INTEREST MEASUREMENT

Effective Rate of Interest

$$i_t = \frac{A(t) - A(t-1)}{A(t-1)}$$

Effective Rate of Discount

$$d_t = \frac{A(t) - A(t-1)}{A(t)}$$

Accumulation Function and Amount Function

$$A(t) = A(0) \cdot a(t)$$

All-in-One Relationship Formula

$$(1+i)^t = \left(1 + \frac{i^{(m)}}{m}\right)^{mt} = (1-d)^{-t} = \left(1 - \frac{d^{(m)}}{m}\right)^{-mt} = e^{\delta t}$$

Simple Interest

$$a(t) = 1 + it$$

Variable Force of Interest

$$\delta_t = \frac{a'(t)}{a(t)}$$

Accumulate 1 from time t_1 to time t_2:

$$AV = \exp\left(\int_{t_1}^{t_2} \delta_s \, ds\right)$$

Discount Factor

$$v = \frac{1}{1+i} = 1 - d$$

$$d = \frac{i}{1+i} = iv$$

ANNUITIES

Annuity-Immediate

$$PV = a_{\overline{n}|} = v + v^2 + \cdots + v^n = \frac{1-v^n}{i}$$

$$AV = s_{\overline{n}|} = 1 + (1+i) + \cdots + (1+i)^{n-1}$$

$$= \frac{(1+i)^n - 1}{i}$$

Annuity-Due

$$PV = \ddot{a}_{\overline{n}|} = 1 + v + v^2 + \cdots + v^{n-1} = \frac{1-v^n}{d}$$

$$AV = \ddot{s}_{\overline{n}|} = (1+i) + (1+i)^2 + \cdots + (1+i)^n$$

$$= \frac{(1+i)^n - 1}{d}$$

Immediate vs. Due

$$\ddot{a}_{\overline{n}|} = a_{\overline{n}|}(1+i) = 1 + a_{\overline{n-1}|}$$

$$\ddot{s}_{\overline{n}|} = s_{\overline{n}|}(1+i) = s_{\overline{n+1}|} - 1$$

Deferred Annuity

m-year deferred n-year annuity-immediate:

$$PV = {}_{m|}a_{\overline{n}|} = v^m \cdot a_{\overline{n}|} = a_{\overline{m+n}|} - a_{\overline{m}|}$$

Perpetuity

- Perpetuity-immediate:

$$PV = a_{\overline{\infty}|} = v + v^2 + \cdots = \frac{1}{i}$$

- Perpetuity-due:

$$PV = \ddot{a}_{\overline{\infty}|} = 1 + v + v^2 + \cdots = \frac{1}{d}$$

$$\ddot{a}_{\overline{\infty}|} = 1 + a_{\overline{\infty}|}$$

MORE GENERAL ANNUITIES

i-effective method is used when payments are more or less frequent than the interest period.

"i-effective" Method

Convert the given interest rate to the equivalent effective interest rate for the period between each payment.

Example: To find the present value of n monthly payments given annual effective rate of i, define j as the monthly effective rate where $j = (1+i)^{1/12} - 1$. Then apply $PV = a_{\overline{n}|}$ using j.

Payments in Arithmetic Progression

- PV of n-year annuity-immediate with payments of P, $P+Q$, $P+2Q$, ..., $P+(n-1)Q$

$$PV = Pa_{\overline{n}|} + Q\frac{a_{\overline{n}|} - nv^n}{i}$$

Calculator-friendly version:

$$PV = \left(P + \frac{Q}{i}\right)a_{\overline{n}|} + \left(-\frac{Qn}{i}\right)v^n$$

$$N = n, \ I/Y = i \ (\text{in \%}), \ PMT = P + \frac{Q}{i}, \ FV = -\frac{Qn}{i}$$

- PV of n-year annuity-immediate with payments of $1, 2, 3, ..., n$

Unit increasing: $(Ia)_{\overline{n}|} = \frac{\ddot{a}_{\overline{n}|} - nv^n}{i}$

P&Q version: $P = 1, Q = 1, N = n$

- PV of n-year annuity-immediate with payments of $n, n-1, n-2, ..., 1$

Unit decreasing: $(Da)_{\overline{n}|} = \frac{n - a_{\overline{n}|}}{i}$

P&Q version: $P = n, Q = -1, N = n$

- PV of perpetuity-immediate and perpetuity-due with payments of $1, 2, 3, ...$

$$(Ia)_{\overline{\infty}|} = \frac{1}{id} = \frac{1}{i} + \frac{1}{i^2} \qquad (I\ddot{a})_{\overline{\infty}|} = \frac{1}{d^2}$$

Payments in Geometric Progression

PV of an n-year annuity-immediate with payments of $1, (1+k), (1+k)^2, ..., (1+k)^{n-1}$

$$PV = \frac{1 - \left(\frac{1+k}{1+i}\right)^n}{i - k}, \ i \neq k$$

Level and Increasing Continuous Annuity

$$\bar{a}_{\overline{n}|} = \int_0^n v^t \, dt = \frac{1-v^n}{\delta} = \frac{i}{\delta}a_{\overline{n}|}$$

$$(\bar{I}\bar{a})_{\overline{n}|} = \int_0^n tv^t \, dt = \frac{\bar{a}_{\overline{n}|} - nv^n}{\delta}$$

YIELD RATES

Two methods for comparing investments:

- *Net Present Value (NPV):* Sum the present value of cash inflows and cash outflows. Choose investment with greatest positive NPV.
- *Internal Rate of Return (IRR):* The rate such that the present value of cash inflows is equal to the present value of cash outflows. Choose investment with greatest IRR.

LOAN AMORTIZATION AND SINKING FUNDS

Outstanding Balance Calculation

- *Prospective:* $B_t = Ra_{\overline{n-t}|}$ R = level payments Present value of future payments.
- *Retrospective:* $B_t = L(1+i)^t - Rs_{\overline{t}|}$ Accumulated value of original loan amount L minus accumulated value of all past payments.

Retrospective	Prospective
Accumulating Past Payments	Discounting Future Payments

Loan Amortization

For a loan of $a_{\overline{n}|}$ repaid with n payments of 1:

	Period t	Total till time t
Interest (I_t)	$1 - v^{n-t+1}$	$t - (a_{\overline{n}|} - a_{\overline{n-t}|})$
Principal repaid (P_t)	v^{n-t+1}	$a_{\overline{n}|} - a_{\overline{n-t}|}$
Total	1	t

General Formulas for Amortized Loan with Level/Non-Level Payments

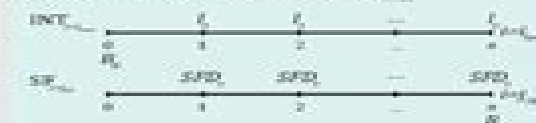$$I_t = i \cdot B_{t-1}$$
$$B_t = B_{t-1}(1+i) - R_t = B_{t-1} - P_t$$
$$P_t = R_t - I_t$$
$$P_{t+k} = P_t(1+i)^k \ (\text{only for Level Payments})$$

Sinking Fund

Loan payment consists of (i) interest paid to the lender based on the total loan amount (L) and (ii) the sinking fund deposit (SFD).

- Interest paid = $i_{loan} \cdot L$
- Sinking fund deposit: $SFD = \frac{L}{s_{\overline{n}|i_{sf}}}$
- Net loan amount at t: $L - SFD s_{\overline{t}|i_{sf}}$

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