

CFA Program Level 1”

CFA[®] Program Level I

FORMULA SHEET (2025)

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CFA Level 1 - Formula Sheet (2025)

Setting Up the Texas BA II Plus Financial Calculator

Video: <https://youtu.be/OMS8d8QOFmc>

Using Texas BA II Plus Financial Calculator

Video: <https://youtu.be/LWmTTiZz8BU>

Video (Requires Login to Facebook): <https://fb.watch/nci5V7Dwtj/>

VOLUME 1: QUANTITATIVE METHODS

Learning Module 1: Rates and Returns

Determinants of Interest Rates

Interest rate, r = Real risk-free rate + Inflation premium + Default risk premium

- Liquidity premium + Maturity premium $(1 + \text{Nominal risk-free rate}) = (1 + \text{Real risk-free rate}) \times (1 + \text{Inflation premium})$

Nominal risk-free rate = Real risk-free rate + Inflation premium

Maturity premium = Interest rate on longer-maturity, liquid Treasury debt

- Interest rate on short-term Treasury debt

Holding Period Return

$$R = \frac{P_1 - P_0 + I_1}{P_0}$$

where:

- P_0 = Price at the beginning of the period
- P_1 = Price at the end of the period
- I_1 = Income

If given holding period returns R_1, R_2, \dots, R_T over the holding period:

$$R = (1 + R_1) \times (1 + R_2) \times \dots \times (1 + R_T) - 1$$

Arithmetic Return

$$\bar{R}_i = \frac{1}{T} \sum_{t=1}^T R_{it} = \frac{1}{T} (R_{i1} + R_{i2} + \dots + R_{iT})$$

Geometric Mean Return

$$\bar{R}_{Gi} = \sqrt[T]{\prod_{t=1}^T (1 + R_{it})} - 1 = \sqrt[T]{(1 + R_{i1}) \times (1 + R_{i2}) \times \dots \times (1 + R_{iT})} - 1$$

Harmonic Mean

$$\bar{X}_{Hi} = \frac{n}{\sum_{i=1}^n (1/X_i)} \quad \text{for } X_i > 0$$

Relationship between Arithmetic Mean, Geometric Mean, and Harmonic Mean

$$(\text{Geometric mean})^2 = \text{Arithmetic mean} \times \text{Harmonic mean}$$

Money-Weighted Return (MWR)

$$\sum_{t=0}^T \frac{CF_t}{(1 + MWR)^t} = 0$$

Time-Weighted Return (TWR)

Given the holding period returns for each sub-period, R_1, R_2, \dots, R_T

If $T > 1$ year, then

$$\text{Annualized TWR} = [(1 + R_1) \times (1 + R_2) \times \dots \times (1 + R_T)]^{1/T} - 1$$

If $T = 1$ year, then

$$\text{Annualized TWR} = (1 + R_1) \times (1 + R_2) \times \dots \times (1 + R_T) - 1$$

If $T < 1$ year, then

$$\text{TWR for holding period} = (1 + R_1) \times (1 + R_2) \times \dots \times (1 + R_T) - 1$$

Non-Annual Compounding

$$PV = FV_N \left(1 + \frac{R_s}{m}\right)^{-mN}$$

where:

- m = Number of compounding periods per year
- R_s = Quoted annual interest rate
- N = Number of years

Annualizing Returns

$R_{\text{annual}} = (1 + R_{\text{weekly}})^{52} - 1$ $R_{\text{annual}} = (1 + R_{\text{monthly}})^{12} - 1$ $R_{\text{annual}} = (1 + R_{\text{daily}})^{252} - 1$
assuming 252 trading days per year $R_{\text{weekly}} = (1 + R_{\text{daily}})^5 - 1$ assuming 5 trading days per week

Continuously Compounded Returns

$$P_t = P_0 e^{r_{0,T}}$$

$$r_{0,T} = \ln \left(\frac{P_t}{P_0} \right)$$

$$r_{0,T} = r_{0,1} + r_{1,2} + \dots + r_{T-2,T-1} + r_{T-1,T}$$

Real Returns

$$(1 + \text{real return}) = (1 + \text{real risk-free rate}) \times (1 + \text{risk premium})$$

Pre-Tax and After-Tax Nominal Return

$$\begin{aligned} \text{After-tax nominal return} &= \text{Pre-tax nominal return} \times (1 - \text{Tax rate}) \\ \text{After-tax real return} &= \frac{[1 + \text{Pre-Tax nominal return} \times (1 - \text{Tax rate})]}{1 + \text{Inflation premium}} - 1 \end{aligned}$$

Leveraged Return

Return on a leveraged portfolio

$$R_L = R_P + \frac{V_B}{V_E} (R_P - r_D)$$

where:

- R_P = Return on the investment portfolio (unleveraged)
- r_D = Cost of debt
- V_B = Debt/borrowed funds
- V_E = Equity of the portfolio

Learning Module 2: Time Value of Money in Finance

$$FV_t = PV(1 + r)^t \quad PV = \frac{FV_t}{(1 + r)^t}$$

where:

- FV_t = Future value at time t
- PV = Present value
- r = Discount rate per period
- t = Number of compounding periods

As compounding frequency becomes very large (i.e., continuous compounding)

$$FV_t = PVe^{rt} \quad PV = FV_te^{-rt}$$

Present Value of Zero-Coupon Bond

$$PV(\text{ Discount Bond }) = \frac{FV}{(1 + r)^t}$$

where:

- FV = Principal (or Face Value)
- r = Market discount rate per period
- t = Maturity of bond

$$r = \left(\frac{FV_t}{PV} \right)^{1/T} - 1$$

Present Value of Coupon Bond

$$PV(\text{ Coupon Bond }) = \frac{PMT}{(1 + r)^1} + \frac{PMT}{(1 + r)^2} + \cdots + \frac{PMT + FV}{(1 + r)^N}$$

where:

- PV = Bond's price
- PMT = Periodic coupon payment
- FV = Face value
- N = Number of periods
- r = Market discount rate per period

Present Value of a Perpetual Bond (Perpetuity)

$$PV(\text{ Perpetual Bond }) = \frac{PMT}{r}$$

Annuity Instruments (e.g., Mortgage)

$$A = \frac{rPV}{1 - (1 + r)^{-t}}$$

where:

- A = Periodic cash flow
- r = Market interest rate per period
- PV = Present value or principal amount of loan/bond
- t = Number of payment periods

Price of a Preferred Share

$$PV_t = \frac{D_t}{r}$$

where:

- D_t = Fixed periodic dividend
- r = Expected rate of return

Price of a Common Share

Constant Dividend Growth Rate into Perpetuity

$$PV_t = \frac{D_t(1+g)}{r-g} = \frac{D_{t+1}}{r-g} \quad r > g$$

where:

- D_t = Common dividend at time t
- g = Constant growth rate
- r = Expected rate of return

$$\begin{aligned} r &= \frac{D_{t+1}}{PV_t} + g \\ \frac{PV_t}{E_t} &= \frac{\frac{D_t}{E_t} \times (1+g)}{r-g} \\ \frac{PV_t}{E_{t+1}} &= \frac{\frac{D_{t+1}}{E_{t+1}}}{r-g} \end{aligned}$$

where:

- E_t = Earnings per share for period t
- $\frac{PV_t}{E_t}$ = Trailing price-to-earnings ratio
- $\frac{PV_t}{E_{t+1}}$ = Forward price-to-earnings ratio

Two-stage Dividend Discount Model

$$PV_t = \sum_{i=1}^n \frac{D_t (1 + g_s)^i}{(1 + r)^i} + \frac{E(S_{t+n})}{(1 + r)^n}$$

where:

- g_s = Higher short-term dividend growth rate
- g_L = Lower long-term dividend growth rate
- n = Initial growth phase
- $E(S_{t+n})$ = Stock value in n periods (Terminal value)

$$= \frac{D_{t+n+1}}{r - g_L}$$

Forward Rate

$$F_{1,1} = \frac{(1 + r_2)^2}{(1 + r_1)} - 1$$

where:

- $F_{1,1}$ = One-year forward rate one year from now
- r_1 = Discount rate on one-year risk-free discount bond
- r_2 = Discount rate on two-year risk-free discount bond

Learning Module 3: Statistical Measures of Asset Returns

Measures of Central Tendency

$$\text{Sample Mean, } \bar{X} = \frac{1}{n} \sum_{i=1}^n X_i$$

where:

- X_i = Observation i ($i = 1, 2, 3, \dots, n$)

Median

$$\text{Position of median} = \frac{\text{Number of observations} + 1}{2}$$

Quantiles

$$\text{Interquartile range} = Q_3 - Q_1$$

where:

- Q_1 = First quartile
- Q_3 = Third quartile

Box and Whisker Plot

$$\text{Upper fence} = Q_3 + 1.5 \times IQR$$

$$\text{Lower fence} = Q_1 - 1.5 \times IQR$$

Measures of Dispersion

$$\text{Range} = \text{Maximum value} - \text{Minimum value}$$

Mean Absolute Deviation (MAD)

$$MAD = \frac{\sum_{i=1}^n |X_i - \bar{X}|}{n}$$

Sample Variance

$$s^2 = \frac{\sum_{i=1}^n (X_i - \bar{X})^2}{n - 1}$$

Sample Standard Deviation

$$s = \sqrt{\frac{\sum_{i=1}^n (X_i - \bar{X})^2}{n - 1}}$$

Sample Target Semideviation

$$s_{\text{Target}} = \sqrt{\frac{\sum_{X_i \leq B}^n (X_i - B)^2}{n - 1}}$$

where:

- B = target
- n = total number of sample observations

Coefficient of Variation

$$CV = \frac{s}{\bar{X}}$$

Sample Skewness

$$\text{Skewness} \approx \left(\frac{1}{n}\right) \frac{\sum_{i=1}^n (X_i - \bar{X})^3}{s^3}$$

Sample Excess Kurtosis

$$K_E \approx \left(\frac{1}{n}\right) \frac{\sum_{i=1}^n (X_i - \bar{X})^4}{s^4} - 3$$

Sample Covariance

$$s_{XY} = \frac{1}{n - 1} \sum_{i=1}^n (X_i - \bar{X}) (Y_i - \bar{Y})$$

Sample Correlation Coefficient

$$r_{XY} = \frac{s_{XY}}{s_X s_Y}$$

Learning Module 4: Probability Trees and Conditional Expectations

Expected Value of a Discrete Random Variable

$$E(X) = \sum_{i=1}^n P(X_i) X_i$$

Variance of a Random Variable

$$\begin{aligned}\sigma^2(X) &= E[X - E(X)]^2 \\ &= \sum_{i=1}^n P(X_i) [X - E(X)]^2\end{aligned}$$

Conditional Expected Value of a Random Variable

$$E(X | S) = P(X_1 | S) X_1 + P(X_2 | S) X_2 + \dots + P(X_n | S) X_n$$

Conditional Variance of a Random Variable

$$\begin{aligned}\sigma^2(X | S) &= P(X_1 | S) [X_1 - E(X_1 | S)]^2 + P(X_2 | S) [X_2 - E(X_2 | S)]^2 + \dots \\ &\quad + P(X_n | S) [X_n - E(X_n | S)]^2\end{aligned}$$

Total Probability Rule for Expected Value

$$E(X) = E(X | S_1) P(S_1) + E(X | S_2) P(S_2) + \dots + E(X | S_n) P(S_n)$$

where:

- S_1, S_2, \dots, S_n are mutually exclusive and exhaustive events.

Bayes' Formula

$$\begin{aligned}P(A | B) &= \frac{P(B | A)}{P(B)} \times P(A) \\ P(\text{Event} | \text{Information}) &= \frac{P(\text{Information} | \text{Event})}{P(\text{Information})} \times P(\text{Event})\end{aligned}$$

Learning Module 5: Portfolio Mathematics

For n assets in a portfolio

Expected return on portfolio

$$E(R_P) = w_1 E(R_1) + w_2 E(R_2) + \dots + w_n E(R_n)$$

Variance on portfolio

$$\sigma^2(R_P) = \sum_{i=1}^n \sum_{j=1}^n w_i w_j \text{Cov}(R_i, R_j)$$

Requires n variances and $\frac{n(n-1)}{2}$ distinct covariances to estimate portfolio variance.

Covariance

$$\begin{aligned} \text{Cov}(R_i, R_j) &= E[(R_i - E(R_i))(R_j - E(R_j))] \\ &= \frac{1}{n-1} \sum_{t=1}^n (R_{i,t} - \bar{R}_i)(R_{j,t} - \bar{R}_j) \end{aligned}$$

For a two-asset ($n = 2$) portfolio:

$$\sigma^2(R_P) = w_1^2 \sigma_1^2 + w_2^2 \sigma_2^2 + 2w_1 w_2 \text{Cov}(R_1, R_2)$$

where:

- $\text{Cov}(R_1, R_2) = \rho(R_1, R_2) \times \sigma(R_1) \times \sigma(R_2)$

Video: <https://youtu.be/IUwulZ9ONCO>

For a three-asset ($n = 3$) portfolio:

$$\begin{aligned} \sigma^2(R_P) &= w_1^2 \sigma_1^2 + w_2^2 \sigma_2^2 + w_3^2 \sigma_3^2 + 2w_1 w_2 \text{Cov}(R_1, R_2) \\ &\quad + 2w_1 w_3 \text{Cov}(R_1, R_3) + 2w_2 w_3 \text{Cov}(R_2, R_3) \end{aligned}$$

Covariance Given a Joint Probability Function

$$\text{Cov}(R_A, R_B) = \sum_{i=1} \sum_{j=1} P(R_{A,i}, R_{B,j}) \times [R_{A,i} - E(R_A)] \times [R_{B,j} - E(R_B)]$$

If X and Y are uncorrelated, then $E(XY) = E(X)E(Y)$

If X and Y are independent, then $P(X, Y) = P(X)P(Y)$

Safety-First Optimal Portfolio

Safety-First Ratio

$$\text{SFRatio} = \frac{E(R_P) - R_L}{\sigma_P}$$

$$\text{Shortfall risk} = \Pr[E(R_P) < R_L] = \text{Normal}(-\text{SFRatio})$$

where:

- R_L = Investor's threshold level
- $E(R_P)$ = Expected portfolio return
- σ_P = Portfolio standard deviation

Video: <https://youtu.be/S3x5JrGIOUA>

Learning Module 6: Simulation Methods

Lognormal Distribution

Mean of a lognormal random variable

$$\mu_L = \exp(\mu + 0.50\sigma^2)$$

Variance of a lognormal random variable

$$\sigma_L^2 = \exp(2\mu + \sigma^2) \times [\exp(\sigma^2) - 1]$$

where:

- μ = Mean of the normal random variable
- σ^2 = Variance of the normal random variable

Continuously Compounded Rates of Return

$$P_T = P_0 \exp(r_{0,T})$$

where:

- P_0 = Current asset price
- P_T = Asset price at time T
- $r_{0,T}$ = Continuously compounded return from 0 to T

If returns are independently and identically distributed (i.i.d.), then

$$r_{0,T} = r_{0,1} + r_{1,2} + \cdots + r_{T-2,T-1} + r_{T-1,T}$$

If the one-period continuously compounded returns are i.i.d. random variables with mean μ and σ^2 , then

$$\begin{aligned} E(r_{0,T}) &= \mu T \\ \sigma^2(r_{0,T}) &= \sigma^2 T \\ \sigma(r_{0,T}) &= \sigma\sqrt{T} \end{aligned}$$

Learning Module 7: Estimation and Inference

$$\text{Sharpe ratio} = \frac{R_P - R_F}{\sigma_P}$$

where:

- R_P = Portfolio return
- R_F = Risk-free rate
- σ_P = Portfolio standard deviation of return

$$\begin{aligned} \text{Variance of the sampling distribution} &= \frac{\sigma^2}{n} \\ \text{of the sample means} \\ \text{Standard error of} &= \frac{\sigma}{\sqrt{n}} \end{aligned}$$

where:

- σ = Population standard deviation
- n = Sample size

Note: If σ is not known, use s , the sample standard deviation.

Bootstrap Resampling

$$s_{\bar{X}} = \sqrt{\frac{1}{B-1} \sum_{b=1}^B (\hat{\theta}_b - \bar{\theta})^2}$$

where:

- $s_{\bar{X}}$ = Estimate of the standard error of the sample mean
- B = Number of resamples drawn from the original sample
- $\hat{\theta}_b$ = Mean of a resample
- $\bar{\theta}$ = Mean across all the resample means

Learning Module 8: Hypothesis Testing

$$\text{Confidence level} = 1 - \alpha$$

$$\text{Power of the test} = 1 - \beta$$

where:

- α = Significance level (Probability of Type I error)
- β = Probability of Type II error

Test of a Single Mean

Test statistic

$$t = \frac{\bar{X} - \mu_0}{s/\sqrt{n}}$$

$$\text{Degrees of freedom} = n - 1 \quad (1 - \alpha)\% \text{ Confidence Interval} = \bar{X} \pm \text{Critical value} \times \left(\frac{s}{\sqrt{n}} \right)$$

Test of the Difference in Means

Test statistic

$$t = \frac{(\bar{X}_{d1} - \bar{X}_{d2}) - (\mu_{d1} - \mu_{d2})}{\sqrt{\frac{s_p^2}{n_{d1}} + \frac{s_p^2}{n_{d2}}}}$$

Degrees of freedom = $n_{d1} + n_{d2} - 2$

$$s_p^2 = \frac{(n_{d1} - 1) s_{d1}^2 + (n_{d2} - 1) s_{d2}^2}{n_{d1} + n_{d2} - 2}$$

Test of the Mean of Differences

Test statistic

$$t = \frac{\bar{d} - \mu_{d0}}{s_{\bar{d}}}$$

Degrees of freedom = $n - 1$

Test of a Single Variance

Test statistic

$$\chi^2 = \frac{(n - 1) s^2}{\sigma_0^2}$$

Degrees of freedom = $n - 1$

Test of the Difference in Variances

Test statistic

$$F = \frac{s_{\text{Before}}^2}{s_{\text{After}}^2}$$

Degrees of freedom = $n_1 - 1, n_2 - 1$

Test of a Correlation

Test statistic

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}}$$

Degrees of freedom = $n - 2$

Test of Independence (Categorical Data)

Test statistic

$$\chi^2 = \sum_{i=1}^m \frac{(O_{ij} - E_{ij})^2}{E_{ij}}$$

Degrees of freedom = $(r - 1)(c - 1)$

where:

- m = Number of cells in the table
- O_{ij} = Number of observations in each cell of row i and column j
- E_{ij} = Expected number of observations in each cell of row i and column j

Learning Module 9: Parametric and Non-Parametric Tests of Independence

Test of a Correlation

Test statistic

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}}$$

Degrees of freedom = $n - 2$

Pearson Correlation (or Bivariate Correlation)

$$r_{XY} = \frac{s_{XY}}{s_X s_Y}$$

Spearman Rank Correlation Coefficient

$$r_S = 1 - \frac{6 \sum_{i=1}^n d_i^2}{n(n^2 - 1)}$$

where:

- d = Difference in ranks

Test of Independence (Categorical Data)

Test statistic

$$\chi^2 = \sum_{i=1}^m \frac{(O_{ij} - E_{ij})^2}{E_{ij}}$$

Degrees of freedom = $(r - 1)(c - 1)$

where:

- m = Number of cells in the table
- O_{ij} = Number of observations in each cell of row i and column j
- E_{ij} = Expected number of observations in each cell of row i and column j

$$= \frac{(\text{Total row } i) \times (\text{Total column } j)}{\text{Overall total}}$$

Standardized Residual (or Pearson Residual)

$$\text{Standardized Residual} = \frac{O_{ij} - E_{ij}}{\sqrt{E_{ij}}}$$

Learning Module 10: Simple Linear Regression

$$Y_i = b_0 + b_1X_1 + \dots + b_nX_n + \varepsilon_i, \quad i = 1, 2, \dots, n$$

where:

- Y = Dependent variable
- X = Independent variable
- b_0 = Intercept
- b_i = Slope coefficient, $i = 1, 2, \dots, n$
- ε_i = Error term
- b_0, b_1, \dots, b_n = Regression coefficients

$$\hat{Y}_i = \hat{b}_0 + \hat{b}_1X_i + e_i$$

where:

- \hat{Y}_i = Estimated value on the regression line for the i th observation
- \hat{b}_0 = Intercept
- \hat{b}_1 = Slope
- e_i = Residual for the i th observation $\hat{b}_1 = \frac{\text{Covariance of } X \text{ and } Y}{\text{Variance of } X} = \frac{\sum_{i=1}^n (Y_i - \bar{Y})(X_i - \bar{X})}{\sum_{i=1}^n (X_i - \bar{X})^2}$ $\hat{b}_0 = \bar{Y} - \hat{b}_1\bar{X}$ Sum of Squares Total, $SST = \sum_{i=1}^n (Y_i - \bar{Y})^2 = SSR + SSE$ Sum of Squares Regression, $SSR = \sum_{i=1}^n (\hat{Y}_i - \bar{Y})^2$ Sum of Squares Error, $SSE = \sum_{i=1}^n (Y_i - \hat{Y}_i)^2 = \sum_{i=1}^n e_i^2$ Coefficient of Determination

$$R^2 = \frac{SSR}{SST} = 1 - \frac{SSE}{SST}$$

Correlation coefficient

$$r = \frac{\text{Covariance of } X \text{ and } Y}{(\text{Standard deviation of } X)(\text{Standard deviation of } Y)}$$

Note: (Correlation coefficient)² = Coefficient of determination

Sample standard deviation of X

$$S_X = \sqrt{\frac{\sum_{i=1}^n (X_i - \bar{X})^2}{n - 1}}$$

Sample standard deviation of Y

$$S_Y = \sqrt{\frac{\sum_{i=1}^n (Y_i - \bar{Y})^2}{n-1}}$$

Homoskedasticity

$$E(\varepsilon_i^2) = \sigma_\varepsilon^2, \quad i = 1, 2, \dots, n$$

ANOVA F-Test

Mean square regression (MSR)

$$MSR = \frac{SSR}{k}$$

Mean square error (MSE)

$$MSE = \frac{SSE}{n-k-1}$$

F-distributed test statistic

$$F = \frac{MSR}{MSE}$$

where:

- n = Number of observations
- k = Number of independent variables

Standard error of estimate

$$s_e = \sqrt{MSE} = \sqrt{\frac{\sum_{i=1}^n (Y_i - \hat{Y}_i)^2}{n-k-1}}$$

Hypothesis Test of the Slope Coefficient

$$t = \frac{\hat{b}_1 - B_1}{s_{\hat{b}_1}}$$

Degrees of freedom, $df = n - k - 1$

where:

- B_1 = Hypothesized population slope
- $s_{\hat{b}_1}$ = Standard error of the slope coefficient

$$= \frac{s_e}{\sqrt{\sum_{i=1}^n (X_i - \bar{X})^2}}$$

Hypothesis Test of the Intercept

$$t_{\text{intercept}} = \frac{\hat{b}_0 - B_0}{s_{\hat{b}_0}}$$

Standard error of the intercept, $s_{\hat{b}_0}$

$$s_{\hat{b}_0} = \sqrt{\frac{1}{n} + \frac{\bar{X}^2}{\sum_{i=1}^n (X_i - \bar{X})^2}}$$

Prediction Intervals

$$\hat{Y}_f \pm t_{\alpha/2} \times s_f$$

where: $\hat{Y}_f = \hat{b}_0 + \hat{b}_1 X_f$

Variance of the prediction error of Y, given X

$$s_f^2 = s_e^2 \left[1 + \frac{1}{n} + \frac{(X_f - \bar{X})^2}{(n-1)s_X^2} \right]$$

Standard error of the forecast

$$s_f = s_e \sqrt{1 + \frac{1}{n} + \frac{(X_f - \bar{X})^2}{(n-1)s_X^2}}$$

The Log-Lin Model

$$\ln Y_i = b_0 + b_1 X_i$$

The Lin-Log Model

$$Y_i = b_0 + b_1 \ln X_i$$

The Log-Log Model

$$\ln Y_i = b_0 + b_1 \ln X_i$$

Learning Module 11: Introduction to Big Data Techniques

No formula.

VOLUME 2: ECONOMICS

Learning Module 1: The Firm and Market Structures

Total profit = Total revenue - Total cost

Economic profit = Total revenue - Total economic costs

Accounting profit = Total revenue - Total accounting costs

Total revenue = Price \times Quantity = $P \times Q$

Average revenue = $\frac{\text{Total revenue}}{\text{Quantity}}$

Marginal cost = $\frac{\Delta TC}{\Delta Q}$

Average variable cost = $\frac{\text{Total variable cost}}{\text{Quantity}}$

Average fixed cost = $\frac{\text{Total fixed cost}}{\text{Quantity}}$

Total cost = Total fixed cost + Total variable cost

Average total cost = Average fixed cost + Average variable cost

Concentration Ratio

$$\text{Concentration ratio} = \sum_{i=1}^n (\text{Market share})_i$$

Herfindahl-Hirschman Index (HHI)

$$HHI = \sum_{i=1}^n (\text{Market share})_i^2$$

Learning Module 2: Understanding Business Cycles

No formula

Learning Module 3: Fiscal Policy

$$\text{Budget surplus/(deficit)} = G - T + B$$

where:

- G = Government spending
- T = Taxes
- B = Payments of transfer benefits

Disposable Income

$$YD = Y - NT = (1 - t)Y$$

where:

- t = Net tax rate
- NT = Net taxes = Taxes - Transfers
- tY = Total tax revenue

The Fiscal Multiplier

$$\text{Fiscal multiplier} = \frac{1}{1 - c(1 - t)}$$

where:

- c = Marginal propensity to consume
- t = Tax rate

Learning Module 4: Monetary Policy

Neutral rate = Trend growth + Inflation target

Learning Module 5: Introduction to Geopolitics

No formula

Learning Module 6: International Trade

No formula

Learning Module 7: Capital Flows and the FX Market

Real exchange rate $_{d/f} = S_{d/f} \times \frac{P_f}{P_d}$ % Change in real exchange rate = $\left(1 + \% \Delta S_{d/f}\right) \times \frac{(1 + \% \Delta P_f)}{(1 + \% \Delta P_d)} - 1$

$$\approx \% \Delta S_{d/f} + \% \Delta P_f - \% \Delta P_d$$

Percentage change in base currency f (vs currency d)

$$\frac{E(S_{d/f}) - S_{d/f}}{S_{d/f}}$$

where:

- $S_{d/f}$ = Spot exchange rate
- P_f = General price level of goods indexed in currency f
- P_d = General price level of goods indexed in currency d

Learning Module 8: Exchange Rate Calculations

Cross-Rate

$$\frac{A}{B} = \frac{A}{C} \times \frac{C}{D}$$

Forward Rate

$$F_{A/B} = S_{A/B} \times \left[\frac{1 + r_A \times T}{1 + r_B \times T} \right]$$

$$\begin{aligned} \text{Forward points} &= F_{A/B} - S_{A/B} \\ &= S_{A/B} \left(\frac{r_A - r_B}{1 + r_B} \right) T \end{aligned}$$

where:

- $S_{A/B}$ = Spot exchange rate
- $F_{A/B}$ = Forward exchange rate
- T = Time to maturity

Learning Module 1: Organizational Forms, Corporate Issuer Features, and Ownership

No formula

Learning Module 2: Investors and Other Stakeholders

No formula

Learning Module 3: Working Capital and Liquidity

$$\begin{aligned} \text{Cash conversion cycle} &= \text{Days of inventory on hand} + \text{Days sales outstanding} - \text{Days payables outstanding} \\ \text{EAR of Supplier} \frac{\text{Days in Year}}{\text{Financing}} &= \left(1 + \frac{\text{Discount \%}}{100\% - \text{Discount \%}} \right)^{\frac{\text{Dayment Period} - \text{Discount Period}}{\text{Total working capital}}} - 1 = \frac{\text{Current assets} - \text{Current Liabilities}}{\text{Net working capital}} \\ \text{capital} &= \text{Current assets (excluding cash and marketable securities)} \\ &\quad - \text{Current Liabilities (excluding short-term and current debt)} \end{aligned}$$

Cash flow from operations = Cash received from customers

- Interest and dividends received on financial investments
- Cash paid to employees and suppliers
- Taxes paid to governments
- Interest paid to lenders

Free cash flow = Cash flow from operations - Investments in long-term assets

$$\text{Current ratio} = \frac{\text{Current assets}}{\text{Current liabilities}}$$

$$\text{Quick ratio} = \frac{\text{Cash} + \text{Short-term marketable instruments} + \text{Receivables}}{\text{Current liabilities}}$$

$$\text{Cash ratio} = \frac{\text{Cash} + \text{Short-term marketable instruments}}{\text{Current liabilities}}$$

Learning Module 4: Corporate Governance: Conflicts, Mechanisms, Risks, and Benefits

No formula

Learning Module 5: Capital Investments and Capital Allocation

Net Present Value

$$NPV = CF_0 + \frac{CF_1}{(1+r)^1} + \frac{CF_2}{(1+r)^2} + \dots + \frac{CF_T}{(1+r)^T} = \sum_{t=0}^T \frac{CF_t}{(1+r)^t}$$

where:

- CF_t = After-tax cash flow at time t
- r = Required rate of return
- CF_0 = Initial outlay

Internal Rate of Return

$$\sum_{t=0}^T \frac{CF_t}{(1+IRR)^t} = 0$$

Video: <https://youtu.be/bzck7QLhICw>

Return on Invested Capital

$$\begin{aligned}\text{ROIC} &= \frac{\text{After-tax operating profit}}{\text{Average invested capital}} \\ &= \frac{\text{Operating profit } t_t \times (1 - \text{Tax rate})}{\text{Average total long-term liabilities and equity}_{t-1,t}} \\ \text{ROIC} &= \frac{\text{After-tax operating profit}}{\text{Sales}} \times \frac{\text{Sales}}{\text{Average invested capital}}\end{aligned}$$

Real Options in Capital Budgeting

$$\begin{aligned}\text{Project NPV} \\ (\text{with option}) &= \text{Project NPV} \\ (\text{without option}) &- \text{Option cost} + \text{Option value}\end{aligned}$$

Learning Module 6: Capital Structure

Weighted Average Cost of Capital

$$WACC = w_d r_d (1 - t) + w_e r_e$$

where:

- w_d = Target weight of debt in capital structure = $\frac{D}{D+E}$
- w_e = Target weight of common stock in capital structure = $\frac{E}{D+E}$
- r_d = Before-tax marginal cost of debt
- t = Marginal tax rate
- $r_d(1 - t)$ = After-tax marginal cost of debt
- r_e = Marginal cost of common stock

Operating Leverage

$$\text{Operating leverage} = \frac{\text{Fixed costs}}{\text{Total costs}}$$

Interest Coverage

$$\text{Interest coverage} = \frac{\text{Profit before interest and taxes}}{\text{Interest expense}}$$

Modigliani-Miller Capital Structure Propositions

$$\begin{aligned}V_L &= V_U + tD \\r_e &= r_0 + (r_0 - r_d)(1 - t)\frac{D}{E} \\E &= \frac{(CF_e - r_d D)(1 - t)}{r_e} \\V_L &= \frac{CF_e(1 - t)}{r_{WACC}}\end{aligned}$$

where:

- V_L = Value of levered firm
- V_U = Value of unlevered firm
- t = Marginal tax rate
- r_e = Cost of equity
- r_d = Cost of debt
- r_0 = Cost of capital (for a 100% equity-financed company)
- D = Market value of debt
- E = Market value of equity
- CF_e = After-tax cash flows to shareholders
- $r_d D$ = Interest expense on debt

Static Trade-off Theory of Capital Structure

$$V_L = V_U + tD - PV(\text{Costs of Financial Distress})$$

Learning Module 7: Business Models

No formula

VOLUME 4: FINANCIAL STATEMENT ANALYSIS

Learning Module 1: Introduction to Financial Statement Analysis

No formula

Learning Module 2: Analyzing Income Statements

Gross profit = Revenue - Cost of Goods Sold

Operating income = Gross margin - Selling, General, and Administrative Expense

Taxable income = Operating income - Interest expense

Net income = Taxable income - Taxes

Ending shareholders' equity = Beginning shareholders' equity + Net income

- Other comprehensive income
- Dividends
- Net capital contributions from shareholders

Ending retained earnings = Beginning retained earnings + Net income - Dividends

Return on Equity

$$ROE = \frac{\text{Net income}}{\text{Average shareholders' equity}}$$

Net Profit Margin

$$\text{Net profit margin} = \frac{\text{Net income}}{\text{Revenue}}$$

Basic EPS

$$\text{Basic EPS} = \frac{\text{Net income} - \text{Preferred dividends}}{\text{Weighted average number of shares outstanding}}$$

Diluted EPS (for convertible preferred stock)

$$\text{Diluted EPS} = \frac{\text{Net income}}{\frac{\text{Weighted average number of shares outstanding}}{\quad} + \frac{\text{New common shares that would have been issued at conversion}}{\quad}}$$

Diluted EPS (for convertible debt)

$$\text{Diluted EPS} = \frac{\text{Net income} - \text{Preferred dividends} + \text{After tax interest expense on convertible debt}}{\text{Weighted average number of shares outstanding} + \text{New common shares that would have been issued at conversion}}$$

Diluted EPS (for options)

$$\text{Diluted EPS} = \frac{\text{Net income} - \text{Preferred dividends}}{\text{Weighted average number of shares outstanding} + \text{Additional common shares issued upon conversion}}$$

Treasury stock method

$$\text{Additional common shares issued upon conversion} = \left(\begin{array}{cc} \text{New shares} & \text{Shares repurchased} \\ \text{issued at} & - \\ \text{option exercise} & \text{from option exercised} \end{array} \right) \times \frac{\text{Proportion of}}{\text{with cash received}} \times \frac{\text{during which c}}{\text{were outstan}}$$

Video (Basic & Diluted EPS): <https://youtu.be/2C-mwVqO2SQ>

Learning Module 3: Analyzing Balance Sheets

Working capital = Current assets - Current liabilities

Liquidity Ratios

$$\begin{aligned} \text{Current ratio} &= \frac{\text{Current assets}}{\text{Current liabilities}} \\ \text{Quick (acid test) ratio} &= \frac{\text{Cash} + \text{Marketable securities} + \text{Receivables}}{\text{Current liabilities}} \\ \text{Cash ratio} &= \frac{\text{Cash} + \text{Marketable securities}}{\text{Current liabilities}} \end{aligned}$$

Solvency Ratios

$$\text{Long-term debt-to-equity} = \frac{\text{Long-term debt}}{\text{Total equity}}$$

$$\text{Debt-to-equity} = \frac{\text{Total debt}}{\text{Total equity}}$$

$$\text{Total debt} = \frac{\text{Total debt}}{\text{Total assets}}$$

$$\text{Financial leverage} = \frac{\text{Total assets}}{\text{Total equity}}$$

Learning Module 4: Analyzing Statements of Cash Flows I

Cash flow Cash
flow Cash flow
Ending =
^{cash}
Beginning +
^{cash}
from operating +
^{activities}
from investing +
^{activities}
from financing
^{activities}

Ending accounts + Revenue - *from customers*
= Beginning
accounts
receivable
receivable

Ending Cost of goods
inventory = sold
inventory

Ending accounts + Purchases - Cash paid to
= Beginning suppliers
accounts payable

Ending wages Cash paid to
payable employees
+ payable

Interest Cash
paid expense
- for interest

_____ taxpaple _____
+

Cash flow Cash
 flow Cash flow
 Ending =
 cash
 Beginning +
 cash
 from operating +
 activities
 from investing +
 activities
 from financing
 activities

Ending Equipment sold
 PP&E =
 Beginning
 PP&E+ _____

Ending equipment sold
 accumulated
 Beginning
 accumulated
 Depreciation
 depreciation
 depreciation
 _____ expense
 expense

$$\text{Gain on sale of equipment} = \text{Cash received from sale of equipment} - \text{Book value of equipment sold}$$

Note:
$$\text{Ending retained earnings} = \text{Beginning retained earnings} + \text{Net income} - \text{Dividends}$$

Learning Module 5: Analyzing Statements of Cash Flows II

Free Cash Flow To Firm (FCFF)

$$\begin{aligned} FCFF &= NI + NCC + \text{Int}(1 - \text{Tax rate}) - FC\text{Inv} - WC\text{Inv} \\ &= CFO + \text{Int}(1 - \text{Tax rate}) - FC\text{Inv} \end{aligned}$$

where:

- NI = Net income
- NCC = Non-cash charges (e.g., depreciation and amortization)
- Int = Interest expense
- $FCInv$ = Capital expenditures
- $WCInv$ = Working capital expenditures
- CFO = Cash flow from operating activities = $NI + NCC - WCInv$

Free Cash Flow to Equity (FCFE)

$$FCFE = CFO - FCInv + NetBorrowing$$

where:

- Net Borrowing = Debt issued - Debt repaid

Performance Ratios

$$\text{Cash flow to revenue} = \frac{CFO}{\text{Revenue}}$$

$$\text{Cash return on assets} = \frac{CFO}{\text{Average total assets}}$$

$$\text{Cash return on equity} = \frac{CFO}{\text{Average shareholders equity}}$$

$$\text{Cash to income} = \frac{CFO}{\text{Operating income}}$$

$$\text{Cash flow per share} = \frac{CFO - \text{Preferred dividends}}{\text{Number of common shares outstanding}}$$

Coverage Ratios

$$\text{Debt coverage ratio} = \frac{CFO}{\text{Total debt}}$$

$$\text{Interest coverage ratio} = \frac{CFO + \text{Interest paid} + \text{Taxes paid}}{\text{Interest paid}} \quad \text{Reinvestment ratio} = \frac{CFO}{\text{Cash paid for long term assets}}$$

$$\text{Debt payment ratio} = \frac{CFO}{\text{Cash paid for long term debt repayment}} \quad \text{Dividend payment ratio} = \frac{CFO}{\text{Dividends paid}}$$

$$\text{Investing and financing ratio} = \frac{CFO}{\text{Cash flow for investing and financing activities}}$$

Learning Module 6: Analysis of Inventories

IFRS

Inventories = Lower of Cost and Net Realizable Value (NRV) NRV = Estimated selling price less estimated costs of completion and costs necessary to complete the sale

US GAAP

Inventories = Lower of Cost and NRV For last-in, first-out (LIFO) method or retail inventory methods Inventories = Lower of Cost and Market Value

Market value = Current replacement cost (subject to lower and upper limits) Lower limit = $NRV - \text{Normal profit margin}$ Upper limit = NRV Video: <https://youtu.be/V8C31msIBzs>

Inventory turnover ratio = $\frac{\text{Cost of sales}}{\text{Average inventory}}$ Days of inventory on hand = $\frac{\text{Number of days in period}}{\text{Inventory turnover ratio}}$

Ending inventory (FIFO) = Ending inventory (LIFO) + LIFO reserve

COGS (FIFO) = COGS (LIFO) - Change in LIFO reserve

Learning Module 7: Analysis of Long-Term Assets

Net book value = Historical cost - Accumulated depreciation

Gain on sale of asset = Sale proceeds - Net book value

$$\frac{\text{Estimated remaining life}}{\text{Estimated useful life}} = \frac{\text{Estimated total useful life}}{\frac{\text{Gross PP\&E}}{\text{Annual depreciation expense}}}$$
$$\frac{\text{Estimated remaining life}}{\text{Estimated useful life}} = \frac{\text{Estimated age of equipment}}{\frac{\text{Accumulated depreciation}}{\text{Annual depreciation expense}}}$$

Straight-line Depreciation

$$\text{Annual depreciation expense} = \frac{\text{Historical cost} - \text{Salvage value}}{\text{Estimated useful life}}$$

Fixed Asset Turnover

$$\text{Fixed asset turnover} = \frac{\text{Revenue}}{\text{Average net PP\&E}}$$

Impairment of Long-Lived Assets

IFRS

Impairment = Carrying amount - Recoverable amount

where:

- Recoverable amount = max(Fair value less costs to sell, Value in use)

US GAAP

If asset's carrying amount > undiscounted expected future cash flows: Impairment = Carrying amount - Fair value

Learning Module 8: Topics in Long-Term Liabilities and Equity

Lessee Accounting - Finance Lease (IFRS)

Interest expense = Implied interest rate \times Beginning lease liability
on lease

Principal repayment = Lease payment - Interest expense

Ending lease liability = Beginning lease liability + Interest expense - Lease payment

If ROU asset is amortized on a straight-line basis:

$$\text{Amortization expense} = \frac{\text{Initial ROU asset value} - \text{Salvage value}}{\text{Lease term}}$$

Ending ROU asset = Beginning ROU asset - Amortization expense

Lessee Accounting - Operating Lease (US GAAP)

$\text{Amortization expense} = \text{Lease payment} - \text{Interest expense}$

$\text{Ending ROU asset} = \text{Beginning ROU asset} - \text{Amortization expense}$

$\text{Ending lease liability} = \text{Beginning lease liability} - \text{Amortization expense}$

Stock Options

$$\text{Compensation expense} = \frac{\text{Fair value of options granted}}{\text{Vesting period}}$$

Learning Module 9: Analysis of Income Taxes

Deferred Tax Asset/Liability

For Assets:

$$\frac{\text{Deferred tax liability}}{\text{asset}} = \text{Tax rate} \times \left(\frac{\text{Carrying amount of asset}}{\text{of asset}} - \frac{\text{Tax base of asset}}{\text{of asset}} \right)$$

For Liabilities:

$$\frac{\text{Deferred tax liability}}{\text{asset}} = \text{Tax rate} \times \left(\frac{\text{Tax base of liability}}{\text{of liability}} - \frac{\text{Carrying amount of liability}}{\text{of liability}} \right)$$

$$\text{Income tax expense} = \text{Income tax payable} + \frac{\text{Changes in deferred tax assets and liabilities}}{\text{assets and liabilities}}$$

$$\text{Effective tax rate} = \frac{\text{Income tax expense}}{\text{Pre-tax income}}$$

$$\text{Cash tax rate} = \frac{\text{Cash tax}}{\text{Pre-tax income}}$$

Learning Module 10: Financial Reporting Quality

Adjusted EBITDA

$$\text{Adjusted EBITDA} = \text{Adjusted EBIT} + \text{Post-IPO Software and R\&D amortization} + \text{Depreciation} + \frac{\text{amortization}}{\text{Share-based amortization}}$$

Straight-line method of depreciation

$$\text{Depreciation expense} = \frac{\text{Cost} - \text{Salvage value}}{\text{Useful life}}$$

Double-Declining Balance method

$$\text{Depreciation expense} = \frac{2}{\text{Useful life}} \times (\text{Cost} - \text{Accumulated depreciation})$$

Video: <https://youtu.be/6RskYAxdAFk>

Units-of-Production method

$$\text{Depreciation expense} = \frac{\text{Units produced}}{\text{Total units over useful life}} \times (\text{Cost} - \text{Salvage value})$$

Learning Module 11: Financial Analysis Techniques

Activity Ratios

$$\text{Inventory turnover} = \frac{\text{Cost of sales}}{\text{Average inventory}}$$

$$\text{Days of inventory on hand} = \frac{\text{Number of days in the period}}{\text{Inventory turnover}}$$

$$\text{Receivables turnover} = \frac{\text{Revenue}}{\text{Average receivables}}$$

$$\text{Days of sales outstanding} = \frac{\text{Number of days in the period}}{\text{Receivables turnover}}$$

$$\text{Payables turnover} = \frac{\text{Purchases}}{\text{Average payables}}$$

$$\text{Number of days of payables} = \frac{\text{Number of days in the period}}{\text{Payables turnover}}$$

$$\text{Working capital turnover} = \frac{\text{Revenue}}{\text{Average working capital}}$$

$$\text{Fixed asset turnover} = \frac{\text{Revenue}}{\text{Average net fixed assets}}$$

$$\text{Total asset turnover} = \frac{\text{Revenue}}{\text{Average total assets}}$$

Liquidity Ratios

$$\text{Current ratio} = \frac{\text{Current assets}}{\text{Current liabilities}}$$

$$\text{Quick ratio} = \frac{\text{Cash} + \text{Short term marketable investments} + \text{Receivables}}{\text{Current liabilities}}$$

$$\text{Cash ratio} = \frac{\text{Cash} + \text{Short term marketable investments}}{\text{Current liabilities}}$$

$$\text{Defensive interval} = \frac{\text{Cash} + \text{Short term marketable investments} + \text{Receivables}}{\text{Daily cash expenditures}}$$

$$\text{Cash conversion cycle} = \frac{\text{Days of inventory on hand}}{\text{on hand}} + \frac{\text{Days of sales outstanding}}{\text{outstanding}} - \frac{\text{Number of days of payables}}{\text{of payables}}$$

Solvency Ratios

$$\text{Debt-to-assets ratio} = \frac{\text{Total debt}}{\text{Total assets}} \\ (\text{"Total debt ratio"})$$

$$\text{Debt-to-capital ratio} = \frac{\text{Total debt}}{\text{Total debt} + \text{Total equity}}$$

$$\text{Debt-to-equity ratio} = \frac{\text{Total debt}}{\text{Total equity}}$$

$$\text{Financial leverage ratio} = \frac{\text{Average total assets}}{\text{Average total equity}}$$

$$\text{Debt-to-EBITDA ratio} = \frac{\text{Total or net debt}}{\text{EBITDA}}$$

Coverage Ratios

$$\text{Interest coverage ratio} = \frac{\text{EBIT}}{\text{Interest payments}} \quad \text{Fixed charge coverage ratio} = \frac{\text{EBIT} + \text{Lease payments}}{\text{Interest payments} + \text{Lease payments}}$$

Profitability Ratios

$$\text{Gross profit margin} = \frac{\text{Gross profit}}{\text{Revenue}} \quad \text{Operating profit margin} = \frac{\text{Operating income}}{\text{Revenue}} \quad \text{Pretax margin} = \frac{\text{EBT}}{\text{Revenue}} \quad \text{Net profit margin} = \frac{\text{Net income}}{\text{Revenue}}$$

$$\text{Operating ROA} = \frac{\text{Operating income}}{\text{Average total assets}} \quad \text{ROA} = \frac{\text{Net income}}{\text{Average total assets}} \quad \text{Return on invested capital} = \frac{\text{EBIT} \times (1 - \text{Effective tax rate})}{\text{Average total debt and equity}} \quad \text{ROE} = \frac{\text{Net income}}{\text{Average total equity}} \quad \text{Return on common equity} = \frac{\text{Net income} - \text{Preferred dividends}}{\text{Average common equity}}$$

DuPont Analysis

$$\text{ROE} = \text{ROA} \times \text{Financial Leverage}$$

$$\text{ROE} = \text{Net profit margin} \times \text{Total asset turnover} \times \text{Financial leverage} \quad \text{ROE} = \frac{\text{Tax}}{\text{burden}} \times \frac{\text{Interest}}{\text{burden}} \times \frac{\text{EBIT}}{\text{margin}} \times \frac{\text{Total asset}}{\text{turnover}} \times \frac{\text{Financial}}{\text{leverage}}$$

where:

- Tax burden = $\frac{\text{Net income}}{\text{EBT}}$
- Interest burden = $\frac{\text{EBT}}{\text{EBIT}}$

Business Risk

$$\begin{aligned} \text{Coefficient of variation of operating income} &= \frac{\text{Standard deviation of operating income}}{\text{Average operating income}} & \text{Coefficient of variation of net income} &= \frac{\text{Standard deviation of net income}}{\text{Average net income}} \\ \text{Coefficient of variation of revenue} &= \frac{\text{Standard deviation of revenue}}{\text{Average revenue}} \end{aligned}$$

Financial Sector Ratios

$$\begin{aligned} \text{Monetary reserve requirement (Cash reserve ratio)} &= \frac{\text{Reserves held at central bank}}{\text{Specified deposit liabilities}} & \text{Net interest margin} &= \frac{\text{Net interest income}}{\text{Total interest earning assets}} \\ \text{Liquid asset requirement} &= \frac{\text{Approved readily marketable securities}}{\text{Specified deposit liabilities}} & \text{Net interest margin} &= \frac{\text{Net interest income}}{\text{Total interest earning assets}} \end{aligned}$$

Learning Module 12: Introduction to Financial Statement Modeling

Nothing new.

VOLUME 5: EQUITY INVESTMENTS

Learning Module 1: Market Organization and Structure

Maximum leverage ratio = $\frac{1}{\text{Minimum margin requirement}}$ Total return on leveraged stock investment:

$$\text{Total Return} = \frac{\text{Sales proceeds} + \text{Dividends} - \text{Loan} - \frac{\text{Margin}}{\text{interest}} - \text{Sales commission}}{\text{Initial equity} + \text{Purchase commission}} - 1$$

Initial equity = $\frac{\text{Minimum margin requirement}}{\text{requirement}} \times \text{Total purchase price}$ Video (Return on Leveraged Stock

Position): <https://youtu.be/tZd4Xtvjill> Margin Call Price = $\frac{P_0(1 - \text{Initial Margin})}{(1 - \text{Maintenance Margin})}$

Learning Module 2: Security Market Indexes

$$\text{Price Return Index, } V_{PRI} = \frac{\sum_{i=1}^N n_i P_i}{D}$$

where:

- n_i = the number of units of constituent security i held in the index portfolio
- N = the number of constituent securities in the index
- P_i = the unit price of constituent security i
- D = value of the divisor

$$\text{Price return of an index, } PR_I = \frac{V_{PRI1} - V_{PRI0}}{V_{PRI0}}$$

$$\text{Total Return Index, } TR_I = \frac{V_{PRI1} - V_{PRI0} + Inc_I}{V_{PRI0}}$$

where:

- V_{PRI1} = value of the price return index at the end of the period
- V_{PRI0} = value of the price return index at the beginning of the period
- Inc_I = total income (dividends and/or interest) from all securities in the index held over the period

Weighting Methods

$$\text{Price weighting, } w_i^P = \frac{P_i}{\sum_{j=1}^N P_j}$$

Video (Recalculating the divisor of a price weighted index): <https://youtu.be/eYiZNK-ETrg>

$$\text{Equal weighting, } w_i^E = \frac{1}{N}$$

$$\text{Market-capitalization weighting, } w_i^M = \frac{Q_i P_i}{\sum_{j=1}^N Q_j P_j}$$

$$\text{Float-adjusted market capitalization weighting, } w_i^M = \frac{f_i Q_i P_i}{\sum_{j=1}^N f_j Q_j P_j}$$

where:

- f_i = fraction of shares outstanding in the market float

- Q_i = number of shares outstanding of security i
- P_i = share price of security i
- N = number of securities in the index

$$\text{Fundamental weighting, } w_i^F = \frac{F_i}{\sum_{j=1}^N F_j}$$

where F_i denotes a fundamental size measure of company i

Learning Module 3: Market Efficiency

No formula

Learning Module 4: Overview of Equity Securities

Return on Equity (using average total book value of equity)

$$ROE_t = \frac{NI_t}{(BVE_t + BVE_{t-1})/2}$$

Return on Equity (using beginning book value of equity)

$$ROE_t = \frac{NI_t}{BVE_{t-1}}$$

where BVE = book value (Assets - Liabilities)

Learning Module 5: Company Analysis: Past and Present

$$\text{Market share} = \frac{\text{Revenue}}{\text{Market size}}$$

$$\text{Sales potential} = 100\% - \text{Market share } \%$$

$$\text{Net sales} = \text{Average selling price} \times \text{Quantity sold}$$

$$\text{Take rate} = \frac{\text{Revenue earned from transactions}}{\text{Total transaction volume}} \times 100\%$$

$$\text{Operating income} = Q \times (P - VC) - FC$$

where:

- Q = Units sold in a period
- P = Price per unit

- VC = Variable operating cost per unit
- FC = Fixed operating costs
- $P - VC$ = Contribution margin per unit

$$\text{Degree of operating leverage (DOL)} = \frac{\frac{\% \Delta \text{ Operating income}}{\% \Delta \text{ Sales}}}{\frac{\% \Delta \text{ Net income}}{\% \Delta \text{ Operating income}}} \quad \text{Degree of financial leverage (DFL)} =$$

$$\text{WACC} = \frac{\text{Weight of debt}}{\text{Gross cost of debt}} \times (1 - \text{tax rate}) + \frac{\text{Weight of equity}}{\text{Cost of equity}}$$

Learning Module 6: Industry and Company Analysis

Herfindahl-Hirschman Index (HHI)

$$HHI = \sum_{i=1}^{\infty} s_i^2$$

where:

- s_i = Market share of participant i (stated as a whole number)

$$\text{Learning Module 7: Company Analysis: Forecasting \% Variable cost} \approx \frac{\% \Delta (\text{Cost of revenue} + \text{Operating expense})}{\% \Delta \text{ Revenue}}$$

$$\% \text{ Fixed cost} \approx 1 - \% \text{ Variable cost} \quad \frac{\text{Number of units sold post-cannibalization}}{\text{Number of units sold pre-cannibalization}} = \frac{\text{Number of units sold pre-cannibalization}}{\text{Number of units sold post-cannibalization}} -$$

$$\frac{\text{Expected cannibalization}}{\text{Expected cannibalization}} = \frac{\text{Number of units sold pre-cannibalization}}{\text{Number of units sold post-cannibalization}} \times \frac{\text{Cannibalization factor}}{\text{Cannibalization factor}}$$

Learning Module 8: Equity Valuation: Concepts and Basic Tools

Dividend Discount Model (DDM)

$$V_0 = \sum_{t=1}^n \frac{D_t}{(1+r)^t} + \frac{P_n}{(1+r)^n}$$

where:

- V_0 = Intrinsic value of a share at $t = 0$
- D_t = expected dividend in year t
- r = required rate of return on stock
- P_n = expected price per share at $t = n$ (terminal value)

Free-cash-flow-to-equity (FCFE) Valuation Model

$$V_0 = \sum_{t=1}^{\infty} \frac{FCFE_t}{(1+r)^t}$$

where:

- $FCFE = CFO - FCInv + NetBorrowing$
- $FCInv$ = Fixed capital investment
- $Net\ Borrowing$ = Borrowings minus repayments Value of preferred stock (non-callable, non-convertible, perpetual)

$$V_0 = \frac{D_0}{r}$$

Value of preferred stock (non-callable, non-convertible, maturity at time n)

$$V_0 = \sum_{t=1}^n \frac{D_t}{(1+r)^t} + \frac{\text{Par value}}{(1+r)^n}$$

Gordon Growth Model

$$P_0 = \frac{D_1}{r-g} = \frac{D_0(1+g)}{r-g}$$

where:

- D_0 = Most recent annual dividend
- D_1 = Expected dividend in the next period
- g = Constant growth rate
- r = Required return on equity

Sustainable growth rate

$$g = b \times ROE$$

where:

- b = earnings retention rate (= 1 - Dividend payout ratio)
- ROE = Return on equity

Video: <https://youtu.be/MnfRRRhuGpA>

Two-Stage Dividend Discount Model

$$V_0 = \sum_{t=1}^n \frac{D_0 (1 + g_s)^t}{(1 + r)^t} + \frac{V_n}{(1 + r)^t}$$

where:

- g_L = Long-term stable growth rate
- g_s = Short-term growth rate
- $V_n = \frac{D_{n+1}}{r - g_L} = \frac{D_0(1+g_s)^t(1+g_L)}{r - g_L}$

Justified forward P/E

$$\frac{P_0}{E_1} = \frac{\text{Dividend payout ratio}}{r - g}$$

Enterprise Value

$$EV = \begin{array}{c} \text{Market value} \\ \text{of equity} \end{array} + \begin{array}{c} \text{Market value} \\ \text{of preferred stock} \end{array} + \begin{array}{c} \text{Market value} \\ \text{of debt} \end{array} - \begin{array}{c} \text{Cash and} \\ \text{short term} \\ \text{investments} \end{array}$$

Asset-based Valuation

$$\begin{array}{c} \text{Adjusted} \\ \text{book value} \end{array} = \begin{array}{c} \text{Market value} \\ \text{of assets} \end{array} - \begin{array}{c} \text{Market value} \\ \text{of liabilities} \end{array}$$

VOLUME 6: FIXED INCOME

Learning Module 1: Fixed-Income Instrument Features Current yield = $\frac{\text{Annual coupon}}{\text{Bond price}}$ Bond price = $\frac{\text{Coupon}}{(1+r)^1} + \frac{\text{Coupon}}{(1+r)^2} + \dots + \frac{\text{Coupon} + \text{Face value}}{(1+r)^n}$

where:

- Coupon per period = Coupon rate per period \times Face value
- r = Yield to maturity per period
- n = Number of payments

Floating-rate Note (FRN) coupon rate = MRR + Spread

Learning Module 2: Fixed-Income Cash Flows and Types

Fully Amortizing Loan with Level Payment

$$A = \frac{r \times \text{Principal}}{1 - (1 + r)^{-N}}$$

where:

- A = Periodic payment
- r = Market interest rate per period
- N = Number of payment periods

If the periodic payment is monthly:

Monthly interest payment = Interest rate per month \times Beginning principal of loan

Monthly principal payment = Total monthly payment $-$ Monthly interest payment

Ending principal of loan = Beginning principal of loan $-$ Monthly principal payment

Capital-Index Bond (e.g., TIPS)

Inflation-adjusted principal = Principal amount \times (1 + Inflation adjustment)

Coupon per period = Coupon rate per period \times Inflation-adjusted principal

Deferred Coupon Bond

Video: <https://youtu.be/erRbAUOGIyM>

Convertible Bonds

$$\begin{array}{c} \text{Conversion} \\ \text{ratio} \end{array} = \frac{\text{Convertible bond par value}}{\begin{array}{c} \text{Conversion price} \\ \text{Conversion} \\ \text{value} \end{array}} = \begin{array}{c} \text{Conversion} \\ \text{ratio} \end{array} \times \begin{array}{c} \text{Current share} \\ \text{price} \end{array}$$

Zero-Coupon Bond

Original issue discount = Bond par value - Issuance price

Learning Module 3: Fixed-Income Issuance and Trading

No formula

Learning Module 4: Fixed-Income Markets for Corporate Issuers

Repurchase Agreements

$$\begin{aligned}\text{Repurchase price} &= \text{Price of bond} \times \left[1 + \text{Repo rate} \times \frac{\text{Repo term (in days)}}{\text{Number of days in a year}} \right] \\ \text{Initial margin} &= \frac{\text{Security price}_0 - \text{Purchase price}_0}{\text{Purchase price}_0} \\ \text{Haircut} &= \frac{\text{Security price}_0 - \text{Purchase price}_0}{\text{Security price}_0}\end{aligned}$$

$$\text{Variation margin} = (\text{Initial margin} \times \text{Purchase price}_t) - \text{Security price}_t$$

Learning Module 5: Fixed-Income Markets for Government Issuers

No formula.

Learning Module 6: Fixed-Income Bond Valuation: Prices and Yields

$$PV = \frac{PMT_1}{(1+r)^1} + \frac{PMT_2}{(1+r)^2} + \dots + \frac{PMT_N + FV_N}{(1+r)^N}$$

where:

- PMT_t = Coupon that occurs in t periods
- r = Market discount rate per period
- N = Number of periods to maturity
- FV = Face value of bond

Full Price, Flat Price, and Accrued Interest (Video: <https://youtu.be/I7G075JAu5w>)

$$\begin{aligned}PV^{\text{Full}} &= PV^{\text{Flat}} + \text{Accrued Interest} \\ &= PV_{BOP} \times (1+r)^{t/T}\end{aligned}$$

where:

- $\text{Accrued Interest} = \frac{t}{T} \times PMT$
- t = number of days from the last coupon payment to the settlement date
- T = number of days in the coupon period

- t/T = fraction of the coupon period that has gone by since the last payment
- PV_{BOP} = price on the previous coupon date (before the settlement date)

Matrix Pricing

$$\text{Interpolated yield} = \text{Yield}_S + \left(\frac{\text{Tenor}_{\text{Target}} - \text{Tenor}_S}{\text{Tenor}_L - \text{Tenor}_S} \right) \times (\text{Yield}_L - \text{Yield}_S)$$

where:

- Yield_S = Yield of shorter-term bond
- Yield_L = Yield of longer-term bond
- Tenor_S = Tenor of shorter-term bond
- Tenor_L = Tenor of longer-term bond
- $\text{Tenor}_{\text{Target}}$ = Tenor of the subject bond
- $\text{Tenor}_S < \text{Tenor}_{\text{Target}} < \text{Tenor}_L$ Required yield spread = Bond YTM - Government Bond YTM (Similar maturity)

Learning Module 7: Yield and Yield Spread Measures for Fixed Rate Bonds

Periodicity Conversion

$$\left(1 + \frac{APR_m}{m} \right)^m = \left(1 + \frac{APR_n}{n} \right)^n$$

where:

- APR_m = Annual percentage rate for m periods per year
 - APR_n = Annual percentage rate for n periods per year
- Current yield $_t = \frac{\text{Annual coupon}_t}{\text{Bond price}_t}$
- Government equivalent yield, $\text{Yield}_{\text{ACT} / \text{ACT}} = \frac{365}{360} \times \text{Yield}_{30/360}$ Simple yield
- $= \frac{\text{Coupon} + (\frac{FV - PV}{N})}{\text{Flat price}}$

Callable Bonds

$$PV = \frac{PMT}{(1 + YTC)^1} + \frac{PMT}{(1 + YTC)^2} + \dots + \frac{PMT + \text{Call price}}{(1 + YTC)^N}$$

where:

- PV = Price of the callable bond
- PMT = Coupon payment per period
- YTC = Yield to call per period

- N = Number of periods to when the bond can be called at the call price

Option-adjusted price = Flat price of bond + Value of embedded call option

Value of call option = Price of option-free bond - Price of callable bond

G-spread = Bond YTM - Interpolated sovereign bond YTM

I-spread = Bond YTM - Swap rate

Z-Spread

$$PV = \frac{PMT}{(1 + z_1 + Z)^1} + \frac{PMT}{(1 + z_2 + Z)^2} + \dots + \frac{PMT + FV}{(1 + z_N + Z)^N}$$

where:

- Z = Z-spread
- z_N = Spot rate for N periods

OAS = Z-spread - Option value (in basis points per year)

Learning Module 8: Yield and Yield Spread Measures for Floating-Rate Instruments

Value of Floating Rate Note (FRN)

$$PV = \frac{\left(\frac{MRR+QM}{m}\right) \times FV}{\left(1 + \frac{MRR+DM}{m}\right)^1} + \frac{\left(\frac{MRR+QM}{m}\right) \times FV}{\left(1 + \frac{MRR+DM}{m}\right)^2} + \dots + \frac{\left(\frac{MRR+QM}{m}\right) \times FV + FV}{\left(1 + \frac{MRR+DM}{m}\right)^n}$$

where:

- QM = Quoted Margin
- DM = Discount Margin
- MRR = Market reference rate
- m = Periodicity (i.e., number of payment periods per year)
- FV = Face Value of FRN
- N = Number of evenly spaced periods to maturity

Video: <https://youtu.be/zqY0tVLkYR8>

Yield Measures for Money Market Instruments

Discount Rate Basis

$$PV = FV \times \left(1 - \frac{Days}{Year} \times DR\right)$$
$$DR = \frac{Year}{Days} \times \left(\frac{FV - PV}{FV}\right)$$

where:

- PV = present value of money market instrument
- FV = future value paid at maturity
- Days = number of days between settlement and maturity
- Year = number of days in the year
- DR = discount rate (stated as annual percentage rate)

Add-on Rate Basis

$$PV = \frac{FV}{\left(1 + \frac{Days}{Year} \times AOR\right)}$$
$$AOR = \frac{Year}{Days} \times \left(\frac{FV - PV}{PV}\right)$$
$$\text{Bond equivalent yield} = \frac{365}{Days} \times \left(\frac{FV - PV}{PV}\right)$$

Learning Module 9: The Term Structure of Interest Rates: Spot, Par, and Forward Curves

Calculation of Bond Price Using Spot Rates

$$PV = \frac{PMT}{(1 + Z_1)^1} + \frac{PMT}{(1 + Z_2)^2} + \dots + \frac{PMT + FV}{(1 + Z_N)^N}$$

where:

- PV = Price of bond
- PMT = Bond coupon payment
- Z_N = Spot rate (or zero-coupon yield or zero rate) for period N
- FV = Face value of bond

Given a Par Rate, $FV = PV$ and $PMT = \text{Par Rate } (\%) \times FV$

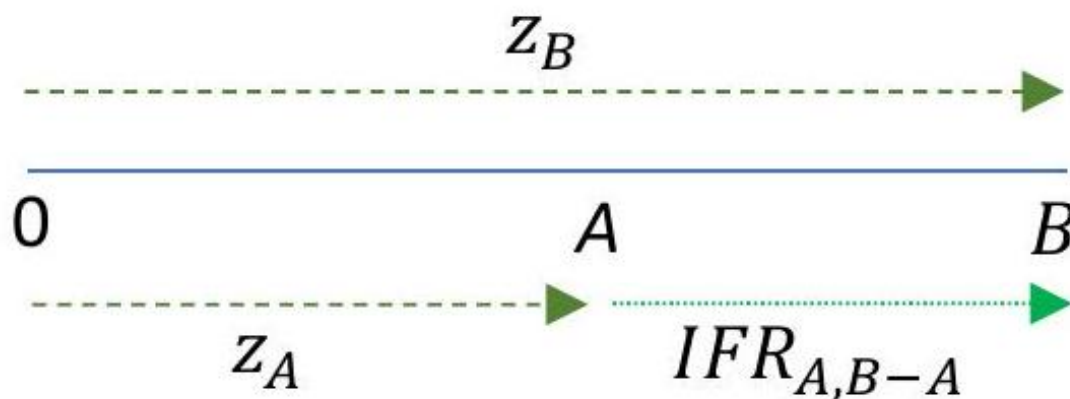
$$100 = \frac{PMT}{(1 + Z_1)^1} + \frac{PMT}{(1 + Z_2)^2} + \dots + \frac{PMT + 100}{(1 + Z_N)^N}$$

Forward Rates, IFR

$$(1 + z_A)^A \times (1 + IFR_{A,B-A})^{B-A} = (1 + z_B)^B$$

where:

- $IFR_{A,B-A}$ = Forward rate for $(B - A)$ periods that starts in period A



Learning Module 10: Interest Rate Risk and Return

Duration Gap

Duration gap = Macaulay duration - Investment horizon

Macaulay Duration

$$\begin{aligned} \text{Macaulay duration} = & \left(1 - \frac{t}{T}\right) \left[\frac{\frac{PMT}{(1+r)^{1-t/T}}}{PV^{Full}} \right] + \left(2 - \frac{t}{T}\right) \left[\frac{\frac{PMT}{(1+r)^{2-t/T}}}{PV^{Full}} \right] + \dots \\ & + \left(N - \frac{t}{T}\right) \left[\frac{\frac{PMT+FV}{(1+r)^{N-t/T}}}{PV^{Full}} \right] \end{aligned}$$

$$\text{Macaulay duration} = \left\{ \frac{1+r}{r} - \frac{1+r+[N \times (c-r)]}{c \times [(1+r)^N - 1] + r} \right\} - \frac{t}{T}$$

where:

- r = Yield per period
- c = Coupon rate per period
- N = Number of evenly spaced periods to maturity as of the beginning of the current period
- t = Number of days from the last coupon payment to the settlement date
- T = Number of days in the coupon period

Video: <https://youtu.be/USgjcdCk7Fs>

Learning Module 11: Yield-Based Bond Duration Measures and Properties

Modified Duration

$$\text{Modified Duration} = \frac{\text{Macaulay Duration}}{1 + r}$$

Approximate Modified Duration

$$\begin{aligned}\text{AnnModDur} &\approx \frac{(PV_-) - (PV_+)}{2 \times (\Delta \text{Yield}) \times (PV_0)} \\ \% \Delta PV^{\text{Full}} &\approx - \text{AnnModDur} \times \Delta \text{Yield}\end{aligned}$$

Money Duration

$$\text{Money duration} = \text{AnnModDur} \times PV^{\text{full}}$$

$$\Delta PV^{\text{Full}} \approx - \text{MoneyDur} \times \Delta \text{Yield}$$

Duration of Zero-Coupon Bond

$$\begin{aligned}\text{MacDur} &= \text{Time to maturity} \\ \text{ModDur} &= \frac{\text{Time to maturity}}{1 + r}\end{aligned}$$

Duration of Perpetual Bond

$$\text{MacDur} = \frac{1+r}{r}$$
$$\text{ModDur} = \frac{1}{r}$$

Duration of Floating-Rate Notes

$$\text{MacDur} = \frac{T-t}{T} = \begin{array}{l} \text{Fraction of period remaining until} \\ \text{the next reset date} \end{array}$$

Learning Module 12: Yield-Based Bond Convexity and Portfolio Properties

Convexity

$$\text{Convexity} = \sum_{t=1}^N \frac{t(t+1) \times \frac{PV_t}{PV^{\text{Full}}}}{(1+YTM)^2}$$

Approximate Annualized Convexity

$$\text{ApproxConv} \approx \frac{(PV_-) + (PV_+) - 2(PV_0)}{(\Delta \text{Yield})^2 \times (PV_0)}$$
$$\% \Delta PV^{\text{Full}} \approx -\text{AnnModDur} \times \Delta \text{Yield} + \frac{1}{2} \times \text{AnnConvexity} \times (\Delta \text{Yield})^2$$

Money Convexity

$$\text{MoneyCon} = \text{AnnConvexity} \times PV^{\text{Full}}$$
$$\Delta PV^{\text{Full}} \approx -(\text{MoneyDur} \times \Delta \text{Yield}) + \left[\frac{1}{2} \times \text{MoneyCon} \times (\Delta \text{Yield})^2 \right]$$

Portfolio Duration and Convexity

$$\text{Portfolio Modified Duration} = \sum_{i=1}^N w_i \times \text{ModDur}_i$$

$$\text{Portfolio Convexity} = \sum_{i=1}^N w_i \times \text{Convexity}_i$$

where:

- w_i = Weight of bond i , measured in market value

Learning Module 13: Curve-Based and Empirical Fixed-Income Risk Measures

Effective Duration

$$\text{EffDur} = \frac{(PV_-) - (PV_+)}{2 \times (\Delta \text{ Curve}) \times PV_0}$$

Effective Convexity

$$\begin{aligned} \text{EffCon} &= \frac{(PV_-) + (PV_+) - 2 \times PV_0}{(\Delta \text{ Curve})^2 \times PV_0} \\ \% \Delta PV^{\text{Full}} &\approx - \text{EffDur} \times \Delta \text{ Curve} + \frac{1}{2} \times \text{EffCon} \times (\Delta \text{ Curve})^2 \end{aligned}$$

Key Rate Duration

$$\begin{aligned} \text{KeyRateDur}_k &= -\frac{1}{PV} \times \frac{\Delta PV}{\Delta r_k} \\ \% \Delta PV &= - \text{KeyRateDur}_k \times \Delta r_k \\ \sum_{k=1}^n \text{KeyRateDur}_k &= \text{EffDur} \end{aligned}$$

where:

- r_k = k th key rate

Learning Module 14: Credit Risk

Expected Loss

$$EL = LGD \times POD$$
$$LGD = EE \times (1 - RR)$$

where:

- POD = Probability of default
- LGD = Loss given default
- EE = Expected exposure
- RR = Recovery rate
- $1 - RR$ = Loss severity

Credit spread \approx $POD \times LGD$

Decomposing Bond Yields

Yield spread = Bond YTM - Government bond YTM (Similar maturity)

Liquidity spread = Bond YTM (Bid) – Bond YTM (Offer)

Credit spread = Yield spread - Liquidity spread

Price Impact Given a Change in Yield Spread

$$\% \Delta PV^{\text{Full}} \approx - \text{AnnModDur} \times \Delta \text{Spread} + \frac{1}{2} \times \text{AnnConvexity} \times (\Delta \text{Spread})^2$$

where:

- $\text{AnnModDur} \approx \frac{(PV_-) - (PV_+)}{2 \times (\Delta \text{Yield}) \times (PV_0)}$
- $\text{AnnConvexity} \approx \frac{(PV_-) + (PV_+) - 2(PV_0)}{(\Delta \text{Yield})^2 \times (PV_0)}$

Learning Module 15: Credit Analysis for Government Issuers

No formula.

Learning Module 16: Credit Analysis for Corporate Issuers

$$\begin{aligned}\text{EBIT margin} &= \frac{\text{Operating income}}{\text{Revenue}} \\ \text{EBIT to interest expense} &= \frac{\text{Operating income}}{\text{Interest expense}} \\ \text{Debt to EBITDA} &= \frac{\text{Debt}}{\text{EBITDA}} \\ \text{RCF to net debt} &= \frac{\text{Retained cash flow}}{\text{Debt - Cash and marketable securities}} \\ \text{FFO to debt} &= \frac{\text{FFO}}{\text{Debt}}\end{aligned}$$

where:

- FFO = Net income from continuing operations + Depreciation & amortization
- Deferred income taxes + Other non-cash items

Learning Module 17: Fixed-Income Securitization

No formula.

Learning Module 18: Asset-Backed Security (ABS) Instrument and Market Features

No formula.

Learning Module 19: Mortgage-Backed Security (MBS) Instrument and Market Features

Loan-to-value (LTV) ratio

$$LTV = \frac{\text{Loan amount}}{\text{House price}}$$

Debt-to-income (DTI) ratio

$$DTI = \frac{\text{Monthly debt payment}}{\text{Monthly pre-tax gross income}}$$

Mortgage Pass-Through Securities

$$WAC = \sum_{i=1}^N c_i \left(\frac{CB_i}{CB} \right)$$
$$WAM = \sum_{i=1}^N MM_i \left(\frac{CB_i}{CB} \right)$$

where:

- WAC = Weighted average coupon
- WAM = Weighted average maturity
- c_i = Coupon rate on mortgage i
- MM_i = Number of months to maturity for mortgage i
- N = Number of mortgages in MBS
- CB_i = Current balance on mortgage i
- CB = Total current balance of mortgages in MBS

Commercial Mortgage-Backed Securities (CMBS)

Debt Service Coverage Ratio (DSCR)

$$DSCR = \frac{\text{Net operating income}}{\text{Debt service}}$$

Net Operating Income (NOI)

$NOI = (\text{Rental income} - \text{Cash operating expenses}) - \text{Replacement reserves}$

VOLUME 7: DERIVATIVES

Learning Module 1: Derivative Instrument and Derivatives Market Features

No formula.

Learning Module 2: Forward Commitments and Contingent Claim Features and Instruments

Forward Contract

$$\begin{aligned}\text{Buyer (Long) payoff} &= S_T - F_0(T) \\ \text{Seller (Short) payoff} &= -[S_T - F_0(T)]\end{aligned}$$

where:

- S_T = Spot price on contract's maturity
- $F_0(T)$ = Forward price with maturity of T

Futures Contract

For one futures contract:

$$\begin{aligned}\text{Long Futures daily mark-to-market} &= f_t(T) - f_{t-1}(T) \\ \text{Short Futures daily mark-to-market} &= -[f_t(T) - f_{t-1}(T)]\end{aligned}$$

where:

- $f_t(T)$ = Closing price of futures contract on day t
- $f_{t-1}(T)$ = Closing price of futures contract on day $t - 1$ T = Maturity of futures contract

If margin balance < maintenance margin:

$$\text{Variation Margin} = \text{Initial margin} - \text{Margin balance}$$

Options Contract

LONG Call option

Payoff or Value at expiration, $c_T = \max(0, S_T - X)$

Profit at expiration, $\Pi = \max(0, S_T - X) - c_0$

where:

- c_0 = Call premium
- X = Exercise/Strike price S_T = Spot price at expiration

SHORT Call option

Payoff or Value at expiration, $c_T = -\max(0, S_T - X)$

Profit at expiration, $\Pi = -[\max(0, S_T - X) - c_0]$

LONG Put option

Payoff or Value at expiration, $p_T = \max(0, X - S_T)$

Profit at expiration, $\Pi = \max(0, X - S_T) - p_0$

SHORT Put option

Payoff or Value at expiration, $p_T = -\max(0, X - S_T)$

Profit at expiration, $\Pi = -[\max(0, X - S_T) - p_0]$

Credit Default Swap (CDS)

CDS MTM Change = Δ CDS Spread \times CDS Notional \times EffDur_{CDS}

In a credit event, payment from CDS seller to CDS buyer $\approx LGD(\%) \times$ Notional

Learning Module 3: Derivative Benefits, Risks, and Issuer and Investor Uses

No formula.

Learning Module 4: Arbitrage, Replication, and the Cost of Carry in Pricing Derivatives

If there are no underlying costs or benefits:

$$\text{Forward price, } F_0(T) = S_0(1 + r)^T$$

If there are underlying costs or benefits in present value terms:

$$\text{Forward price, } F_0(T) = [S_0 - PV_0(\text{Income}) + PV_0(\text{Cost})](1 + r)^T$$

where:

- S_0 = Current spot price
- r = Risk-free rate
- T = Tenor of forward contract

Under continuous compounding, $F_0(T) = S_0 e^{rT}$ Under continuous compounding, with income (i) and cost (c) expressed in %:

$$F_0(T) = S_0 e^{(r+c-i)T}$$

Foreign Exchange Forward Contract

$$F_{0,f/d}(T) = S_{0,f/d}(T) e^{(r_f - r_d)T}$$

where:

- $F_{0,f/d}$ = Forward exchange rate
- $S_{0,f/d}$ = Spot exchange rate
- r_f = Continuously compounded risk-free rate (for price/quote currency)
- r_d = Continuously compounded risk-free rate (for base currency)
- T = Maturity of forward contract

Learning Module 5: Pricing and Valuation of Forward Contracts and for an Underlying with Varying Maturities

Value of LONG Forward Prior to Expiration

$$\begin{aligned} V_0(T) &= 0 \\ V_t(T) &= S_t - \frac{F_0(T)}{(1+r)^{T-t}} = S_t - F_0(T) \times (1+r)^{-(T-t)} \\ V_T(T) &= S_0 - F_0(T) \end{aligned}$$

If the asset incurs cost or generates income from time t through maturity,

$$V_t(T) = [S_t - PV_t(\text{Income}) + PV_t(\text{Cost})] - F_0(T) \times (1+r)^{-(T-t)}$$

For foreign exchange forward contract,

$$V_t(T) = S_{t,f/d} - F_{0,f/d}(T) \times e^{-(r_f - r_d)(T-t)}$$

Value of SHORT Forward Prior to Expiration

$$\begin{aligned}V_0(T) &= 0 \\V_t(T) &= - \left[S_t - \frac{F_0(T)}{(1+r)^{T-t}} \right] \\V_T(T) &= - [S_0 - F_0(T)]\end{aligned}$$

Interest Rate Forward Contracts (Forward Rate Agreements (FRA))

$$(1 + z_A)^A \times (1 + IFR_{A,B-A})^{B-A} = (1 + z_B)^B$$

where:

- z_A = Spot rate for A periods
- z_B = Spot rate for B periods
- $IFR_{A,B-A}$ = Implied forward rate for $(B - A)$ periods, starting in A periods

Payoff for a Long FRA = $(MRR_{B-A} - IFR_{A,B-A}) \times \text{Notional principal} \times \text{Period}$

Payoff for a Short FRA = $-(MRR_{B-A} - IFR_{A,B-A}) \times \text{Notional principal} \times \text{Period}$

Learning Module 6: Pricing and Valuation of Futures Contracts

If there are no underlying costs or benefits:

$$\text{Futures price, } f_0(T) = S_0(1+r)^T$$

If there are underlying costs or benefits in present value terms:

$$f_0(T) = [S_0 - PV_0(\text{Income}) + PV_0(\text{Cost})] (1+r)^T$$

Under continuous compounding, $f_0(T) = S_0 e^{rT}$

Under continuous compounding, with income (i) and cost (c) expressed in %:

$$f_0(T) = S_0 e^{(r+c-i)T}$$

Foreign Exchange Forward Contract

$$f_{0,f/d}(T) = S_{0,f/d}(T) e^{(r_f - r_d)T}$$

Interest Rate Futures Contract

$$f_{A,B-A} = 100 - (100 \times MRR_{A,B-A})$$

where:

- $f_{A,B-A}$ = Futures price for a market reference rate for ($B - A$) periods that begins in A periods

Futures contract basis point value, $BPV = \text{Notional principal} \times 0.01\% \times \text{Period}$

Learning Module 7: Pricing and Valuation of Interest Rates and Other Swaps

For a fixed-rate payer in an interest rate swap:

$$\text{Periodic settlement value} = (MRR - s_N) \times \text{Swap Notional} \times \text{Period}$$

For a fixed-rate receiver in an interest rate swap:

$$\text{Periodic settlement value} = (s_N - MRR) \times \text{Swap Notional} \times \text{Period}$$

where:

- s_N = Fixed swap rate
- MRR = Market reference rate

Calculating Par Swap Rate

$$\sum_{i=1}^N \frac{IFR}{(1 + z_i)^i} = \sum_{i=1}^N \frac{s_N}{(1 + z_i)^i}$$

where:

- IFR = Implied forward rates
- s_N = Fixed swap rate
- N = Tenor of swap contract

Valuation of Interest Rate Swap

Value of a pay-fixed interest rate swap on a settlement date after inception =
Current settlement value + $\Sigma(\text{Floating payments}) - \Sigma(\text{Fixed payments})$

Value of a receive-fixed interest rate swap on a settlement date after inception
= Current settlement value + $\Sigma(\text{Fixed payments}) - \Sigma(\text{Floating payments})$

Learning Module 8: Pricing and Valuation of Options

Option value = Exercise value + Time value

At time t (prior to option expiration):

Call option exercise value = $\text{Max}[0, S_t - X(1+r)^{-(T-t)}]$

Call option time value = $c_t - \text{Max}[0, S_t - X(1+r)^{-(T-t)}]$

Put option exercise value = $\text{Max}[0, X(1+r)^{-(T-t)} - S_t]$

Put option time value = $p_t - \text{Max}[0, X(1+r)^{-(T-t)} - S_t]$

Lower bound of call option value = $\text{Max}[0, S_t - X(1+r)^{-(T-t)}]$

Upper bound of call option value = S_t

Lower bound of put option value = $\text{Max}[0, X(1+r)^{-(T-t)} - S_t]$

Upper bound of put option value = X

where:

- S_t = Spot price at time t
- X = Exercise price (or strike price)
- T = Maturity of option
- r = Risk-free rate

Learning Module 9: Option Replication Using Put-Call Parity

Put-Call Parity

$$S_0 + p_0 = c_0 + X(1+r)^{-T}$$

Put-Call Forward Parity

$$F_0(T)(1+r)^{-T} + p_0 = c_0 + X(1+r)^{-T}$$

Value of the Firm

$$V_0 = c_0 + PV(\text{Debt}) - p_0$$

Value of debt = $PV(\text{Debt}) - p_0$ Value of equity = c_0

Learning Module 10: Valuing a Derivative Using a One-Period Binomial Model

Risk-neutral probability of a price increase in underlying

$$\pi = \frac{1+r-R^d}{R^u-R^d}$$

where:

- $R^u = \text{Up factor} = \frac{S_1^u}{S_0} > 1$
- $R^d = \text{Down factor} = \frac{S_1^d}{S_0} < 1$
- $S_0 = \text{Current asset price}$
- $S_1^u = \text{One-period asset price when price moves up}$
- $S_1^d = \text{One-period asset price when price moves down}$

Video: <https://youtu.be/ymUIKgZ-rAw>

Hedge ratio

$$h^* = \frac{c_1^u - c_1^d}{S_1^u - S_1^d}$$

where:

- $c_1^u = \max(0, S_1^u - X)$
- $c_1^d = \max(0, S_1^d - X)$

Riskless portfolio with a Call: h of the underlying, S , and short call position, c $V_0 = hS_0 - c_0$
 $V_1^u = hS_1^u - c_1^u$ $V_1^d = hS_1^d - c_1^d$

Riskless portfolio with a Put: h of the underlying, S , and long put position, p

$$V_0 = hS_0 + p_0 \quad V_1^u = hS_1^u + p_1^u \quad V_1^d = hS_1^d + p_1^d$$

Value of a one-period call option

$$c_0 = \frac{\pi c_1^u + (1 - \pi)c_1^d}{1 + r}$$

Value of a one-period put option

$$p_0 = \frac{\pi p_1^u + (1 - \pi)p_1^d}{1 + r}$$

where:

- $p_1^u = \max(0, X - S_1^u)$
- $p_1^d = \max(0, X - S_1^d)$ Video: <https://youtu.be/bXEC-78yAU>

Learning Module 1: Alternative Investment Features, Methods, and Structures

GP Compensation Structure

Ignoring management fee; no catch-up clause

$$r_{GP} = \max[0, p(r - r_h)]$$

Ignoring management fee; with catch-up clause

$$r_{GP} = \max[0, r_{cu} + p(r - r_h - r_{cu})]$$

where:

- r_{GP} = GP' s rate of return
- p = Performance fee as a percentage of total return
- r = Single-period rate of return
- r_h = Hard hurdle rate
- r_{cu} = Catch-up clause

Learning Module 2: Alternative Investment Performance and Returns

Multiple on Invested Capital

$$MOIC = \frac{\text{Realized value of investment} + \text{Unrealized value of investment}}{\text{Total amount of invested capital}}$$

Leveraged Portfolio Return

$$r_L = r + \frac{V_b}{V_c} (r - r_b)$$

where:

- r = Periodic rate of return on invested funds
- r_b = Periodic cost of borrowing
- V_b = Amount of borrowed funds
- V_c = Amount of cash (investor's own capital)

Investor's Return Net of Fees

$$r_i = \frac{P_1 - P_0 - R_{GP}}{P_0}$$

$$R_{GP} = (P_1 \times r_m) + \max[0, (P_1 - P_0) \times p]$$

where:

- P_0 = Beginning-of-period asset value
- P_1 = End-of-period asset value
- p = GP performance fee
- R_{GP} = GP's return in current terms
- r_m = GP's management fees as a percentage of assets under management

Calculating Hedge Fund Fees and Returns

Management Fee Based on Beginning Market Value

$$\text{Management Fee} = \frac{\text{Management}}{\text{Beginning Market}} \%$$

Management Fee Based on Ending Market Value

$$\text{Management Fee} = \% \text{ Management Fee} \times \text{Ending Market Value}$$

Incentive Fee Calculated Independent of Management Fee

$$\text{Incentive Fee} = \% \text{ Incentive Fee} \times \text{Gain}$$

Incentive Fee Calculated Net of Management Fee

$$\text{Incentive Fee} = \% \text{ Incentive Fee} \times (\text{Gain} - \text{Management Fee})$$

Incentive Fee with Hard Hurdle (Independent of Management Fee)

$$\text{Incentive Fee} = \% \text{ Incentive Fee} \times (\text{Gain} - \text{Hurdle})$$

Incentive Fee with Hard Hurdle (Net of Management Fee)

$$\text{Incentive Fee} = \% \text{ Incentive Fee} \times (\text{Gain} - \text{Management Fee} - \text{Hurdle})$$

$$\text{Hurdle} = \text{Hurdle Rate} \times \text{Beginning market value}$$

Note: 1) No incentive is paid if hedge fund incurs loss for the year. 2) Gain may be subject to high watermark.

¹ ## Learning Module 3: Investments in Private Capital: Equity and Debt

No formula.

Learning Module 4: Real Estate and Infrastructure

Loan-to-Value (LTV) Ratio

$$LTV = \frac{\text{Mortgage liability}}{\text{Portfolio value}}$$

Required reduction in mortgage liability = Mortgage liability - Required mortgage liability

¹Video: <https://youtu.be/ODKMcGsAAdc>

Learning Module 5: Natural Resources

No formula.

Learning Module 6: Hedge Funds

No formula.

Learning Module 7: Introduction to Digital Assets

No formula.

VOLUME 9: PORTFOLIO MANAGEMENT

Learning Module 1: Portfolio Risk and Return: Part I

Expected Return on Asset

$$1 + E(R) = (1 + r_{rF}) \times [1 + E(\pi)] \times [1 + E(RP)]$$

where:

- r_{rF} = Real risk-free rate
- $E(\pi)$ = Expected inflation
- $E(RP)$ = Expected risk premium for the asset

Utility on Investment

$$U = E(R) - \frac{1}{2}A\sigma^2$$

where:

- U = Utility of investment
- $E(R)$ = Expected return of investment
- A = Risk aversion coefficient
- σ^2 = Variance of investment (Note: Substitute σ in decimals)

Capital Allocation Line (CAL)

For a portfolio of risky assets (Weight: w_i) and risk-free asset:

$$E(R_p) = R_f + \left[\frac{E(R_i) - R_f}{\sigma_i} \right] \sigma_p$$

where:

- R_f = Rate of return on risk-free asset
- $E(R_i)$ = Expected return of risky asset
- $E(R_p)$ = Expected return of portfolio
- σ_i = Standard deviation of risky asset's returns
- σ_p = Standard deviation of portfolio's returns = $w_i \times \sigma_i$
- $\frac{E(R_i) - R_f}{\sigma_i}$ = Market price of risk

Two-asset portfolio

Portfolio expected return, $E(R_p) = w_1 R_1 + w_2 R_2$

Portfolio variance, $\sigma_p^2 = w_1^2 \sigma_1^2 + w_2^2 \sigma_2^2 + 2w_1 w_2 \text{Cov}(R_1, R_2)$

Portfolio standard deviation, $\sigma_p = \sqrt{w_1^2 \sigma_1^2 + w_2^2 \sigma_2^2 + 2w_1 w_2 \text{Cov}(R_1, R_2)}$

Note: 1) $\text{Cov}(R_1, R_2) = \rho_{12} \sigma_1 \sigma_2$ 2) n securities requires n variances and $\frac{n(n-1)}{2}$ covariances

Video: <https://youtu.be/IUwulZ9ONCO>

Foreign Asset

Return of a foreign asset in domestic currency

$$R_D = (1 + R_{lc}) \times (1 + R_{FX}) - 1$$

Standard deviation of return of a foreign asset in domestic currency

$$\sigma_D = \sqrt{\sigma_{lc}^2 + \sigma_{FX}^2 + 2 \times \rho \times \sigma_{lc} \times \sigma_{FX}}$$

where:

- R_{lc} = Return of foreign asset (in local currency)
- R_{FX} = Change in exchange rate (FX rate quoted as domestic currency/foreign currency)

- σ_{lc} = Standard deviation of foreign asset's returns
- σ_{FX} = Standard deviation of the exchange rate (DC/FC)
- ρ = Correlation coefficient between returns on foreign asset and exchange rate

Portfolio of Many Risky Assets

$$\sigma_p^2 = \frac{\bar{\sigma}^2}{N} + \frac{N-1}{N} \overline{\text{Cov}} = \frac{\bar{\sigma}^2}{N} + \frac{N-1}{N} \rho \bar{\sigma}^2$$

where:

- N = Number of assets in portfolio
- $\bar{\sigma}^2$ = Average variance
- $\overline{\text{Cov}}$ = Average covariance

Learning Module 2: Portfolio Risk and Return: Part II

Capital Market Line (CML)

$$E(R_p) = w_f R_f + (1 - w_f) E(R_m) = R_f + \left[\frac{E(R_m) - R_f}{\sigma_m} \right] \sigma_p \sigma_p = (1 - w_f) \sigma_m$$

Return-Generating Models

$$E(R_i) - R_f = \beta_{i1} [E(R_m) - R_f] + \sum_{j=2}^k \beta_{ij} E(F_j)$$

where:

- $E(R_i) - R_f$ = Expected excess return on asset i
- k = Number of factors β_{ij} = Factor weights (also called factor loadings) $E(R_m)$ = Expected return on market

The Single-Index Model

$$E(R_i) - R_f = \left(\frac{\sigma_i}{\sigma_m} \right) [E(R_m) - R_f]$$

where:

- $\frac{\sigma_i}{\sigma_m}$ = Factor loading (or factor weight)

Capital Asset Pricing Model

$$E(R_i) = R_f + \beta_i [E(R_m) - R_f]$$

The Market Model

$$R_i = \alpha_i + \beta_i R_m + e_i$$

Beta of security i

$\beta_i = \frac{\text{Cov}(R_i, R_m)}{\sigma_m^2} = \frac{\rho_{i,m} \sigma_i}{\sigma_m}$ Portfolio beta, $\beta_p = \sum_{i=1}^n w_i \beta_i$ Total variance = Systematic variance + Nonsystematic variance

$$\sigma_i^2 = \beta_i^2 \sigma_m^2 + \sigma_e^2$$

Total risk, $\sigma_i = \sqrt{\beta_i^2 \sigma_m^2 + \sigma_e^2}$

Arbitrage Pricing Theory (APT) Model

$$E(R_P) = R_F + \lambda_1 \beta_{P,1} + \cdots + \lambda_K \beta_{P,K}$$

where:

- $E(R_P)$ = Expected return on portfolio
- R_F = Risk-free rate
- λ_j = Risk premium for factor j
- $\beta_{P,1}$ = Sensitivity of the portfolio to factor j
- K = Number of risk factors

Fama-French Model

$$E(R_{it}) = \alpha_i + \beta_{i,MKT} MKT_t + \beta_{i,SMB} SMB_t + \beta_{i,HML} HML_t$$

Carhart Model

$$E(R_{it}) = \alpha_i + \beta_{i,MKT}MKT_t + \beta_{i,SMB}SMB_t + \beta_{i,HML}HML_t + \beta_{i,UMD}UMD_t$$

where:

- $E(R_i)$ = Return on an asset in excess of the one-month T-bill return
- MKT = Excess return on the market portfolio
- SMB = Difference in returns between small-capitalization stocks and large-capitalization stocks (Size)
- HML = Difference in returns between high-book-to-market stocks and low-book-to-market stocks (Value versus growth)
- UMD = Difference in returns of the prior year's winners versus losers (Momentum)

Portfolio Performance Appraisal Measures

$$\text{Sharpe ratio} = \frac{R_p - R_f}{\sigma_p}$$

$$\text{Treynor ratio} = \frac{R_p - R_f}{\beta_p} \quad M^2 = (R_p - R_f) \frac{\sigma_m}{\sigma_p} + R_f = \text{Sharpe ratio} \times \sigma_m + R_f \quad M^2 \text{ alpha} = M^2 - R_m$$

$$\text{Jensen's Alpha, } \alpha_p = R_p - [R_f + \beta_p (R_m - R_f)]$$

Security Characteristic Line (SCL)

$$R_i - R_f = \alpha_i + \beta_i (R_m - R_f)$$

$$\text{Information ratio} = \frac{\alpha_i}{\sigma_{ei}}$$

Learning Module 3: Portfolio Management: An Overview

No formula.

Learning Module 4: Basics of Portfolio Planning and Construction

No formula.

Learning Module 5: The Behavioral Biases of Individuals

No formula.

Learning Module 6: Introduction to Risk Management

No formula.