The time value of money

Interest rate calculations

Alternative readings

- Links off class web page
  - *Time value of money* and *internal rate of return* (Wikipedia)
  - *Using a financial calculator* (Prof. Pamela Peterson Drake, James Madison University)
  - *Using your calculator for financial decisions* (Dr. Michael Kinsman, Pepperdine University)

- Problems and exercises
  - These notes (solutions will be posted to the course web site).
Basic Definitions

- **Present Value** \((PV)\) – Cash or a hypothetical value that exists “today”
  - Principal – the amount used to compute the interest earned or paid
- **Future Value** \((FV)\) – Cash/hypothetical value that will exist later.
- **Interest rate** \((r, i, y)\) – “exchange rate” between value today and value tomorrow.
  - If the annual interest rate is 10%, then $1 today is equivalent to $1.10 in one year

The time line

- “0” is “today”
- “1” is one year later
  - end of the first year or beginning of second year
- Basic problems involve:
  - an initial deposit: \(PV\)
  - a future withdrawal: \(FV\)
  - an interest rate: \(i, r, y,\)
  - maturity: \(n\) or \(N\)
A simple problem done two ways

- \( PV = \$100 \) on deposit for \( n = 2 \) years at \( r = 10\% \) compounded annually. What is the balance (\( FV \)) in the account?

- \( FV = 100(1 + 0.10)(1 + 0.10) = 121 \), or
- \( FV = 100(1.10)^2 = 121 \) (use the \([y^x]\) key)

- General formula: \( FV = PV(1 + r)^n \)
  - If \( r \uparrow \), then \( FV \uparrow \)
  - If \( n \uparrow \), then \( FV \uparrow \)

Using the HP 10bII+

- The shift key is the orange \([\downarrow]\)
- Set P/YR (“compounding periods per year”) to 1: \([1][\downarrow][P/YR]\)
- Clear: \([\downarrow][C\;ALL]\)
- To enter the number of periods: \([2][N]\) To avoid writing brackets, I’ll indicate this as \( 2 \rightarrow N \)
- \( 100 \rightarrow PV \)
- \( 10 \rightarrow I/YR \)
- To compute FV, just hit \([FV]\). The display shows: \(-121.00\)
- To change the number of displayed digits after the decimal point to six: \([\downarrow][DISP][6]\)
Using the TI baII+

- The “shift” key is the yellow [2nd]
- Set P/YR (“periods per year”) to 1:
  - [2nd] [P/Y] [1] [Enter] [2nd] [QUIT]
- Clear: [2nd] [CLR] [TVM]
- To enter the number of periods: [2] [N]
  - To avoid writing brackets, I’ll indicate this as 2 → N
- 100 → PV
- 10 → I/Y
- To compute the FV, use [CPT] FV displays − 121.00
- To change the number of displayed digits after the decimal point to six
  - [2nd] [FORMAT] [6] [ENTER] [2nd] [QUIT]

Using the HP 12C

- The HP 12C does not have a P/YR functionality.
- Clear: [f] [CLEAR FIN]
- To enter the number of periods: [2] [n]
  - To avoid writing brackets, I’ll indicate this as 2 → n
- 100 → PV
- 10 → i
- FV displays − 121.00
- To change the numbers of digits displayed after the decimal point to six:
  - [f] [6]
- Also see the “calculator notes” on the course web page.
The sign convention

- Positive for inflows; negative for outflows
- $PV = +100$: From the bank’s viewpoint, 100 is an inflow, deposit into the account.
- $FV = -121$ is a withdrawal (outflow)
- Or, from the saver’s viewpoint, $-100 \rightarrow PV$ is a cash outflow, and $FV: +121$ is the return of the investment with interest.

Fractional periods

- In $FV = PV(1 + r)^n$, $n$ does not have to be a whole number.
- $100 on deposit for six months (one-half year) at 10% per year compounded annually.
  - *Just because we’re investing for “six months” this does not imply that the quoted rate is compounded semiannually or monthly.*
  - $FV = 100 \times (1.10)^{0.5} = 104.88$
- You can get this using the $y^x$ function on your calculator.
- Try it using your calculators TVM functions: $100 \rightarrow PV, 10 \rightarrow i, 0.5 \rightarrow n, FV: ?$
- If you’re getting $FV = 105$, the calculator is assuming that interest accrual over fractional periods is “simple interest” (“straight line”). *This is standard for most consumer loans.*
Embedded problems (solutions on web as TVMSolutions.pdf)

- $5,000 is placed on deposit for 6 years at 7% (annually compounded) interest. How much will you have at the end?
- $5,000 is placed on deposit for 6 years. I need $10,000 at the end. What (annually compounded) rate of return do I need?
- The average annual return on common stocks was 8.4% over the period from 1802-1997 (assume year-end to year-end). At this rate, what would $1 invested at the end of 1802 grown to by the end of 1997?

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A zero-coupon bond ...

- ... a US government security that pays $100 when it matures.
- Bid and ask quotes for the 02/15/2040 zero, as of 2/6/2015 (source: fidelity.com)

<table>
<thead>
<tr>
<th>Row #</th>
<th>Description</th>
<th>Coupon</th>
<th>Maturity Date</th>
<th>Ratings (Moody's/S&amp;P)</th>
<th>Bid Yield</th>
<th>Bid Price Qty (min)</th>
<th>Ask Price Qty (min)</th>
<th>Ask Yield to Worst</th>
<th>Ask Yield to Maturity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>US TREAS SEC STRIPPED INT PMT 0.000000% 02/15/2040 INT PMT</td>
<td>0.000</td>
<td>2/15/2040</td>
<td>--/--</td>
<td>2.664</td>
<td>51.560</td>
<td>999.999(1)</td>
<td>52.415</td>
<td>999.999(1)</td>
</tr>
</tbody>
</table>

- If we buy it, we pay Fidelity’s asking price ($52.415).
- If we hold it until it matures, what is our rate of return?
- Draw the time line.

- Solve for the interest rate.

**Present Value**

- “What is it [a future cash flow] worth to me at some earlier time?”
  - Or, “If I know I’ll need $x$ at some future time, how much do I need to invest today?”
- Start with $FV = PV \times (1 + r)^n$
- Rearrange:
  \[ PV = FV \times \frac{1}{(1 + r)^n} \]
  - If $r \uparrow$, then $PV \downarrow$
  - If $n \uparrow$, then $PV \downarrow$
Example

I’m investing $x$ today at 10%. At the end of 5 years, I need $4,000. What is $x$?

- $FV = 4,000 \times \frac{1}{1.10^5} = \$2,483.69$
- $10 \rightarrow i, 4000 \rightarrow FV, 5 \rightarrow n, PV: -2,483.69$

Embedded problem: A bank account has a balance of $20,000. It was set up with a one-time initial deposit ten years ago, and it’s been earning interest at 8% (annually compounded). What was the size of the initial deposit?

Loans and investments

- 0 1 2 3 4 5
  -1,000 2,000
- A 1,000 investment matures in 5 years, paying 2,000. What is my (annually) compounded rate of return?
- I borrow 1,000, agreeing to pay 2,000 in 5 years. What is the rate on the loan?
- The bank loans me 1,000, they receive 2,000 in 5 years, what is the rate of return on their investment?
- Basic idea of loans: $PV(payments) = amount\ borrowed$
A lottery buyout problem

- I’ve just won a lottery: $100,000 payable in 6 years.
- Stonebridge Inc. has offered to exchange my lottery ticket for $60,000 today.
- I can borrow at 10%, but invest at 7%.
- Should I take the Stonebridge offer?

\[
\begin{align*}
\text{PV} & = \frac{100,000}{1.10^6} = 56,447 \\
\text{Value of ticket to me today} & \begin{cases} \text{Accept} & \text{PV} < 60,000 \text{ take} \\
\text{Reject} & \text{PV} > 60,000 \text{ No!} \end{cases}
\end{align*}
\]
With multiple inflows/outflows, PV and FV are additive

- The total FV = Sum of the individual FVs
- Example: deposits to a 10% account:
  0  1  2  3  4
  +1,500  +2,000  ?
- What is the balance at the end of year 4?
- \( FV = 1,500(1.10)^3 + 2,000(1.10)^1 \)
  = 1,997 + 2,200 = 4,197
- And likewise for PVs.

... but interest rate calculations are complicated.

- Suppose the balance at the end of year 4 is 4,500. What is the rate of return?
- \( 1,500(1 + r)^3 + 2,000(1 + r)^1 = 4,500 \)
- To find \( r \), we need to make repeated guesses to find the number that makes the equation true.
Annuities

- Annuity – series of equal payments at regular intervals.
- For an ordinary annuity each payment occurs at the end of the period
  ▪ This is the default mode for most calculators.
- An annuity problem has five variables: $PV, FV, i, n, \text{pmt}$

Annuities and loans

- Most repayment schedules involve regular fixed payments.
- A car buyer borrows $20,000 for five years at 8%. It will be repaid in five equal annual payments.
- What is the size of the payment?
- Recall that for loans: PV of payments = amount borrowed.
- The time line is:

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>-20,000</td>
<td>$\text{pmt}$</td>
<td>$\text{pmt}$</td>
<td>$\text{pmt}$</td>
<td>$\text{pmt}$</td>
<td>$\text{pmt}$</td>
</tr>
</tbody>
</table>
$8,000 will be paid off in five equal annual payments of $2,100. What is the interest rate on the loan?

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>+8</td>
<td>-2.1</td>
<td>-2.1</td>
<td>-2.1</td>
<td>-2.1</td>
<td>-2.1</td>
</tr>
</tbody>
</table>

Embedded problem: $20,000 is borrowed at 7.5% (compounded annually). It will be paid back in 8 equal annual payments. What is the size of the payment?

Annuities: a future value example

We make four end-of-year $600 deposits to a 7% account.
Immediately after the last deposit, what is the account balance?
<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>600</td>
<td>600</td>
<td>600</td>
<td>600</td>
<td></td>
</tr>
</tbody>
</table>

If the account balance is actually 2,900, what is the rate of return on the account?
Loan amortization

- Amortization is the “payback” of the amount borrowed.
- The payments on a loan will cover the interest owed on the loan and the full amortization of the principal.
- The amounts and timing may vary depending on the type of the loan.

Example: $1,000 term loan, 5 years @10%

- $1,000 → PV 10 → i 5 → n pmt → -263.80 (“264”)

<table>
<thead>
<tr>
<th>Year</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loan balance BOY</td>
<td>1,000</td>
<td>836</td>
<td>656</td>
<td>458</td>
<td>240</td>
<td>0</td>
</tr>
<tr>
<td>Interest</td>
<td>100</td>
<td>84</td>
<td>66</td>
<td>46</td>
<td>24</td>
<td>0</td>
</tr>
<tr>
<td>Payment</td>
<td>264</td>
<td>264</td>
<td>264</td>
<td>264</td>
<td>264</td>
<td>0</td>
</tr>
<tr>
<td>Amortization</td>
<td>164</td>
<td>180</td>
<td>198</td>
<td>218</td>
<td>240</td>
<td>0</td>
</tr>
<tr>
<td>Loan balance EOY</td>
<td>1,000</td>
<td>836</td>
<td>656</td>
<td>458</td>
<td>240</td>
<td>0</td>
</tr>
</tbody>
</table>
The relative amounts

- The total of the interest payments on this loan is $319.
- The loan is for $1,000.
- The term of the loan is 5 years.
- The average interest payment per year is only $64.
- So on average, you’re paying $64 per year on a $1,000 loan.
- So the real interest rate on this loan is only 64/1,000 = 6.4%.
House mortgages

- $100,000, 30-year mortgage at 5%, with annual payments.
- What is the annual payment size?

\[
\text{PV} \begin{array}{cccccc}
\text{N} \amp \text{I/Y} \amp \text{PV} \amp \text{FV} \amp \text{PMT} \amp \text{FV}
\end{array}
\]

- What are the principal and interest components of the first payment?

\[
5\% \text{ on } 100,000 = 5,000 \text{ int} \quad 1,505 \text{ amort}
\]

- For the last (30th) payment, the principal and interest components are 6,195.37 and 309.77.
  - You can get this using the amortization functions on your calculator.
  - On an exam, you won’t need to use the amortization functions. Any required computations will be simple enough to do manually (like the first one, here).

Constant amortization loans

- Loan payments can be structured in any way that has \( PV(\text{payments}) = \text{amt borrowed} \)
- 1,000 to be amortized over 5 years (200 per year)

<table>
<thead>
<tr>
<th>Year</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loan balance BOY</td>
<td>1,000</td>
<td>800</td>
<td>600</td>
<td>400</td>
<td>200</td>
<td>0</td>
</tr>
<tr>
<td>Interest</td>
<td>100</td>
<td>80</td>
<td>60</td>
<td>40</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Payment</td>
<td>300</td>
<td>280</td>
<td>260</td>
<td>240</td>
<td>220</td>
<td></td>
</tr>
<tr>
<td>Amortization</td>
<td>200</td>
<td>200</td>
<td>200</td>
<td>200</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>Loan balance EOY</td>
<td>1,000</td>
<td>800</td>
<td>600</td>
<td>400</td>
<td>200</td>
<td>0</td>
</tr>
</tbody>
</table>
Perpetuities

- A perpetuity is an annuity with an infinite horizon.
- \( PV = \frac{pmt}{r} \)
- Example: a perpetuity of $100/year with a discount rate of 5% is worth $100 / 0.05 = $2,000 today.

Preferred stock (MarketWatch.com)

<table>
<thead>
<tr>
<th>Bank Of America Corporation. BAC .PRD (NYSE)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>$25.25</strong> Change: <strong>+0.03</strong> +0.12% Volume: 4,700</td>
</tr>
<tr>
<td>Open: $25.33 Shares 33.00M P/E: N/A</td>
</tr>
<tr>
<td>High: $25.33 Market Cap: $833.25M</td>
</tr>
<tr>
<td>Low: 52-Wk High: $25.22 $27.11 Dividend: 0.39</td>
</tr>
<tr>
<td>Bid: N/A 52-Wk Low: $24.77 Yield: 6.14</td>
</tr>
<tr>
<td>Ask: N/A Avg: 43,800 Ex Date: 8/29/07</td>
</tr>
</tbody>
</table>

quarterly
And the back-of-the-envelope analysis ...

- The annual dividend is 4 x 0.39 = $1.56
- If the “market” is valuing the share as the $PV$ of an annual perpetuity, what interest rate is it using?

$$25 \cdot 25 = \frac{1.56}{r} \quad r \approx 6.2\%$$

Within-period compounding.

- Compounding: how often does accrued interest get credited to the principal?
- With interest compounded annually, the FV of 100 at 12% for one year is 112.
  - Semiannual compounding: $FV = 100(1.06)(1.06) = 100(1.06)^2 = 112.36$
  - Quarterly compounding, $FV=100(1.03)^4 = 112.55$
  - Monthly compounding, $FV=100(1.01)^{12} = 112.68$
- “With compounding $m$ periods per year, divide the annual rate by $m$, multiply the number of years by $m$”
Recompute the rate of return for the 02/15/2040 zero with semiannual compounding

\[ m = 2 \]

<table>
<thead>
<tr>
<th>Year 25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pay $52.415</td>
</tr>
</tbody>
</table>

\[
\frac{-52.415}{P/2R} \times 2 = 50 \quad \text{N} \\
\frac{25}{I/Y} \rightarrow 2.60070 \\
\frac{100}{FV} \\
\frac{25 \times 2 = 50}{N} \quad \frac{100}{FV} \\
\rightarrow 2.60070 \\
\]

\[ r = 2.618\% \]

House mortgage with monthly payments

- $100,000 for 30 years at 5% compounded monthly. What’s the monthly payment?
- HP-10bII+
  - \([\bar{\varpi}][\text{C ALL}], 12[\bar{\varpi}][\text{P/YR}], 100,000 \rightarrow \text{PV}, 5\% \rightarrow \text{I/YR}, 360 \rightarrow \text{N}, \text{PMT} \rightarrow 536.82\]
- HP-12C
  - \([f][\text{CLEAR FIN}], 360 \rightarrow \text{n}, 5\%/12 \rightarrow 0.41667\% \rightarrow \text{i}, 100,000 \rightarrow \text{PV}, \text{PMT} \rightarrow 536.82\]
- BAII+
  - \([2\text{nd}][\text{CLEAR TVM}], [2\text{nd}][\text{P/Y}] [12] [\text{Enter}] [2\text{nd}][\text{QUIT}] 100,000 \rightarrow \text{PV}, 5\% \rightarrow \text{I/Y}, 360 \rightarrow \text{N}, \text{PMT} \rightarrow 536.82\]
The Effective Annual Rate (EAR)

- EAR is an annual rate compounded annually.
- “An annual percentage rate (APR) of 12% compounded monthly has an effective annual rate (EAR) of 12.68%.”
- I am indifferent between investing at 12% compounded monthly or 12.68% compounded annually.
- If you want to compare two alternative investments with different compounding periods you need to compute the EAR and use that for comparison.

Annual Percentage Rate (APR)

- This is the annual rate that is quoted by law.
- By definition APR = period rate times the number of periods per year
- Period rate = APR / number of periods per year

Never $\times \text{EAR} \times m$ or $\text{EAR}/m \times$
APR and EAR on the HP-10bII+

- P/YR is the number of compounding periods per year
- I/YR is the APR
- N is the number of periods (not years)
- NOM% ("nominal") is the APR
- EFF% ("effective") is the EAR
- What is the EAR of 12% APR compounded 12x per year?
  - [2nd][C ALL], 12 [↵][P/YR],
  - 12 [↵][NOM%]
  - [↵][EFF%] displays 12.68

APR and EAR on the BAII+

- APR and EAR are on the interest conversion menu.
- [2nd][ICONV] pulls up the menu; [↓] cycles over:
  - NOM: ("nominal"), the APR
  - EFF: ("effective"), the EAR
  - C/Y: number of compounding periods per year.
- What is the EAR of 12% APR compounded 12x per year?
  - [2nd][ICONV], [2nd][CLR WORK],
  - Enter NOM using: 12 [ENTER]
  - [↓] [↓], to get to C/Y, then 12 [ENTER]
  - [↓] [↓], to get to EFF, then [CPT] should display 12.68%
EAR and APR on the HP-12c

- The 12c does not have a periods per year functionality.
- The workaround is to use the period rate.
- What is the EAR of 12% APR compounded 12x per year?
  - 12% per year / 12 = 1% per month
  - 1 → i, 12 → n, $1 → PV, FV displays = 1.1268
  - "$1 on deposit for 12 months at 1% per month grows to $1.1268. This is effectively 12.68% compounded annually."

What’s a better investment? 7.99% compounded semiannually or 7.96% compounded monthly?

- 2 → P/YR 7.99 → NOM% EFF% 8.150%
- 12 → P/YR 7.96 → NOM% EFF% 8.257%
- Embedded problem
  - What’s a better investment: 6.60% compounded quarterly or 6.50% compounded monthly?
Remember: the HP12c doesn’t have a P/YR functionality. You have to explicitly work with the period interest rate.

In the last problem:
- $7.96\% / 12 = .6633\%$
- The FV of $1$ on deposit for 12 months at $0.6633\%$ per month is...
  \[ 1 \rightarrow PV, \hspace{1em} 12 \rightarrow n, \hspace{1em} 0.6633 \rightarrow i, \hspace{1em} FV \rightarrow -1.08257 \]
- This is the same FV as we’d get on an annually compounded rate of $8.257\%$

Borrowing and investing with differential rates.

A bank will pay $8\%$ interest on deposits.

Suppose I can borrow up to $10,000$ for five years at $6\%$, repaid with a single payment.
- Some compensation packages (or government programs) offer subsidized below-market rates.

Borrow at $6\%$, invest at $8\%$: how much will I have at the end?

Can I simply compute the FV of $10,000$ at $2\% (= 8\% - 6\%)$ for five years?
Alternative loan repayment schedules

- Borrow $1,000 for 5 years @10%
- Base case: five equal annual payments
  - $1,000 → PV 10 → i 5 → n pmt → -263.80 (“264”)
- Special case: prepayment
- Special case: partial payment

Partial amortization schedule with a prepayment of $50 in the first year

<table>
<thead>
<tr>
<th>Year</th>
<th>0</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loan balance BOY</td>
<td>1,000</td>
<td>786</td>
<td></td>
</tr>
<tr>
<td>Interest</td>
<td>100</td>
<td>79</td>
<td></td>
</tr>
<tr>
<td>Contractual pmt</td>
<td>264</td>
<td>248</td>
<td></td>
</tr>
<tr>
<td>Contractual amort</td>
<td>164</td>
<td>169</td>
<td></td>
</tr>
<tr>
<td>Actual pmt</td>
<td>314</td>
<td>248</td>
<td></td>
</tr>
<tr>
<td>Prepayment</td>
<td>50</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Loan balance EOY</td>
<td>1,000</td>
<td>786</td>
<td>617</td>
</tr>
<tr>
<td>Contractual pmt:</td>
<td>264</td>
<td>248</td>
<td>248</td>
</tr>
</tbody>
</table>

- The extra $50 gets applied to the amortization.
- The loan balance drops.
- The payment is recalculated going forward.
Partial amortization schedule with a partial payment (a shortfall of $50) in the first year.

<table>
<thead>
<tr>
<th>Year</th>
<th>0</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loan balance BOY</td>
<td>1,000</td>
<td>886</td>
<td></td>
</tr>
<tr>
<td>Interest</td>
<td>100</td>
<td>89</td>
<td></td>
</tr>
<tr>
<td>Contractual pmt</td>
<td>264</td>
<td>280</td>
<td></td>
</tr>
<tr>
<td>Contractual amort</td>
<td>164</td>
<td>191</td>
<td></td>
</tr>
<tr>
<td>Actual pmt</td>
<td>214</td>
<td>280</td>
<td></td>
</tr>
<tr>
<td>Prepayment</td>
<td>-50</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Loan balance EOY</td>
<td>1,000</td>
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<tr>
<td>Contractual pmt:</td>
<td>264</td>
<td>280</td>
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- The shortfall means that the amortization is too low.
- The payment is recalculated going forward.
- It increases to 280.
Note: The first payment might be so small that it doesn't even cover the interest on the loan. The shortfall is added to the balance of the loan: negative amortization.

### Points

- **Bank A**: $100,000 house mortgage at 6%, with 30 equal annual payments.
  - payment = $7,264.90.
- **Bank B** offers the same payment schedule, but charges 2% points (an upfront fee).
- What is the **APR** (assuming that the calculation calls for the initial loan amount to be reduced by the points)?
  - $98,000 is proceeds of the loan.
If payment doesn’t cover the interest ... negative amortization

- Sometimes negative amortization is built into the mortgage by design.
- It allows for a lower initial payment.
- Next slide: the evolution of the loan when the first two payments are 60

### ... the loan balance grows

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