Week 7: FNCE10002 Principles of Finance

Modern Portfolio Theory and Asset Pricing II

Asjeet S. Lamba, Ph.D., CFA
Associate Professor of Finance
Room 12.043, Faculty of Business and Economics
8344-7011
asjeet@unimelb.edu.au

7. Modern Portfolio Theory and Asset Pricing II

1. Analyze the limitations to the benefits of risk diversification
2. Explain the relation between systematic risk and expected return using the CAPM
3. Use the security market line to price securities
4. Examine how security betas are estimated, interpreted and used
5. Apply the CAPM to value ordinary shares

Required Readings: Weeks 7 – 9

- *Week 7*
  - GRAH, Ch. 7 (Review Sec 7.1 – 7.2)
- *Week 8*
  - GRAH, Ch. 9 (skip Sec 9.3)
- *Week 9*
  - GRAH, Ch. 10 and Ch. 11

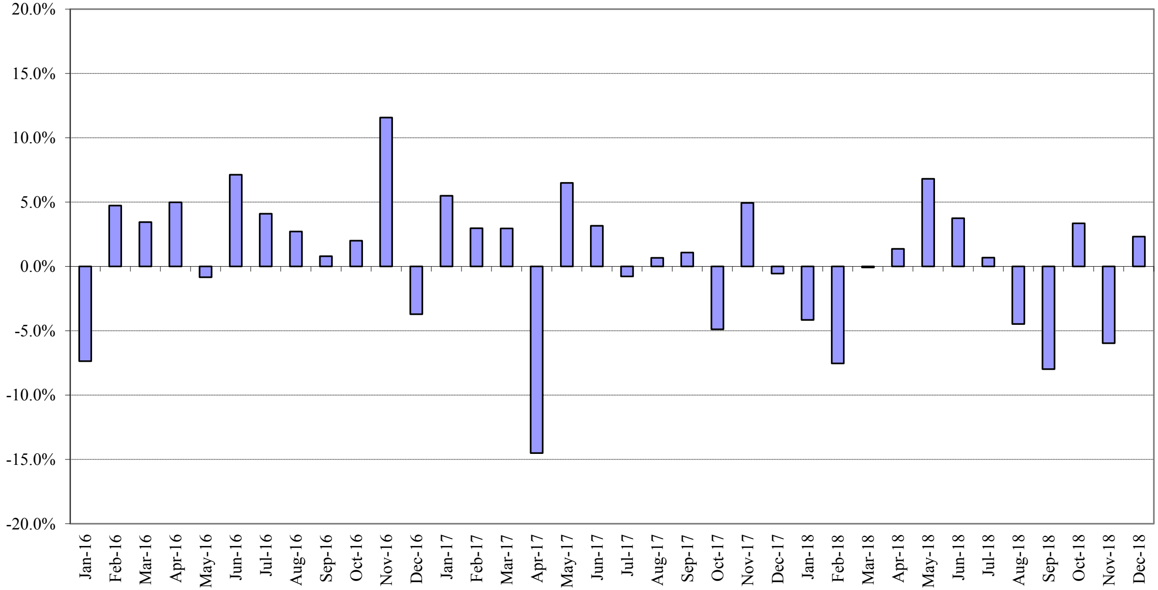
7.1 Are There Limits to Diversification Benefits?

- *What happens to total risk as an investor adds more and more securities to a portfolio?*

	Mean	*Std Dev*	*ANZ*	*BHP*	*NAB*	*TLS*
ANZ	8.3%	18.1%	1.00			
BHP	33.6%	23.2%	0.12	1.00		
NAB	4.2%	17.3%	0.80	0.26	1.00	
TLS	-11.0%	19.2%	0.13	0.11	0.24	1.00

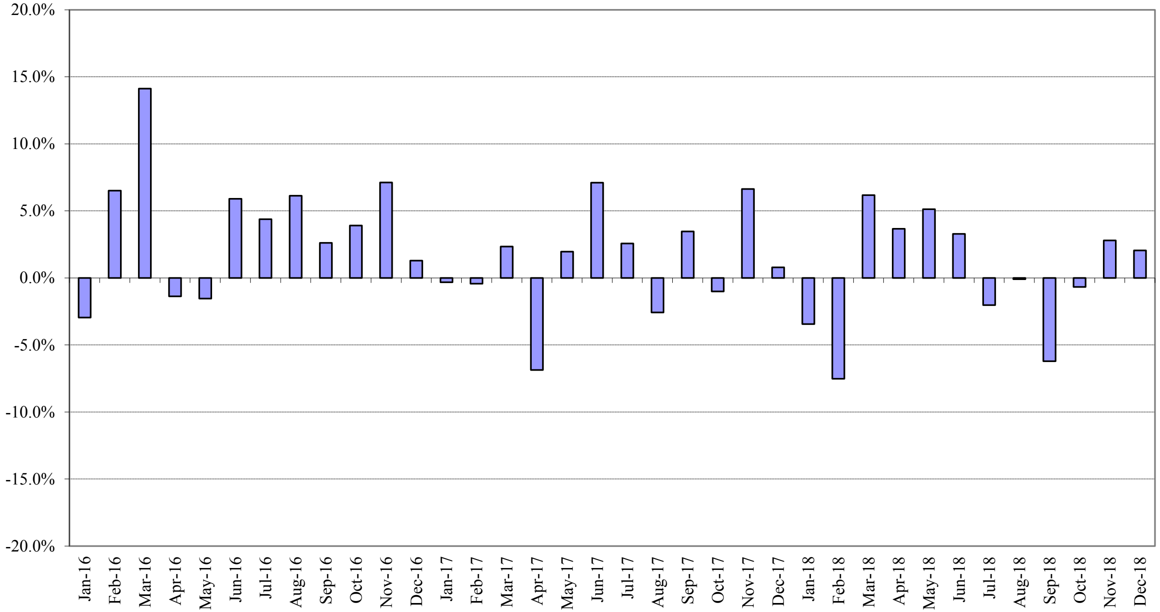
Note: The sample period is Jan 2016 – Dec 2018. The mean and standard deviation of returns are based on monthly returns which have been annualized.

Case Study 1: Have You Diversified Lately?



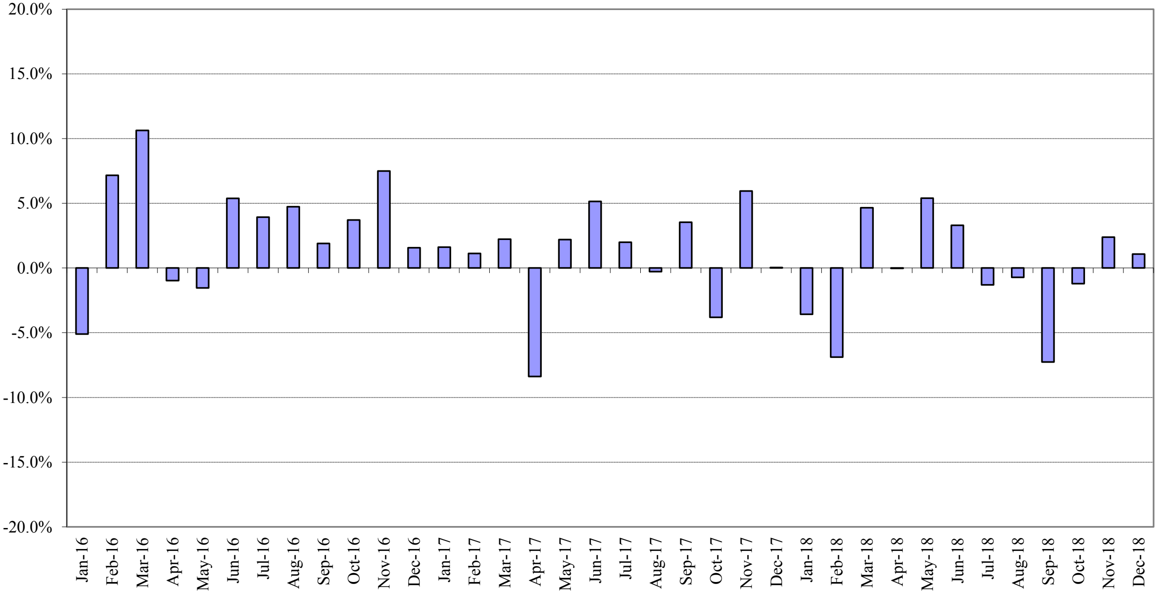
Portfolio with all funds invested in ANZ. Monthly returns are from Jan 2016 – Dec 2018. The annualized standard deviation of returns is 18.1%

Case Study 1: Have You Diversified Lately?



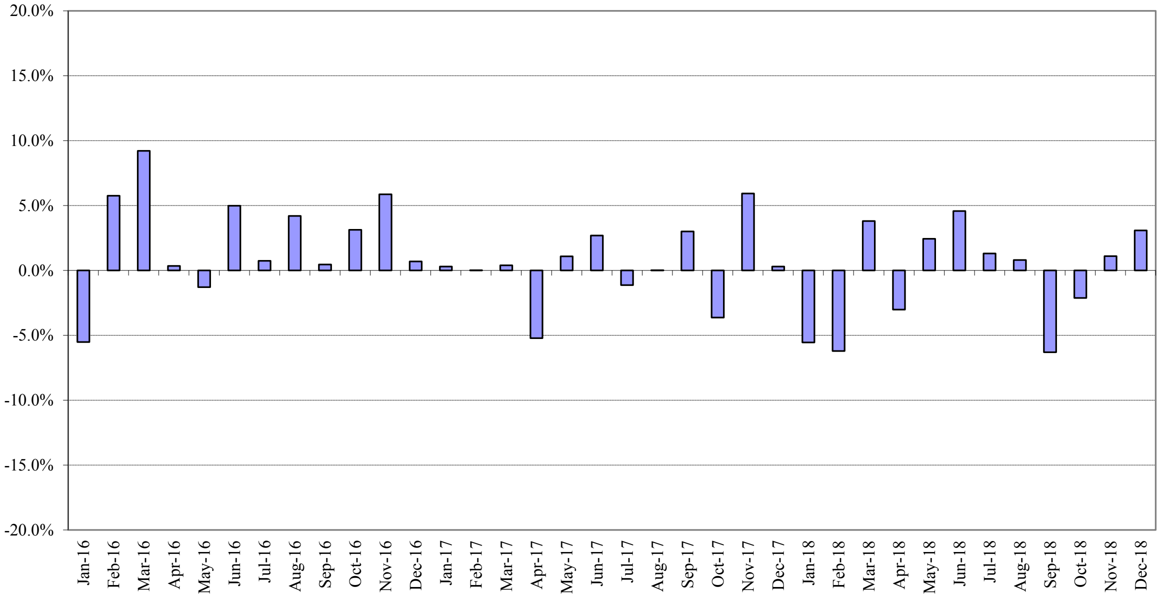
Equally weighted portfolio of ANZ and BHP. Monthly returns are from Jan 2016 – Dec 2018. The annualized standard deviation of returns is 15.5%

Case Study 1: Have You Diversified Lately?



Equally weighted portfolio of ANZ, BHP and NAB. Monthly returns are from Jan 2016 – Dec 2018. The annualized standard deviation of returns is 14.8% not too significant since co(ANZ, NAB) is high

Case Study 1: Have You Diversified Lately?



Equally weighted portfolio of ANZ, BHP, NAB and Telstra. Monthly returns are from Jan 2016 – Dec 2018. The annualized standard deviation of returns is 13.0%

Limits to Diversification Benefits

- *If you diversify broadly enough can you eliminate risk altogether?* No
- *Illustration:* Consider portfolios of 2, 5, 10, 20, 50, 100 and 500 stocks where you invest 1/N of your wealth in *each* stock, where each stock has a standard deviation of return of 10%, and where each *pair* of stocks has a return correlation of 0.6. Calculate the standard deviations for these portfolios. What general relation between portfolio standard deviation and the number of stocks is being illustrated here?

Limits to Diversification Benefits

- *Assumptions made…*
  - $x_j = 1/N$
  - $\sigma_j = \sigma_k = \sigma = 10\%$
  - $\rho_{jk} = \rho = 0.6$ ($< +1.0$) for all j and k
- Only in this case, we have…
- $\sigma_p^{\,2} = \sigma^2/N + [(N - 1)/N]\sigma_{jk}$?
- As N becomes very large…
  - The first term approaches *zero*
  - The second term approaches σ_{jk} since $(N - 1)/N$ approaches 1

    average covariance between the individual pairs
- *What's the general implication here?*

? portfolios of portfolios ?

Limits to Diversification Benefits

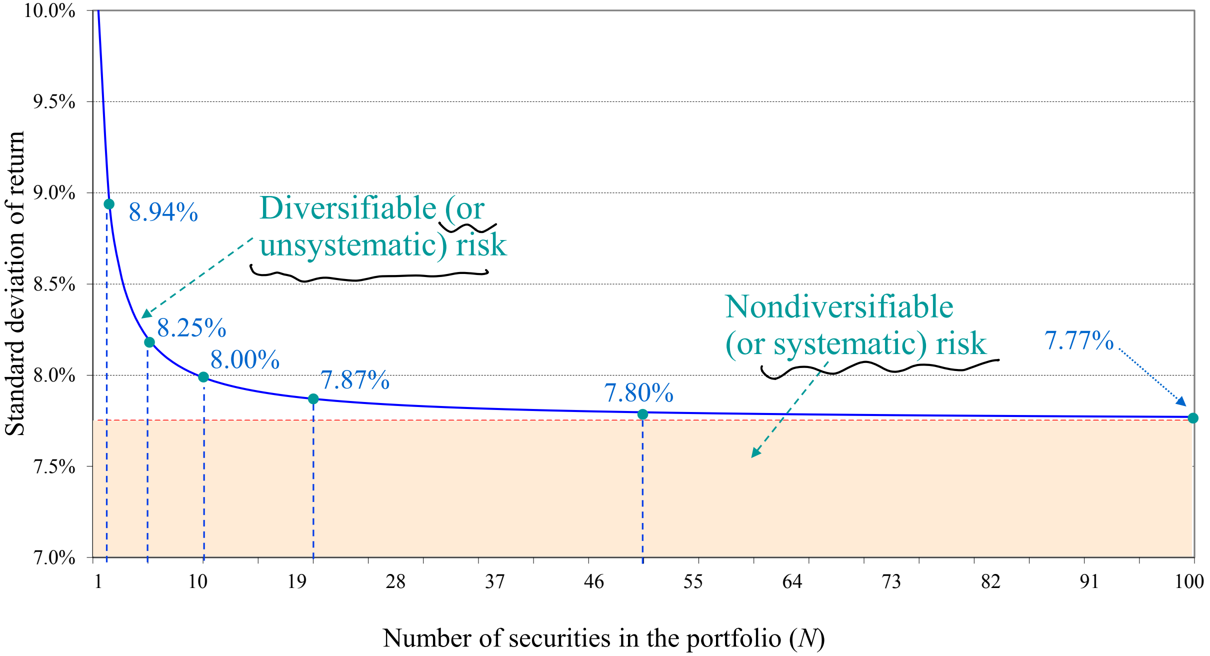
- $\sigma_{jk} = (0.1)(0.1)(0.6) = 0.006$
- $\sigma_p^{\,2} = (0.1)^2/N + [(N - 1)/N]0.006$
  - $N = 2$: $\sigma_p = 0.0894$ or 8.94%
  - $N = 5$: $\sigma_p = 0.0825$ or 8.25% (σ_p falls by 0.69%)
  - $N = 10$: $\sigma_p = 0.0800$ or 8.00% (σ_p falls by 0.25%)
  - $N = 20$: $\sigma_p = 0.0787$ or 7.87% (σ_p falls by 0.13%)
  - $N = 50$: $\sigma_p = 0.0780$ or 7.80% (σ_p falls by 0.07%)
  - $N = 100$: $\sigma_p = 0.0777$ or 7.77% (σ_p falls by 0.03%)
  - $N = 500$: $\sigma_p = 0.0775$ or 7.75% (σ_p falls by 0.02%)

fall at tiny risk

→ never riskfree

- In large portfolios, return *covariances* determine portfolio risk
- As a portfolio becomes large in size its total risk (standard deviation) falls, but at a *declining* rate

Limits to Diversification Benefits



7.2 The Capital Asset Pricing Model

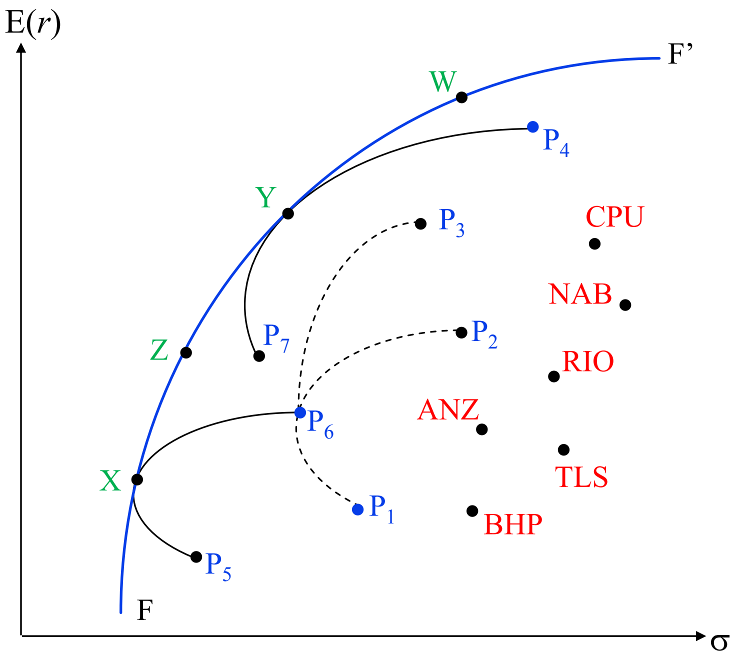
- The CAPM is a theoretical model that can be used to "price" individual securities
  - "Pricing" a security here means estimating its required rate of return (using the CAPM) and then obtaining a price estimate based on the security's future expected cash flows (that is, dividends and future price)
- The CAPM relates a security's required rate of return to its *non-diversifiable or systematic* risk
  - The higher the systematic risk the higher the required rate of return ?
  - *Note:* Total risk is *no longer relevant* to pricing securities, or portfolios of securities

The CAPM's Main Assumptions

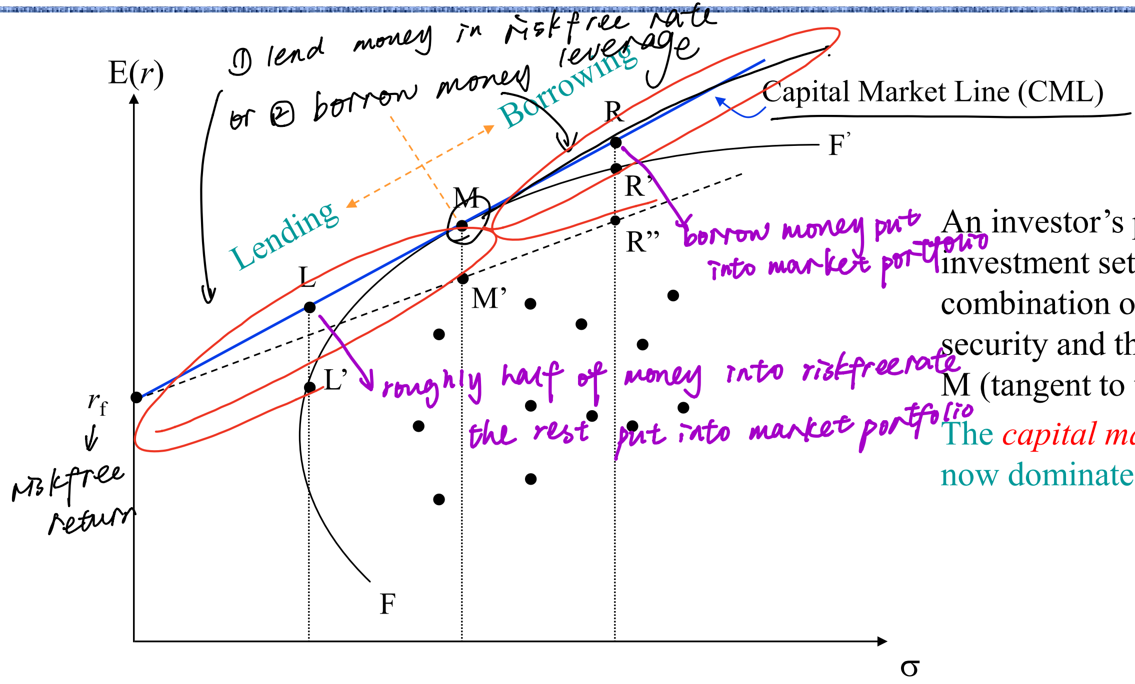
- Investors are risk averse individuals who maximize the expected utility of their end-of-period wealth
  - Investors make portfolio decisions on the basis only of expected return and the variance (or standard deviation) of returns
- Investors have homogeneous expectations about the volatilities, correlations and expected returns of securities
- ? The returns on these securities are jointly normally distributed 回报正常分配
- Capital markets are perfect as there are no taxes, transactions costs or government interference
- Unlimited borrowing and lending at the riskfree rate is possible
- Investors only hold *efficient portfolios* of securities that are all traded in financial markets

Risk-Return Frontiers with Many Securities

- The *efficient frontier* FF' is an envelope of risk-return frontiers made up of individual securities and their portfolios
- FF' plots risky portfolios which have the *lowest* risk, σ, for a *given* expected return, E(*r*)
- *What efficient portfolio would you prefer?*



Investor Choice With a Riskfree Security



An investor's preferred investment set is now a combination of the riskfree security and the risky portfolio M (tangent to the line through r_f)

The *capital market line*, r_fM, now dominates FF'

The Market Portfolio

price share value

$P \times S = V$

- In equilibrium, portfolio M *must* be the (value-weighted) *market portfolio* of *all* risky securities
- Why is M the market portfolio?
  - Suppose security A comprises 5% of all risky securities by its market cap
  - Suppose that only 2% of portfolio M is composed of security A
  - That is, 3/5th of security A is *not* held by anyone
    - Security A is now in excess supply supply > demand
    - The price of security A will fall, and its expected return will rise so investors will be willing to hold the remaining 3/5th of A as part of the risky portfolio M
- In equilibrium, M *must* be the market portfolio

Proxies for the Market Portfolio

- In theory, the market portfolio should consist of *all* securities traded on financial markets
  - In practice, market indices are often used proxy for the "true" market portfolio
- In Australia…
  - The All Ordinaries index which is a *value-weighted index* of the top 500 ASX-traded firms
  - The S&P/ASX 200 index and the S&P/ASX 100 index which are value-weighted indices of the top 200 and 100 ASX-traded firms
  - Note that there are *equally-weighted* versions of these indices available as well
- *Further information on the ASX market indices…*
  - https://www.asx.com.au/products/capitalisation-indices.htm

Proxies for the Market Portfolio

- In the US…
  - The Dow Jones Industrial Average which is a *price-weighted index* of the top 30 firms traded on the US markets
  - The S&P 500 index which is a *value-weighted index* of the top 500 firms traded on the US markets
  - The Wilshire 5000 Total Market Index which is also a value-weighted index of between 3,700 – 3,800 US-based firms trading on US markets for which there are readily available price data
- *Further information on the US and other market indices…*
  - https://www.investing.com/markets/
- *How do price-weighted, equally-weighted and value-weighted indices differ from each other?* least prefer most

  higher value
  more dominant
- *What are the attributes of a "good" market index?*

The CAPM's Intuition

- *All* investors hold *efficient portfolios* comprising the market portfolio, M and the riskfree security
  - Investors who don't diversify gain *no* increase in expected return for bearing this additional (diversifiable) risk
- Any security A is held as part of this efficient market portfolio, M
- The expected return on security A reflects its contribution to the non-diversifiable risk of the market portfolio
- Security A's contribution to the non-diversifiable risk of the market portfolio depends on its *covariance* with the market portfolio, and *not* on its own risk (standard deviation)

The CAPM's Intuition

- The CAPM can be written as…
  - Expected return on A = Riskfree return + Risk premium
- *Risk premium* = Amount of risk × Market price of risk
  - The *amount of risk* is measured by the covariance of the security with the market portfolio (the *beta* of the security, β_j)
  - The *market price of risk* is the return above the riskfree rate that investors earn for holding the (risky) market portfolio
  - Higher the market price of risk and/or higher the amount of risk, greater the risk premium
- The security market line (SML) equation is…
  - $E(r_j) = r_f + [E(r_m) - r_f]\beta_j$

Systematic Risk and the CAPM

- *A security's beta measures how sensitive a security's return is to movements in the return on the market portfolio*
  - What is the expected percentage change in the security's return for a 1% change in the return on the market portfolio?
- *Illustration:* Assume that it is equally likely that the market portfolio's return will increase by 5% when the economy is strong and decline by 3% when the economy is weak. Consider three types of firms: *S, T* and *I*. Type *S* firms' returns move by around 6% on average when the economy is strong and by –4% when the economy is weak. Type *T* firms' returns move by around 8% on average when the economy is strong and 4% when the economy is weak. Type *I* firms' returns do not move with the market. What are their betas?

$\beta_I = 0$

Systematic Risk and the CAPM

- Uncertainty related to economy's strength produces a 5% – (–3%) = 8% change in the return of the market portfolio
- Type *S* firms' returns change on average by: 6% – (–4%) = 10%
- Type *T* firms' returns change on average by 8% – (4%) = 4%
- Type *S* firms' beta, $\beta_S = \Delta R_j / \Delta R_m = 0.10/0.08 = 1.25$ market ↑ 1% s firm ↑ 1.25%
- Type *T* firms' beta, $\beta_T = 0.04/0.08 = 0.5$
- *Interpretation:* A 1% change in the return of the market portfolio will likely lead to a 1.25% (0.5%) change in the type *S* (*T*) firms' returns, on average
- What about type *I* firms? $\beta_I = 0 = \frac{\Delta R}{\Delta R_m} = \frac{0}{\Delta R_m} = 0$

Systematic Risk and the CAPM

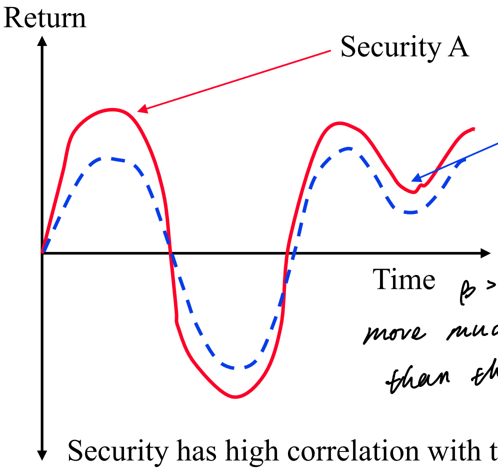
- $E(r_j) = r_f + [E(r_m) - r_f]\beta_j$
- The market "price" of risk is measured as $\boxed{E(r_m) - r_f}$
- The systematic risk is measured by the beta, β_j
  - $\beta_j = Cov(r_j, r_m)/Var(r_m) = \sigma_{jm}/\sigma_m^2$

$\beta_{market} = \frac{cov(r_m, r_m)}{Var(r_m)} = 1$ $\Rightarrow Var(r_m)$

- Since $\sigma_{jm} = \rho_{jm}\sigma_m\sigma_j$ we also have…
  - $\beta_j = \rho_{jm}(\sigma_j/\sigma_m)$
- What's the intuition behind the above measures of beta?
- $\beta_j = 1$: Security (portfolio) has the same risk as the market portfolio
- $\beta_j = 0$: Security (portfolio) has zero risk
- $\beta_j < 1$: Security (portfolio) has lower risk than the market portfolio
- $\beta_j > 1$: Security (portfolio) has higher risk than the market portfolio
- Are negative betas possible?

Systematic Risk and Correlations

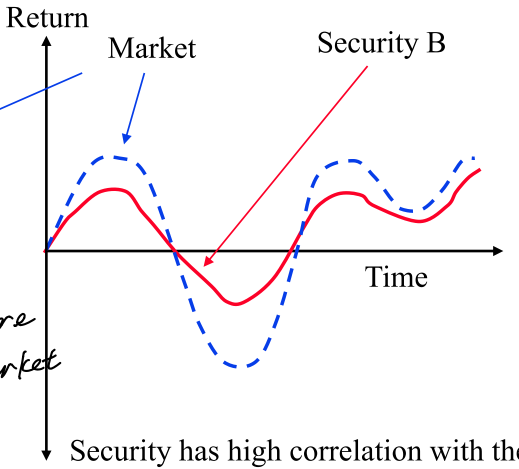
- Note that beta is not the same as the return correlation between a security (portfolio) and the market portfolio!



Security has high correlation with the market portfolio and has a high level of systematic risk or beta (relative to the market portfolio)

$\beta > 1$

move much more than the market



Security has high correlation with the market portfolio but has a low level of systematic risk or beta (relative to the market portfolio)

$\beta < 1$

less move compared to market

7.3 Using the Security Market Line

- *Example:* Assume that the riskfree rate is 7% and the expected market return is 12%. What is the market risk premium? Locate the expected returns for securities with the following betas on the SML
  - $\beta_A = 1.5$
  - $\beta_B = 0.5$
  - $\beta_C = -0.5$

12% - 7% = 5%

- Will an investor ever invest in a security like security C? *Explain*.

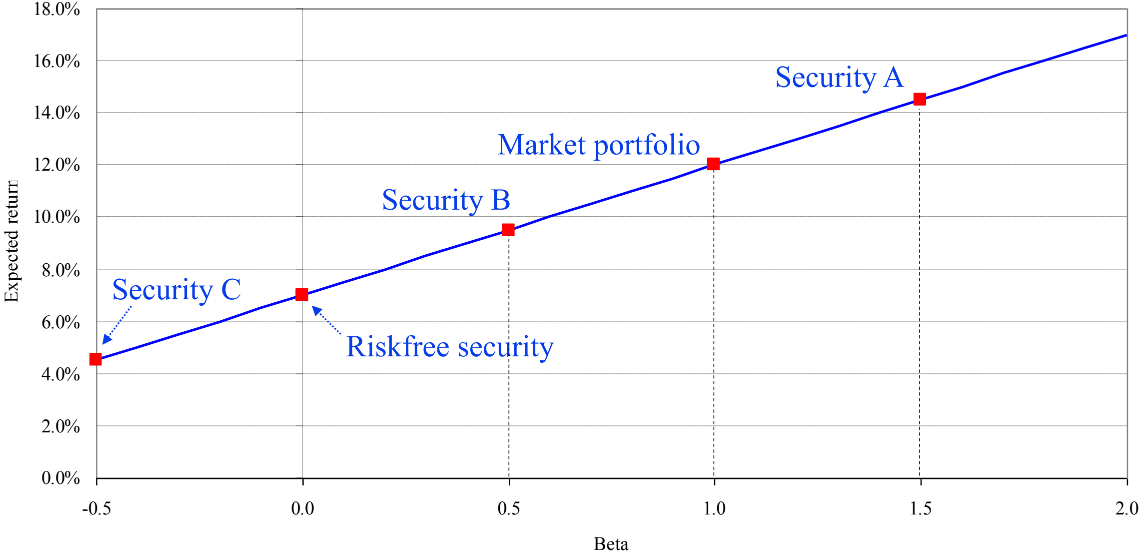
suppose the market drop

a kind of protect

Using the Security Market Line

- *Given:* $r_f = 7\%$, $E(r_m) = 12\%$
- Market risk premium = $E(r_m) - r_f = 0.12 - 0.07 = 5.0\%$
- The SML is…
  - $E(r_j) = r_f + [E(r_m) - r_f]\beta_j$
- $E(r_A) = 0.07 + (0.12 - 0.07)1.5 = 14.5\%$
- $E(r_B) = 0.07 + (0.12 - 0.07)0.5 = 9.5\%$
- $E(r_C) = 0.07 + (0.12 - 0.07)(-0.5) = 4.5\% << 7\% = r_f$!
- Why would an investor ever invest in security C?

Using the Security Market Line



Would an investor ever invest in security C?

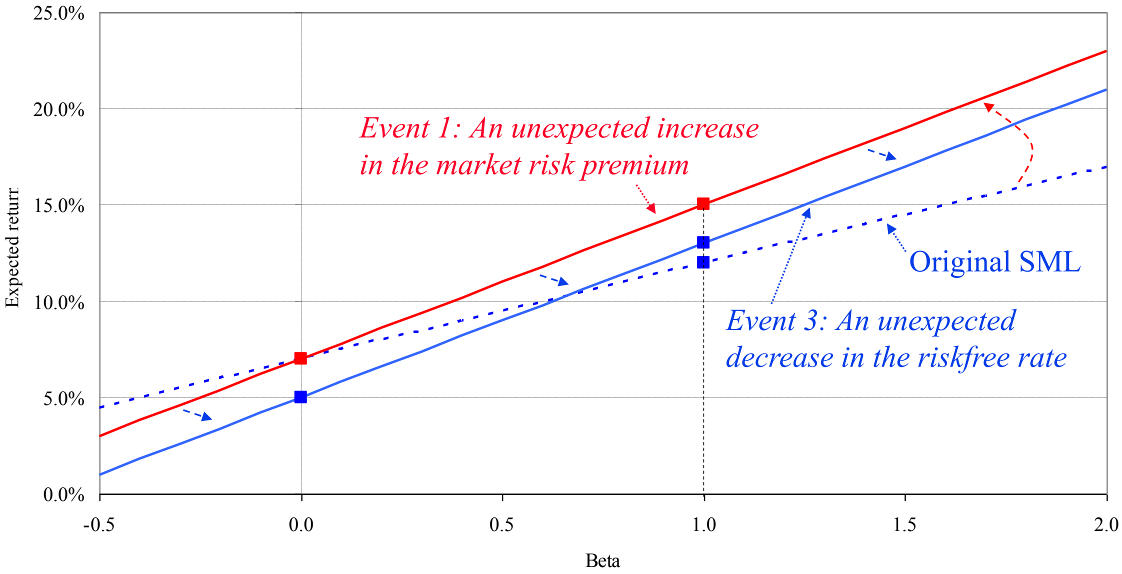
Case Study 2: Valuing Computershare Ltd

- Recall that in *Week 4* we used a required rate of return of 8% p.a. to value the shares of Computershare (*ASX:* CPU). An online broker's estimate of CPU's beta is 0.57. Using a riskfree return of 4% and a expected market risk *premium* of 7% p.a. what is CPU's required rate of return?
- *Given:* $\beta_{\text{CPU}} = 0.57$, $r_f = 5\%$, $E(r_m) - r_f = 7\%$
- Using the SML, the required return is…
- $E(r_{\text{CPU}}) = r_f + [E(r_m) - r_f]\beta_{\text{CPU}}$
- $E(r_{\text{CPU}}) = 0.04 + (0.07)0.57 = 8.0\%$

Case Study 3: The Expected and the Unexpected

- Financial markets do not like uncertainty and quickly react to new information if they are informationally efficient. What would you expect to happen to the security market line, required returns and security prices if the following events occurred one after the other…
- *Event 1:* There is an unexpected increase in the market risk premium as a result of the Trump administration resigning en masse
- *Event 2:* The Reserve Bank meets in an emergency session and lowers the cash rate by 1% to shore up equity markets, a move widely expected by the market
- *Event 3:* As things begin to settle down in the US, the Reserve Bank meets on schedule and unexpectedly lowers in the cash rate by another 0.25%

Case Study 3: The Expected and the Unexpected

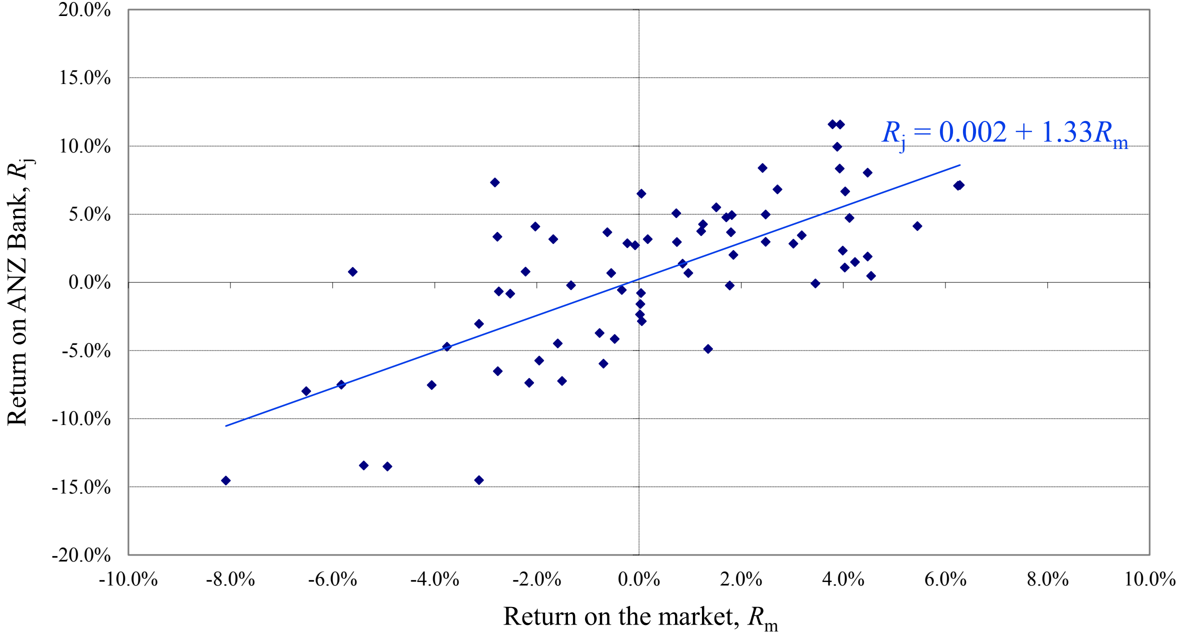


What about Event 2 when there was an *expected* decrease in the riskfree rate?

7.4 Estimating and Interpreting Betas

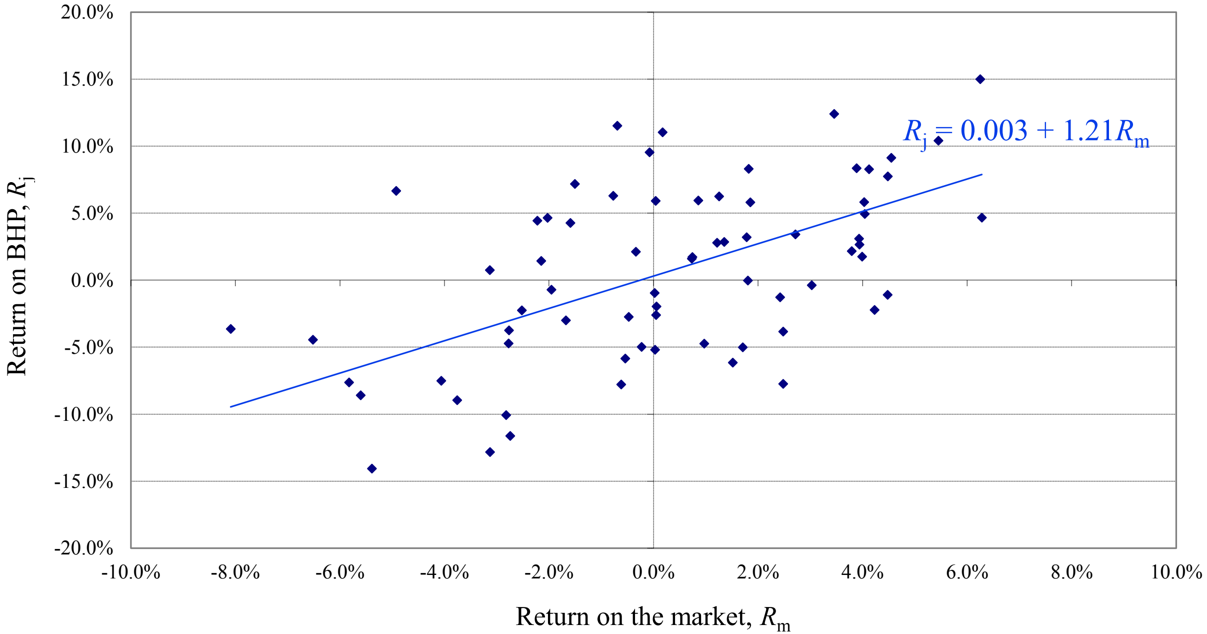
- Betas can be estimated using the *market model* regression, which is…
  - $R_{jt} = \alpha_j + \beta_j R_{mt} + e_{jt}$ $\qquad t = 1, 2, \ldots T$
  - α_j is the intercept, β_j is the regression's slope and e_{jt} is the error term
- Note that the market model is an *empirical* model while the CAPM is a *theoretical* model
- The market model is related to the CAPM as follows…
  - $E(r_j) = r_f + \beta_j[E(r_m) - r_f]$
  - $E(r_j) = r_f + \beta_j E(r_m) - \beta_j(r_f)$
  - $E(r_j) = r_f(1 - \beta_j) + \beta_j E(r_m)$ $\qquad$ where $\alpha_j = r_f(1 - \beta_j)$

ANZ Bank's Beta Estimate: Jan 2013 – Dec 2018



The beta estimate of 1.33 is based on monthly returns over Jan 2013 – Dec 2018 with the market portfolio proxied by the All Ordinaries Index

BHP's Beta Estimate: Jan 2013 – Dec 2018



The beta estimate of 1.21 is based on monthly returns over Jan 2013 – Dec 2018 with the market portfolio proxied by the All Ordinaries Index

Some Beta Estimates: Jan 2013 – Dec 2018

Stock	*Jan 13 – Dec 18*	*Jan 13 – Dec 15*	*Jan 16 – Dec 18*
ANZ	1.33	1.36	1.29
BHP	1.21	1.33	0.88
CBA	0.92	0.94	0.91
NAB	1.23	1.27	1.17
Rio Tinto	1.01	1.02	0.92
Telstra	0.63	0.61	0.74

The beta estimates are based on monthly returns over Jan 2013 – Dec 2018 with the market portfolio proxied by the All Ordinaries Index

Interpreting and Using Betas

- Recall that betas measure how sensitive the returns on a particular stock are relative to (unexpected) changes in the market portfolio's return
- *Application:* Using the more recent data from Jan 2016 – Dec 2018, what would you expect to happen to the return on BHP if the market's return suddenly falls by 1%. What about the case where investors believe that the market's return will rise by 1% soon? What would the effect of the above changes be on an equally-weighted portfolio of BHP and Rio Tinto?

Interpreting and Using Betas

- A sudden drop in the market portfolio's return of 1% is an *unexpected* move and you'd expect BHP's return to drop by around 0.88% (= 1 × 0.88)
- What would happen in the second case?
- The beta of a portfolio of two securities is…
  - $\beta_p = w_1\beta_1 + w_2\beta_2$
- In this case, the portfolio beta is…
  - $\beta_p = 0.5(0.88) + 0.5(0.92) = 0.90$
- A sudden drop in the market portfolio's return of 1% is an unexpected move and you'd expect the portfolio's return to drop by around 0.90% (= 1 × 0.90)

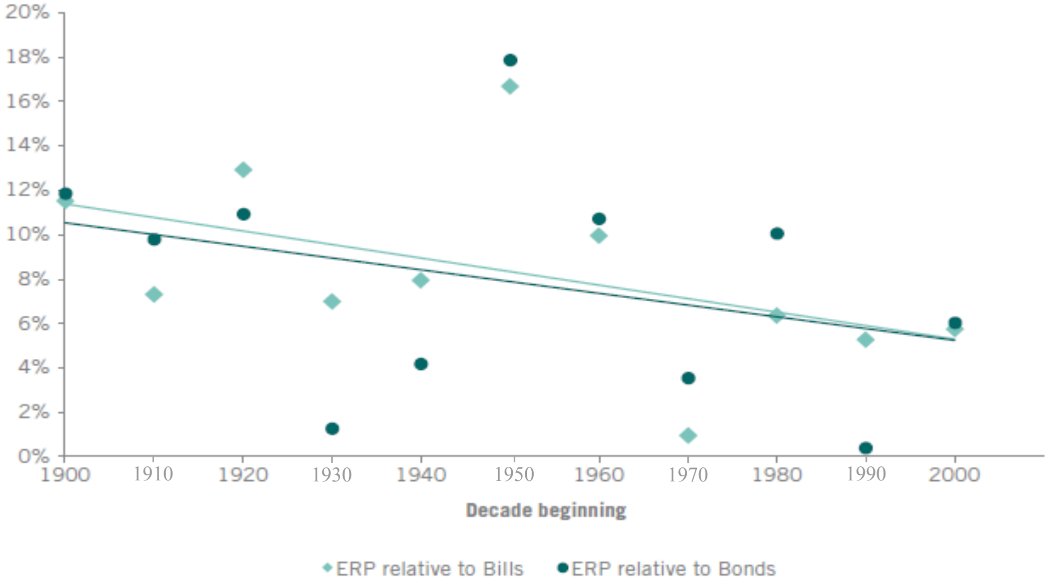
Estimating the Other CAPM Parameters

- In addition to the beta, the other parameters that need to be estimated are…
  - The riskfree rate, r_f
  - The market return, $E(r_m)$ *or* the market risk premium, $[E(r_m) - r_f]$
- The riskfree rate, r_f
  - Generally estimated as the yield to maturity on long-term government bonds
  - The 10-year bond rate in Australia, 10- or 30-year rates in the US
- The market risk premium, $[E(r_m) - r_f]$
  - Generally estimated as an historical average premium
- The next few slides show information related to *observed/historical* risk premiums

Yield on the 10-Year Treasury Bond: 1971-2018

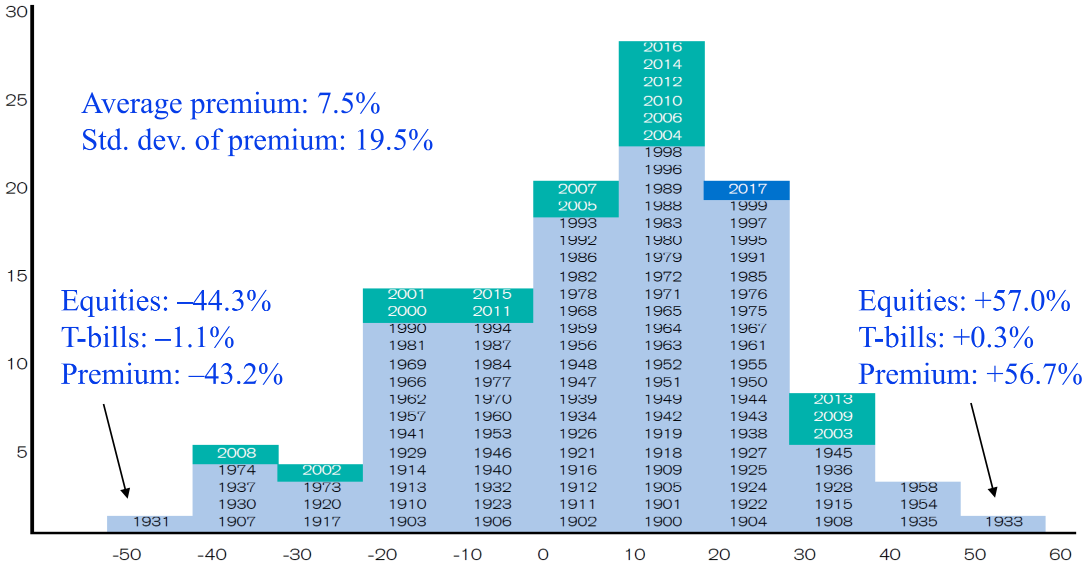
Source: Trading Economics, https://tradingeconomics.com/australia/government-bond-yield. The graph shows the yield to maturity on the 10-year Treasury bond over 1971-2018.

Australian Equity Risk Premiums:1900-2010



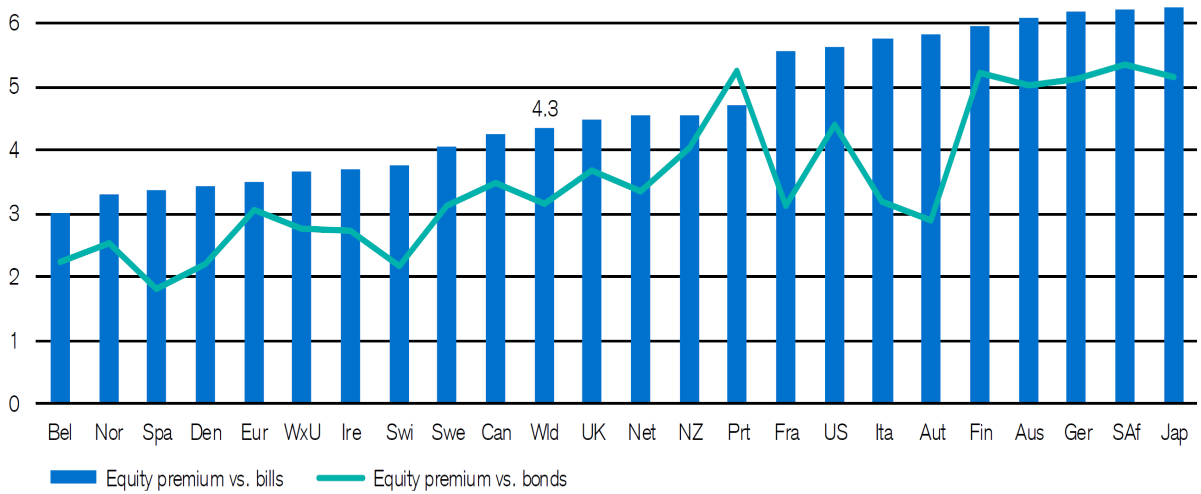
Source: Bianchi, R. J., Drew, M. E. and Walk, A. N., [The Equity Risk Premium in Australia](), 2015, Figure 5. The graph shows equity risk premiums (ERPs) relative to T-bills and T-bonds every decade.

Distribution of US Equity Risk Premiums: 1900-2017



Source: Dimson, E., Marsh, P. and Staunton, M., Credit Suisse Global Investment Returns Yearbook, 2018, Figure 7. Distribution of annualized equity risk premiums relative to US Treasury bills in the US.

Worldwide Equity Risk Premiums: 1900-2017



Source: Elroy Dimson, Paul Marsh, and Mike Staunton, Triumph of the Optimists, Princeton University Press, 2002, and subsequent research. Premiums for Austria and Germany are based on 116 years, excluding 1921–22 for Austria and 1922–23 for Germany.

Note: Wld = World, WxU = World excluding US

Source: Dimson, E., Marsh, P. and Staunton, M., Credit Suisse Global Investment Returns Yearbook, 2018, Figure 8. Worldwide annualized equity risk premiums relative to bills and bonds.

7.5 *Applying the CAPM*

- The CAPM is used for various purposes by practitioners…
- Estimating the cost of equity capital (more in later lectures)
- Designing portfolios to match investors’ risk preferences
  - Low beta portfolios are relevant for less risk tolerant investors
  - High beta portfolios are relevant for more risk tolerant investors
- Evaluating the performance of portfolios
  - Comparing their actual performance relative to what’s expected using the CAPM
- Using the CAPM for security selection

The CAPM and Portfolio Evaluation

- The three main metrics used to evaluate the performance of portfolios (and securities) are…
- The Sharpe ratio, $S = [E(r_p) - r_f]/\sigma_p$
  - The portfolio with the highest (lowest) Sharpe ratio has the best (worst) performance
  - *Note:* The numerator must be positive for all the portfolios being compared
- Main limitation
  - The ratio uses *total* risk as a measure of risk when only *systematic* risk is priced in the market

The CAPM and Portfolio Evaluation

- The Treynor ratio, $T = [E(r_p) - r_f]/\beta_p$
  - The portfolio with the highest (lowest) Treynor ratio has the best (worst) performance
  - This ratio is a simple extension of the Sharpe ratio and addresses the Sharpe ratio's main limitation by substituting beta (or systematic) risk for total risk
  - *Note:* The numerator and denominator must be positive for the Treynor ratio to be meaningful

The CAPM and Portfolio Evaluation

- Jensen's alpha, $A = r_p - [r_f + [E(r_m) - r_f]\beta_p]$
  - Here, r_p is the portfolio's observed return
  - *Note:* By definition, Jensen's alpha for the market is 0
- Jensen's alpha is commonly used to evaluate the performance of investment funds and fund managers
  - Values of alpha can be used to rank different managers and the performance of their portfolios, as well as the magnitude of underperformance or overperformance
  - *Example:* If portfolio 1's alpha is 2% and portfolio 2's alpha is 5%, then portfolio 2 has outperformed portfolio 1 by 3% and the market by 5%
  - Jensen's alpha is also the *maximum* amount that you should be willing to pay a manager to manage your money!

The CAPM and Security Selection

- *Security selection* involves identifying securities that are under- or over-valued at present
- In the CAPM's context, *correctly priced* securities will lie on the security market line implying that investing in them is a *zero NPV* decision
- In contrast, under- or over-valued securities will not lie on the security market line implying that investing in them is a non-zero *NPV* decision

Case Study 4: To Buy or Not to Buy…

- It was around November 2018 when your lecturer was considering whether or not to buy more shares of Sonic Healthcare (*ASX:* SHL). Sonic is a health care company that offers laboratory medicine/pathology and radiology/diagnostic imaging services to clinicians, hospitals, community health services, and their patients. The company operates 238 primary care clinics in Australia, the US, Germany, and internationally.
- Your lecturer used Sonic's estimated beta of 0.7, a riskfree rate of 4% and an expected market risk premium of 7% to estimate the required return on its shares. At that time, the consensus estimate of Sonic's dividend next year was \$0.85 which was expected to grow at 5.5% p.a. for the foreseeable future. Based on the price of Sonic at that time of \$22.50 what was the expected return implied by this information? Was Sonic correctly priced at that time? What would you have expected to happen to its price and why? What has happened to Sonic's price since then? How would the analysis have changed if the expected growth in dividends was 4.5% p.a. rather than 5.5% p.a.?

Case Study 4: To Buy or Not to Buy…

- Using the SML, the required return is…
  - $E(r_{SHL}) = r_f + [E(r_m) - r_f]\beta_{SHL} = 0.04 + (0.07)0.7 = 8.9\%$
- Recall (*from Week 4*) that the estimated price using constant dividend growth model is…
  - $P_0 = D_1/(r_E - g)$
- So, the expected return on equity is…
  - $r_E = D_1/P_0 + g$
- The expected return implied by a current price of $22.50 is…
  - $r_E = 0.85/22.50 + 0.055 = 9.3\%$

9.3% expected to fall to 8.9%.

so price ↑

- *What would you expect to happen?*

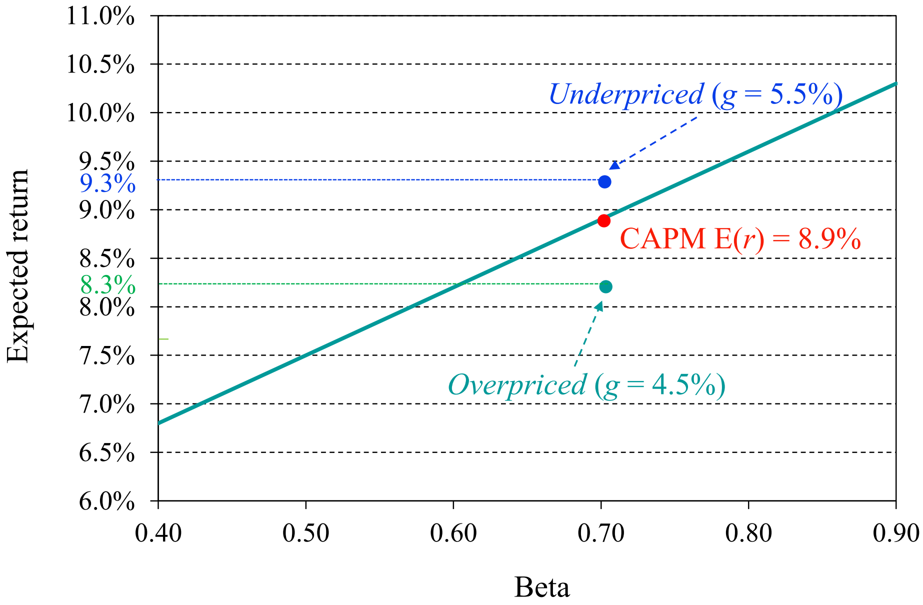
Case Study 4: To Buy or Not to Buy…

- From the CAPM, the equilibrium required return is 8.9%
- So, the expected return of 9.3% will *fall* to the equilibrium required return of 8.9%
- Assuming that the expected dividend and its growth rate are unchanged you'd expected Sonic's price to *rise* so at that time (Nov 2018) Sonic shares were *underpriced* or *undervalued*
- *What should your lecturer have done?*
- *Expected* $P_0 = D_1/[E(r_{SHL}) - g] = 0.85/(0.089 - 0.055)$
- *Expected* $P_0 = \$25.00$
- *Did your lecturer invest wisely?*

Case Study 4: To Buy or Not to Buy…

- How do things change if the growth in dividends (g) is estimated to be 4.5% instead of 5.5%?
  - *Revised* $r_E = D_1/P_0 + g = 0.85/22.50 + 0.045 = 8.3\%$
- You'd expect the return of 8.3% to *rise* to the equilibrium level of 8.9%
- You'd expect ~~Sonic's price to *fall* (why?) implying that the shares were *overpriced* or *overvalued* at that time~~
- *What should your lecturer have done in this case?*
- *Revised* $P_0 = D_1/[\mathrm{E}(r_{\mathrm{SHL}}) - g] = 0.85/(0.089 - 0.045)$
- *Revised* $P_0 = \$19.32$

Case Study 4: To Buy or Not to Buy…



Key Concepts

- As portfolio size increases its standard deviation falls, but at a declining rate
- In large portfolios, return covariances of securities determine total portfolio risk
- The risk that cannot be eliminated via portfolio diversification is referred to as non-diversifiable (systematic) risk, measured by its beta
- In equilibrium, all risky securities will be priced so that their expected returns plot on the security market line
- Beta can be used in portfolio design and portfolio evaluation and in estimation of cost of equity capital
- In equilibrium a correctly priced security would lie on the SML
- A security lying above the SML is currently underpriced and a security lying below the SML is currently overpriced

Formula Sheet

- Variance of a very large portfolio: $\sigma_p^{\,2} = \sigma^2/N + [(N-1)/N]\sigma_{jk}$
- The SML: $E(r_j) = r_f + [E(r_m) - r_f]\beta_j$
- Security beta: $\beta_j = \sigma_{jm}/\sigma_m^{\,2}$
- Security beta: $\beta_j = \rho_{jm}(\sigma_j/\sigma_m)$
- Beta of a two security portfolio: $\beta_p = w_1\beta_1 + w_2\beta_2$
- The Sharpe ratio: $S = [E(r_p) - r_f]/\sigma_p$
- The Treynor ratio: $T = [E(r_p) - r_f]/\beta_p$
- Jensen's alpha: $A = r_p - [r_f + [E(r_m) - r_f]\beta_p]$

(*Note:* The formula sheets on the mid semester and final exams will contain all the formulas covered in lectures but *without* the descriptions)