Introduction to Financial Models
Lecture 05: Financial Markets & Instruments I

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  - Consumption timing (saving and borrowing)
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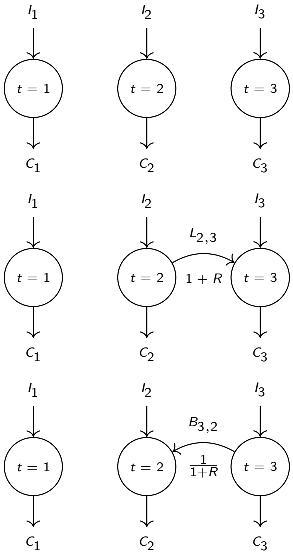
- Shifting consumption comes with compensation in the form of interest rates

Shifting Consumption in Time



(a) Income equals consumption

(b) Shifting consumption forward by saving

(c) Shifting consumption backward by borrowing

Figure: Shifting consumption forward and backward in time

Flow Balance Equations

- When saving (shifting consumption forward):

$$C_2 = I_2 - L_{2,3}$$
$$C_3 = I_3 + L_{2,3}(1 + R)$$

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- Alternative expression when borrowing at $t = 2$:

$$C_2 = I_2 + B^*_{3,2}$$
$$C_3 = I_3 - B^*_{3,2}(1 + R)$$

where $B^*_{3,2}$ is the amount borrowed at $t = 2$

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- Risk management: Identifying, measuring, and controlling risk exposures

Holding Period Return and Gain

- **Definition 1.1 (Holding period return)** Let us consider a holding period $[0, T]$, where the initial asset price is $S(0)$ and the terminal random asset price is $S(T, \omega)$. We define the holding period return as

$$R(\omega) \doteq \frac{S(T,\omega)-S(0)}{S(0)}$$

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- Term "rate of return" typically reserved for annual returns

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- The return depends on the measurement approach

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- Risky and risk-free assets form the foundation of many financial models

Market Scenario Trees

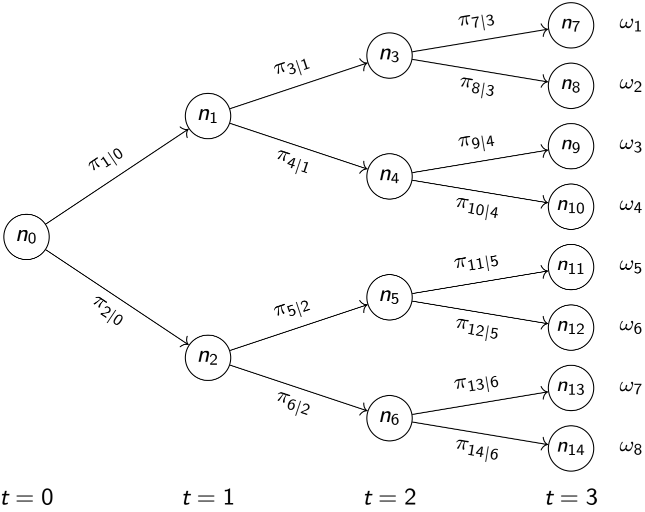

Figure: A scenario tree: uncertainty unfolding progressively over time

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  - Uses include hedging, speculation, and portfolio enhancement

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    - Principal repayment guaranteed, coupons linked to index
    - Often used to circumvent derivative restrictions
- Securitization:
  - Creates liquid securities from illiquid assets
  - Example: mortgage-backed securities (MBS)
  - Can involve tranching by risk level
  - Both benefits (enhanced returns, risk distribution) and risks (complexity, correlation)
  - 2008 financial crisis revealed dangers of securitized products

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  - Interest on borrowed funds reduces net return
  - Example: 50% leverage can nearly double returns
  - Increased bankruptcy risk with excessive leverage
  - LTCM collapse demonstrated dangers of extreme leverage
- Feedback effects in illiquid markets
  - Margin calls can force asset sales
  - Price drops may trigger more margin calls
  - Asset liquidation in thin markets depresses prices further
  - Vicious cycle can lead to market crashes

Margin Trading and Leverage

- Buying on margin: borrowing money to buy assets
  - Assets serve as collateral plus cash buffer
  - Balance sheet view: assets, liabilities, and equity
  - Initial margin requirement (e.g., 50% or 60%)
  - Maintenance margin requirement (e.g., 25% or 30%)
  - Margin ratio: equity divided by asset value
  - Margin calls when ratio falls below maintenance threshold
  - Position may be liquidated if margin call not met
- Effect of leverage:
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  - Vicious cycle can lead to market crashes
  - Particularly dangerous with illiquid assets

Example of Margin Trading

Initial scenario:

- Boom Corp stock price: \$100 per share
- Buy 100 shares (\$10,000 total)
- Borrow \$4,000 from broker
- Initial margin ratio: $\frac{\$6{,}000}{\$10{,}000} = 60\%$
- Maintenance margin: 30%

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Assets

Stock	\$10,000

Liabilities

Loan from broker	\$4,000
Equity	\$6,000

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If price falls to \$70:

Assets	
Stock	\$7,000

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Assets		**Liabilities**	
Stock	\$10,000	Loan from broker	\$4,000
		Equity	\$6,000

If price falls to \$70:

Assets		**Liabilities**	
Stock	\$7,000	Loan from broker	\$4,000
		Equity	\$3,000

Margin ratio: $\frac{\$3{,}000}{\$7{,}000} = 43\%$

Example 1.14: Margin Trading (cont.)

Limit price calculation:

- Margin ratio: $\frac{100P - \$4{,}000}{100P}$
- Setting equal to maintenance margin (30%):

$$
\begin{aligned}
\frac{100P - \$4{,}000}{100P} &= 30\% \\
100P - \$4,000 &= 0.3 \times 100P \\
100P - 30P &= \$4,000 \\
70P &= \$4,000 \\
P &= \$57.14
\end{aligned}
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Leverage effect on returns:

- Asset rises 30%: ROE $= \frac{\$10{,}000 \times 0.30 - \$4{,}000 \times 0.03}{\$6{,}000} = 48\%$
- 50% leverage (borrow \$5,000): ROE $= \frac{\$10{,}000 \times 0.30 - \$5{,}000 \times 0.03}{\$5{,}000} = 57\%$
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Leverage magnifies both gains and losses

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- Alternative short positions through derivatives
  - Using futures or options to create synthetic short
  - May be less expensive or restricted than direct shorting

Example of A Short Trade

Initial scenario:

- We are bearish on DotBomb stock (currently \$100)
- Short-sell 1000 shares, generating \$100,000 proceeds
- Initial margin requirement: 50% (\$50,000 in cash/T-bills)
- Total margin account: \$150,000

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Balance sheet representation:

Assets		**Liabilities**	
Cash + T-bills	\$150,000	Short position in stock	\$100,000
		Equity	\$50,000

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Balance sheet representation:

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		Equity	\$50,000

If price falls to \$70:

- Close position with \$30,000 profit

If price rises to \$110:

Assets		**Liabilities**	
Cash + T-bills	\$150,000	Short position in stock	\$110,000
		Equity	\$40,000

Margin ratio: $\frac{\$40{,}000}{\$110{,}000} = 36\%$

Example of A Short Trade (cont.)

Limit price calculation:

- Margin ratio: $\frac{\$150{,}000-1000P}{1000P}$
- Setting equal to maintenance margin (30%):

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\frac{\$150{,}000-1000P}{1000P} &= 30\% \\
\$150,000 - 1000P &= 0.3 \times 1000P \\
\$150,000 &= 1000P + 300P \\
\$150,000 &= 1300P \\
P &= \$115.38
\end{aligned}$$

Example of A Short Trade (cont.)

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Key considerations:

- Short-selling can be expensive (borrowing costs)
- Risk of short-squeeze (forced to close at unfavorable prices)
- Theoretically unlimited loss potential (no upper bound on prices)
- Alternatives: futures or options can create synthetic short positions

Market Indexes

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Market Indexes

- Types of market indexes:
  - Equity indexes (DJIA, S&P500, NASDAQ)
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  - Different handling in price-based vs. market-value indexes

Example of Price-based vs. Market-value-weighted Indexes

Scenario:

- Stock A: initial price \$25, increases 20% to \$30
  - 20 million shares outstanding (\$500M market cap)
- Stock B: initial price \$100, drops 10% to \$90
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$$\text{Initial value} = \frac{25+100}{2} = 62.5$$
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Market-value-weighted index (e.g., S&P500):

$$\text{Initial value} = \frac{25\times 20M+100\times 1M}{10^6} = 600$$
$$\text{Final value} = \frac{30\times 20M+90\times 1M}{10^6} = 690$$
$$\text{Change} = +15\%$$

Example of Index Adjustments

Initial scenario:

- Company A: 50 shares outstanding, price \$2
- Company B: 10 shares outstanding, price \$10
- Price-based index value: 6
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$$\text{Current divisor } D = 2 \text{ (since } \frac{2+10}{2} = 6)$$
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Market-value-weighted index:

$$\text{Current divisor } D = 2 \text{ (since } \frac{2\times 50 + 10\times 10}{D} = 100)$$

$$\text{No adjustment needed for stock split}$$

$$\text{New value} = \frac{50\times 4 + 20\times 5}{2} = 150$$

Example 1.3: The Balance Sheet and Financial Ratios

Assets	
Current assets	
Cash	\$80M
Accounts receivable	\$120M
Fixed assets	
Equipment	\$2,500M
Total assets	\$2,700M

Liabilities	
Current liabilities	
Accounts payable	\$300M
Long-term debt	\$1,800M
Total liabilities	\$2,100M
Total equity	\$600M

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Fixed assets				
Equipment	\$2,500M		**Total liabilities**	\$2,100M
Total assets	\$2,700M		**Total equity**	\$600M

- Book value per share (10M shares): $\frac{\$600M}{10M} = \$60$
- Book-to-market ratio (market price \$40): $\frac{\$60}{\$40} = 1.5$
- Total debt ratio: $\frac{\$2{,}100M}{\$2{,}700M} \approx 0.78$

Example 1.3: The Balance Sheet and Financial Ratios (cont.)

Assuming net income = \$200M:

- Return on assets (ROA): $\frac{\$200M}{\$2{,}700M} \approx 7.4\%$
- Return on equity (ROE): $\frac{\$200M}{\$600M} \approx 33\%$
- Earnings per share (EPS): $\frac{\$200M}{10M} = \$20$
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Stock classifications:

- **Value stocks**: Undervalued, low PE and price-to-book ratios
- **Growth stocks**: Look overvalued but promise growth, higher volatility

Example 1.4: The Liquidity Trap in Thin Markets

In a deep and liquid market, a trade has little impact on prices, but:

- Markets can become thin during stress periods
- Hedge funds often purchase illiquid assets for additional return
- During market stress, flight to quality occurs (selling risky assets)

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The vicious feedback cycle:

1. Asset values drop, eroding equity of leveraged hedge funds
2. Margin requirements force funds to liquidate assets to raise cash
3. Selling illiquid assets further reduces market prices
4. Lower prices lead to further equity erosion and more margin calls
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Historical examples:

- LTCM collapse in 1998 (triggered by Russian default)
- Subprime mortgage crisis: Illiquid MBS couldn't be liquidated, forcing investors to sell liquid securities (stocks)

Example 1.5: Are You On-The-Run?

- Treasury bonds are issued at regular intervals to finance government debt
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Trading opportunities:

- Traders may try to profit from this price differential
- Strategy: Buy cheaper off-the-run bonds and short-sell more expensive on-the-run bonds
- Requires careful risk management of yield curve shifts

Example 1.7: A Long Hedge

Scenario:

- In six months we will need 500 ounces of gold
- Current forward price for delivery in 0.5 years: $F(0, 0.5) = 1250$ \$/ounce

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- With physical delivery: -1250 \$/ounce $\times$ 500 ounces $= -\$625,000$
- With cash settlement (if spot price is 1150 \$/ounce):

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The hedger buys at a cheaper spot price, but the savings are offset by a loss on the forward position

Example 1.9: Mechanics of Futures Markets

Initial conditions:

- Day 1: Gold futures price is \$1350 per ounce
- Enter long position for two contracts (100 ounces each)
- Initial margin: \$8000 per contract (total \$16,000)
- Maintenance margin: \$5000 per contract

Day	Settlement price	Daily gain	Cumulative gain	Account balance
1	\$1346	−\$800	−\$800	\$15,200
2	\$1330	−\$3,200	−\$4,000	\$12,000
3	\$1334	\$800	−\$3,200	\$12,800
4	\$1315	−\$3,800	−\$7,000	\$9,000
5	\$1304	−\$2,200	−\$9,200	\$7,800

Example 1.9: Mechanics of Futures Markets (cont.)

Day	Settlement price	Daily gain	Cumulative gain	Account balance
4	\$1315	−\$3, 800	−\$7, 000	\$9,000
5	\$1304	−\$2, 200	−\$9, 200	\$7,800
6	\$1320	\$3,200	−\$6, 000	\$13,200
7	\$1330	\$2,000	−\$4, 000	\$15,200
8	\$1328	−\$400	−\$4, 400	\$14,800
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Key observations:

- Day 4: Margin call for \$1,000 (account below maintenance margin)
- Day 5: Another margin call for \$2,200
- Day 6-7: Prices recover, improving account balance
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Daily marking-to-market ensures losses are recognized immediately, reducing counterparty risk

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Tradeoffs:

- Protection is not free - put option costs money
- Higher strike price = more protection = more expensive option
- Unlike hedging with forwards/futures (zero initial cost), options preserve upside potential
- We give up some profit potential to pay for downside protection

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Strategy 2: Buy a call option (strike price $K = \$100$, premium \$5)

- If price rises to \$120, return $= \frac{\max\{120-100,0\}-5}{5} = \frac{15}{5} = 300\%$
- If price falls 1% to \$99, return $= \frac{\max\{99-100,0\}-5}{5} = \frac{-5}{5} = -100\%$

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Key tradeoff:

- Options provide leverage - multiplying both gains and losses
- Limited downside risk (can only lose premium paid)
- But lose entire investment if option expires out of the money

Example 1.12: A Structured Bond

Real-life example of a structured bond:

- Bond maturity: four years
- Face value payment guaranteed at maturity
- Single coupon, paid at maturity (no periodic coupons)
- Coupon linked to monthly average value of basket of 10 telecom stocks
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Underlying structure:

- Zero-coupon bond to ensure principal protection
- Complex option on basket of stocks:

$$\max\left(0, \tfrac{1}{48}\sum_{i=1}^{48}\sum_{j=1}^{10} S_j(t_i) - K\right)$$

where K is initial basket value