Net Present Value (NPV)

Discount rate r: you're indifferent between receiving \$1 today and $\$\frac{1}{1+r}$ in one period.

Present Value (PV): $\boxed{PV(CF_t) = \frac{CF_t}{(1+r)^t}}$ how much a cash flow (CF) at time t is worth at time 0 (today). Computing a PV is often called "discounting".

NPV: $\boxed{NPV = \sum_{t=0}^{T} \frac{CF_t}{(1+r)^t}}$ summs over PVs of all cash flows in a project.

- **Scalability**: $NPV(\alpha CF_1, \ldots, \alpha CF_T) = \alpha NPV(CF_1, \ldots, CF_T)$
- **Additivity**: $NPV(X_1 + Y_1, \ldots, X_T + Y_T) = NPV(X_1, \ldots, X_T) + NPV(Y_1, \ldots, Y_T)$
- **Breaking up by time**: $NPV(CF_1, \ldots, CF_T) = NPV(CF_1, \ldots, CF_j) + NPV(CF_{j+1}, \ldots, CF_T)$

Future Value (FV): $\boxed{FV_T(CF_0) = CF_0(1+r)^T}$ how much a cash flow at time 0 (today) is worth in T periods.

Perpetuity:

- Constant recurring cash flow A forever starting **1 period from now**: $\boxed{PV = \frac{A}{r}}$
- Growing perpetuity starting **1 period from now** with cash flow A, growth rate g: $\boxed{PV = \frac{A}{r-g} (r > g)}$

Annuity:

- Constant recurring cash flow A for T periods starting **1 period from now**: (E.g. a loan)
  $\boxed{PV = \frac{A}{r}\left(1 - \frac{1}{(1+r)^T}\right)}$
  $\boxed{FV = PV \cdot (1+r)^T = A\frac{(1+r)^T - 1}{r}}$
- Growing annuity starting **1 period from now** with cash flow A, growth rate g for T periods.
  - If $r \neq g$ $\boxed{PV = \frac{A}{r-g}\left(1 - \frac{(1+g)^T}{(1+r)^T}\right)}$; $\boxed{FV = A\left(\frac{(1+r)^T - (1+g)^T}{r-g}\right)}$
  - If $r = g$ $\boxed{PV = T\left(\frac{A}{1+r}\right)}$; $\boxed{FV = T \cdot A \cdot (1+r)^{T-1}}$

Annual Percentage Rate (APR) & Effective Annual Rate (EAR):

$\boxed{(1 + EAR) = \left(1 + \frac{APR}{k}\right)^k = (1+r)^k}$ where k is the number of compounding periods per year and r is the per-period (e.g. monthly) interest rate.

- APR $= r \cdot k$
- EAR i.e. Annual Percentage Yield (APY)

Mortgage-related terms

Principal: the amount of \$ borrowed in a lending agreement. E.g. Buy a \$1,000,000 house with a 20% down payment, the principal is \$800,000.

Interest:

- **Fixed rate**: No matter what happens to interest rates around the world, you would still be charged interest at this same rate.
- **Adjustable rate (ARM)**: E.g. an adjustable rate of 3% above the federal funds rate (the Fed's benchmark rate). If this rate is around 4.5%, you would be charged a 7.5% interest rate. If in the next month the Fed raises to 5%, you would be charged an 8% interest rate.

Amortization schedule: sequence of payments made through the loan's lifetime. A part of the payments goes to reduce (i.e. amortize) the principal owed, and the rest goes to pay the interest on the loan.

Collateral: An asset offered by the borrower as a guarantee in a loan. If you fail to make payments, the bank can take the collateral.

Refinancing: Paying off an existing loan with a new loan that has better terms. E.g. lower interest rate, lower monthly payment, shorter loan term.

E.g.: a 30-year fixed-rate mortgage, APR 9% compounded monthly. Fixed monthly payment = \$3000. First payment will start next month and last until the contract expires in 30 years.

- **How much borrowed when took out the mortgage?**: use the constant annuity formula, where $A = \$3000$, $r = \frac{0.09}{12} = 0.0075$, $T = 30 \times 12 = 360$. $PV = \frac{A}{r}\left(1 - \frac{1}{(1+r)^T}\right) = \frac{3000}{0.0075}\left(1 - \frac{1}{(1+0.0075)^{360}}\right) = \$372,845.60$
- **10 years later, how much must pay back to the bank if sell the house?**: (i.e. NPV of the remaining principal amount as of this future date.) $T = 20 \times 12 = 240$
  $PV = \frac{3000}{0.0075}\left(1 - \frac{1}{(1+0.0075)^{240}}\right) = \$333,434.86$
- **Why the remaining principal is still so high after 10 years' worth of repayments?**: Because the amortization schedule is front-loaded. I.e. Early on in the life of the mortgage, the vast majority of each monthly payment is interest: interest is applied to the remaining principal amount, and this remaining principal is highest in month 1 and decreases over time. Because the majority of each monthly payment in the early years is interest, the principal repayment amounts are small, and the remaining principal de-creases very slowly. (It's only toward the end of the mortgage that interest payments decline enough to repay the principal more quickly.)

Inflation i: the change in CPI $\boxed{1 + i_{t+1} = \frac{CPI_{t+1}}{CPI_t}}$

- **"Nominal"**: not adjusted for inflation
- **"Real"**: adjusted for inflation

Real rate of return: $r_{\text{real}} = \frac{1+r_{\text{nominal}}}{1+i} - 1$ $\boxed{r_{\text{real}} \approx r_{\text{nominal}} - i}$

Treat inflation consistently for NPV: $\boxed{PV(CF_T) = \frac{CF_{\text{nominal,T}}}{(1+r_{\text{nominal,T}})^T} = \frac{CF_{\text{real,T}}}{(1+r_{\text{real,T}})^T}}$ ("$_T$" denotes the cash flow at time T)

Capital Budgeting

To maximize value, take on only projects with positive NPV.

- **Single**: take it only if it has positive NPV.
- **Independent**: take all with positive NPV.
- **Mutually exclusive**: take the one with the highest positive NPV.
- Ignore sunk costs, including opportunity costs.

Cash operating expenses:

- **COGS**: direct costs attributable to the production of the goods sold by a business.
- **R&D**: costs associated with discovering new knowledge or develop new products, processes, and services.
- **SG&A**: costs not directly tied to the production of goods. e.g. "S": advertising and sales commissions. "G": salaries of non-production personnel. "A": legal, accounting, and exec salaries.

Depreciation: non-cash expense that reduces the value of an asset over time. For most finance problems, we want to strip out effects of depreciation to get back to free cash flow. Exception: if depreciation affects free cash flows through taxes.

EBITDA: $\boxed{= \text{(Op. Rev.)} - \text{(All Op. Exp. w/o depreciation)}}$

EBIT: $\boxed{= \text{EBITDA} - \text{Depreciation (\& Amort.)}}$

Cash Flows: from accounting statements

$\boxed{CF = (1-\tau)(\text{EBITDA}) + \tau(\text{Dep.}) - (\text{CapEx}) - \Delta\text{WC}}$

$\boxed{CF = (1-\tau)(\text{EBIT}) + (\text{Dep.}) - (\text{CapEx}) - \Delta\text{WC}}$

Working Capital (WC): $\boxed{= \text{Inventory} + \text{A/R} - \text{A/P}}$ We are about changes (i.e. Δ) in WC, not levels because if keeping WC constant, no new cash flow required.

TODO: CB example needed

Alternatives to NPV

Internal rate of return: discount rate that makes zero NPV. $\boxed{NPV = \sum_{t=0}^{T} \frac{CF_t}{(1+IRR)^t} = 0}$ Determine some fixed IRR^* i.e. "threshold rate":

- **Independent**: take if $IRR > IRR^*$.
- **Mutually exclusive**: take the one with the highest IRR among projects $IRR > IRR^*$.

IRR leads to the same decision as NPV if:

- Cash outflow occurs only at time 0
- Only one project is being considered
- Opportunity cost of capital (discount rate r) remains constant for all periods
- $IRR^* = r$

Shortcomings: no solution, multiple solutions, project size not accounted for, different projects' horizons not fully considered.

Payback period: min. length of time k such that sum of CFs from a project is positive. $\boxed{\sum_{t=1}^{k} CF_t \geq -CF_0 = I_0}$ Determine some fixed threshold k^*:

- **Independent**: take if $k \leq k^*$.
- **Mutually exclusive**: take the one with the minnimum k among projects $k \leq k^*$.

Discounted payback period: ditto but discount CFs. $\boxed{\sum_{t=1}^{k} \frac{CF_t}{(1+IRR)^t} \geq -CF_0 = I_0}$

Shortcomings: ignores CFs after k.

Profitability index (PI): ratio of the NPV of future CFs to the initial investment. $\boxed{PI = \frac{NPV}{I_0}}$

- **Independent**: take all $PI > 1$.
- **Mutually exclusive**: take the one with the highest PI and $PI > 1$.

Shortcomings: doesn't account for project size.