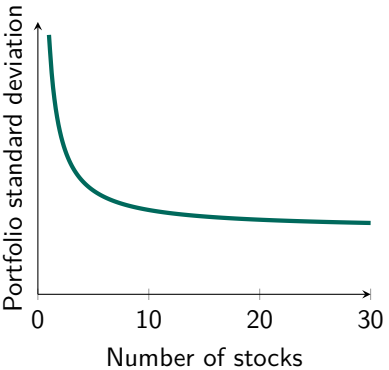
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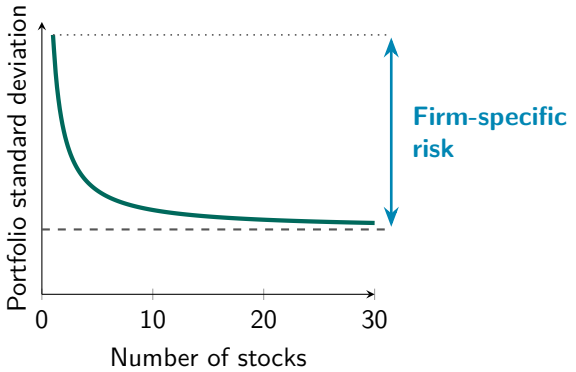
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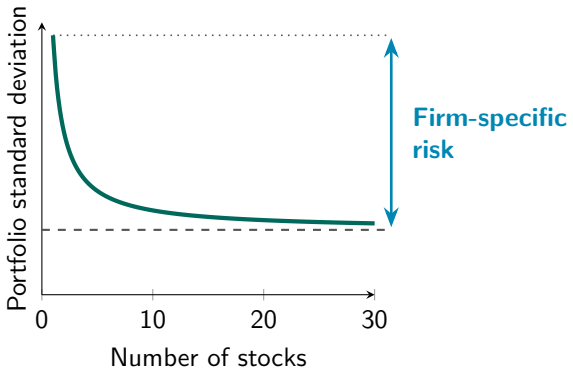
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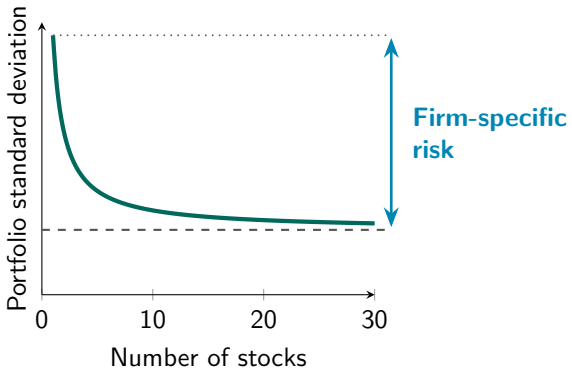
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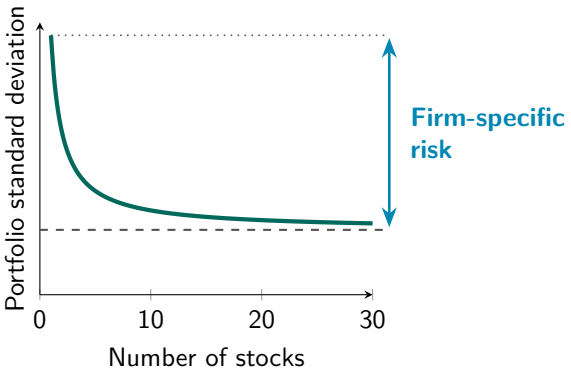
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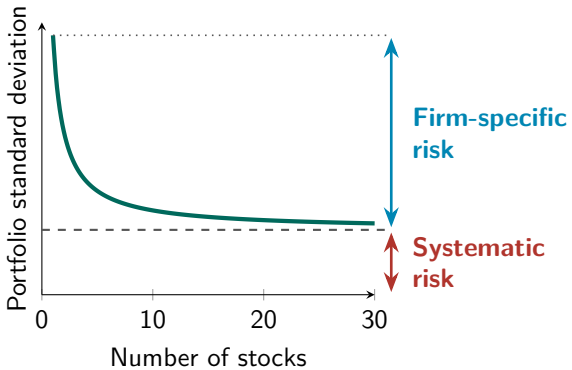
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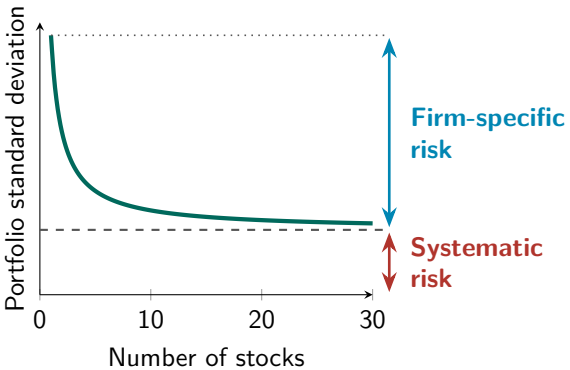
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- The end game, a diversified portfolio carries systematic risk only



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- **Volatility**, how much returns vary, the **variance** or **standard deviation**

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Module 8, Part 3

Beta

From Standard Deviation to Beta

- **Part 2**'s lesson, a diversified investor is left with systematic risk only

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From Standard Deviation to Beta

- **Part 2**'s lesson, a diversified investor is left with systematic risk only
- So the risk of a stock that matters is its systematic risk, not its standard deviation
- How much systematic risk does a stock carry?

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- It only has systematic risk (e.g., a government shutdown, a pandemic)
- In practice, represented by a broad market index such as the S&P 500

Beta

- Recall the **return**, percentage growth of an asset's value over some period of time

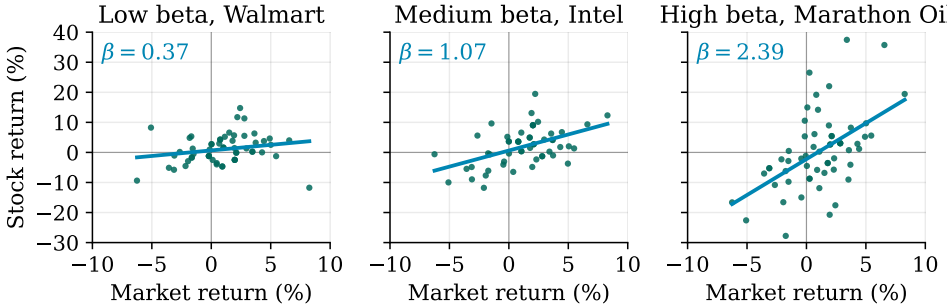
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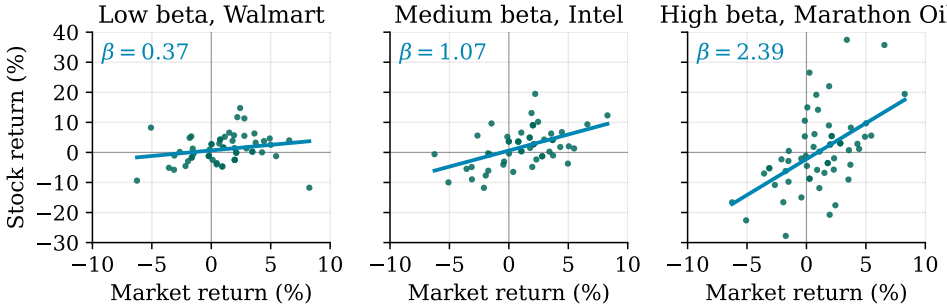
Beta

- Recall the **return**, percentage growth of an asset's value over some period of time
- **Excess return**, a security's realized return over the risk-free rate in period t, $R_{i,t} - r_{f,t}$
- **Beta**, the sensitivity of a security's (or portfolio's) excess return to the market portfolio's excess return

Example, Low vs. Medium vs. High Beta Stocks

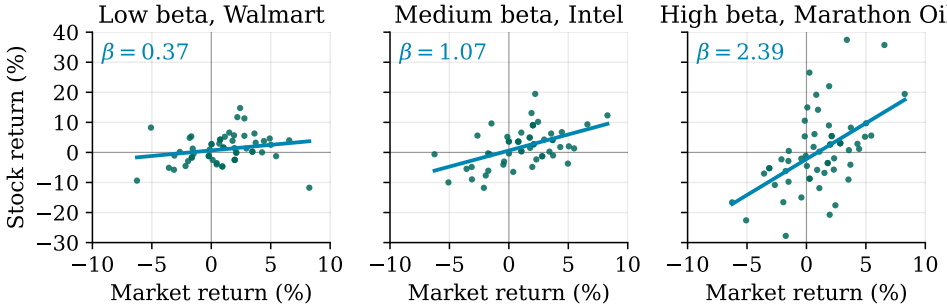


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  - Its return moves one for one with the market's, because it is the market

A Primer on Regression Analysis

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- **Regression analysis**, a statistical tool for describing the "best-fit" linear relation between two variables, X (the "explanatory" variable) and Y (the "dependent" variable)

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- The best-fit line keeps the residuals e_i as small as possible overall

Example, Height and Weight

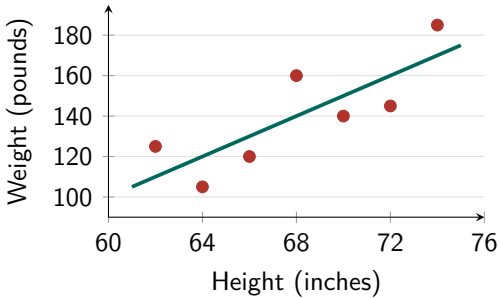
- Seven people's heights and weights, what is the best-fit line between weight (Y) and height (X)?

Person	Height (inches)	Weight (pounds)
1	62	125
2	64	105
3	66	120
4	68	160
5	70	140
6	72	145
7	74	185

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- Solution, the best-fit line is Weight $= -200 + 5 \times$ Height, so $\alpha = -200$ and $\beta = 5$

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- The coefficient β from this regression is the estimate of the stock's beta

Example, Measuring Beta

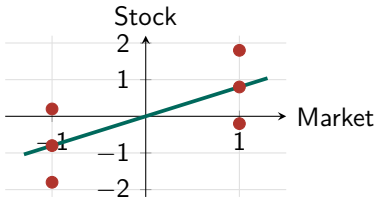
- A company's stock has the following excess returns, alongside the market portfolio's (both in %). What is its beta?

Month	Market excess return	Stock excess return
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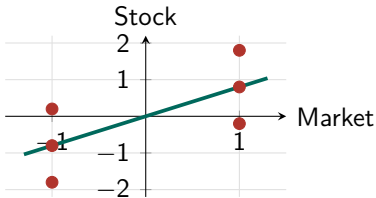


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- The slope is the estimate of the stock's beta, here $\beta = 0.8$

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Module 8, Part 4

The CAPM

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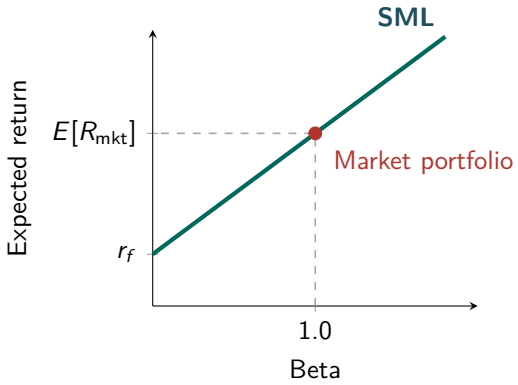
$$E[R_i] = r_f + \beta_i \times (E[R_{\text{mkt}}] - r_f)$$

  - $E[R_{\text{mkt}}] - r_f$, the **market risk premium**, the expected return on the market portfolio over the risk-free rate

CAPM, the Security Market Line

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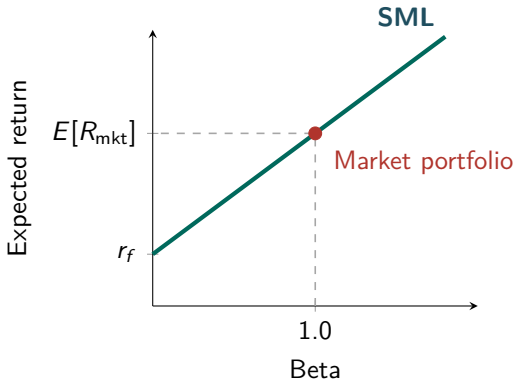


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- A straight line, it starts at r_f for $\beta = 0$ and passes through the market portfolio, $\beta = 1$ and $E[R_{\text{mkt}}]$



CAPM, Expected Returns for Selected Companies

- With $r_f = 3\%$ and a market risk premium $E[R_{\text{mkt}}] - r_f = 7\%$, the expected returns are,

Company	Business	Beta
Marathon Oil	Oil and gas	2.39
Disney	Entertainment	1.39
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Coca-Cola	Beverages	0.70	7.9
Walmart	Retail	0.37	5.6

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- It earned him the Nobel Prize in economics in 1990



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c. True. The asset's beta is a function of its sensitivity to macroeconomic risks, among other factors

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Module 8, Part 5

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- Is this return the project's discount rate r in capital budgeting?

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Discount rate of a project = Expected return on stocks with the same beta

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3. Discount the project's cash flows at r as in **Module 7**, accept if NPV > 0 (equivalently, if IRR $> r$)

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- Should the company invest if the future cash flow has the same risk as the market portfolio ($\beta = 1$)?

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- Solution, compare the project with what the same \$100 million would earn in securities with the same beta (\$ millions),

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- $\beta = 0$, Treasury bills turn \$100 million into \$101 million, the project into \$105 million, more. NPV $= -100 + 105/1.01 = 3.96 > 0$, accept

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0	Treasury bills	$1\% + 0 \times 7\% = 1\%$	101	105	**Accept**
1	The market portfolio	$1\% + 1 \times 7\% = 8\%$	108	105	**Reject**

- $\beta = 0$, Treasury bills turn \$100 million into \$101 million, the project into \$105 million, more. NPV $= -100 + 105/1.01 = 3.96 > 0$, accept
- $\beta = 1$, the market portfolio turns \$100 million into \$108 million, the project into \$105 million, less. NPV $= -100 + 105/1.08 = -2.78 < 0$, reject

Example, the Project's Beta Sets the Discount Rate

- Solution, compare the project with what the same \$100 million would earn in securities with the same beta (\$ millions),

Beta	Same-beta securities	Discount rate r	\$100 becomes	Project pays	Decision
0	Treasury bills	$1\% + 0 \times 7\% = 1\%$	101	105	**Accept**
1	The market portfolio	$1\% + 1 \times 7\% = 8\%$	108	105	**Reject**

- $\beta = 0$, Treasury bills turn \$100 million into \$101 million, the project into \$105 million, more. NPV $= -100 + 105/1.01 = 3.96 > 0$, accept
- $\beta = 1$, the market portfolio turns \$100 million into \$108 million, the project into \$105 million, less. NPV $= -100 + 105/1.08 = -2.78 < 0$, reject
- Same cash flows, opposite answers. The discount rate comes from the project's beta, and accepting only the projects with NPV > 0 at this rate makes the shareholders better off

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- Should the oil project be discounted at the company's 6.5%?

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- The company is a portfolio of its two businesses, with weights 80% and 20%, so its beta is the weighted average (**Part 3**),

$$\beta_{\text{company}} = 0.8 \times \beta_{\text{soup}} + 0.2 \times \beta_{\text{oil}} = 0.8 \times 0.5 + 0.2 \times 2.0 = 0.8$$

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- The oil project drags up the company's systematic risk, so its shareholders now require more on the company as a whole, 8.6% instead of 6.5%,

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- That is exactly the weighted average of each business's own CAPM rate,

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- So discount the oil project at 17%, its own rate, not at the company's 6.5%

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- A company can set two or more discount rates for different types of projects

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- Use the project's own beta (the twin method), not the company's

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- **Module 9**, the discount rate becomes the weighted average cost of capital (WACC), a mix of what lenders and shareholders require
- Then debt policy, does the mix of debt and equity change what a company is worth?

Thank you!

Please let me know if you have any questions.