15.482 Healthcare Finance
Spring 2017

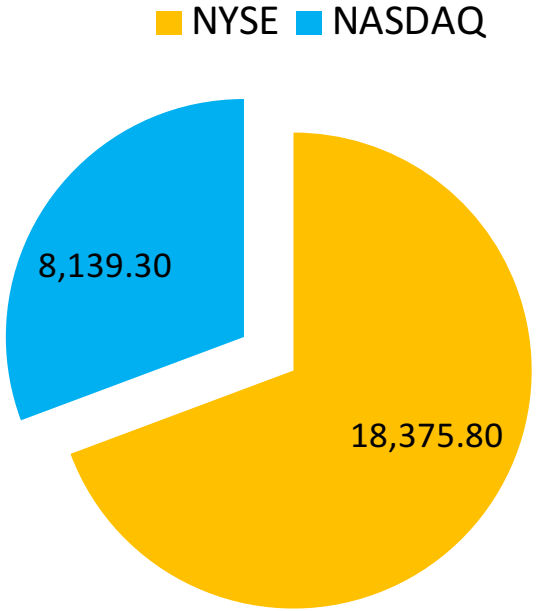
Andrew W. Lo, MIT

Unit 3: Stocks and Bonds

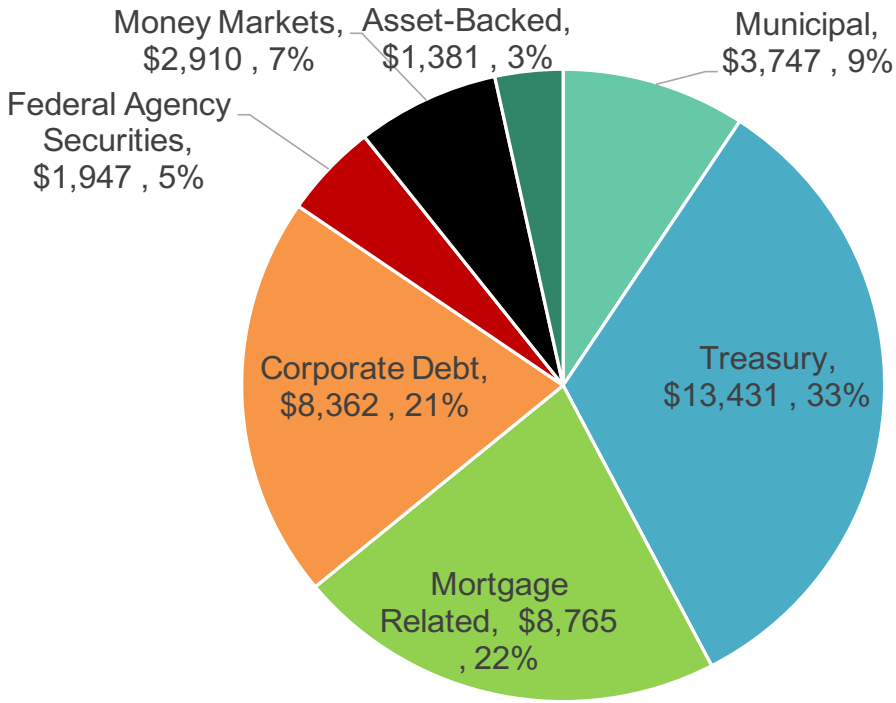
Pricing Stocks and Bonds

Stock and Bond Markets

U.S. Stock Market Capitalization, 2016
($ billions)



U.S. Bond Market Outstanding 2016Q1
($ billions)



Stock and Bond Markets

U.S. Equity Issuance ($ billions)

Year	Common Stock	Preferred Stock	Total Equity Issued	All IPOs	"True" IPOs	Secondaries
2000	167.7	12.5	180.2	61.5	60.3	106.2
2001	127.9	26.4	154.4	43.2	36.3	84.7
2002	117.1	16.9	134.0	42.0	25.7	75.1
2003	120.2	28.7	148.9	45.3	16.2	74.9
2004	170.1	27.8	197.9	73.3	48.0	96.8
2005	159.0	25.1	184.0	61.3	38.6	97.6
2006	159.2	38.5	197.6	59.5	45.4	99.7
2007	191.2	53.1	244.3	93.7	53.9	97.5
2008	165.6	51.2	216.8	11.1	7.5	154.4
2009	251.2	5.5	256.7	25.9	23.6	225.4
2010	239.6	12.7	252.3	52.1	43.1	187.5
2011	185.7	10.7	196.4	47.8	40.4	137.8
2012	246.1	35.6	281.8	55.5	42.7	190.6
2013	272.9	27.9	300.8	75.5	58.9	197.4
2014	274.5	36.9	311.4	100.8	94.3	173.7
2015	224.1	32.7	256.8	38.9	32.5	185.2
2016	174.2	22.8	197.0	20.8	17.8	153.4

U.S. Bond Market Issuance ($ billions)

Municipal	Treasury	Mortgage-Related	Corporate Debt	Federal Agency Securities*	Asset-Backed	Total
198.3	312.4	778.8	574.1	446.6	246.8	2,557.0
286.2	380.7	1,818.1	771.9	941.0	266.8	4,464.7
355.8	571.6	2,519.4	636.0	1,041.5	273.9	5,398.2
380.2	745.2	3,505.0	772.9	1,219.5	287.9	6,910.7
358.1	853.3	2,411.5	774.6	877.8	349.2	5,624.5
407.2	746.2	2,782.1	750.0	635.0	482.5	5,803.0
386.0	788.5	2,730.9	1,057.5	691.8	678.1	6,332.8
429.2	752.3	2,494.3	1,136.2	831.2	634.0	6,277.2
389.3	1,037.3	1,436.8	711.3	984.9	289.3	4,848.9
409.6	2,074.9	2,106.4	940.1	1,086.7	154.0	6,771.7
433.1	2,319.8	2,010.7	1,055.1	1,203.7	108.4	7,130.9
294.7	2,103.3	1,701.4	1,023.4	838.4	126.5	6,087.5
378.9	2,304.5	2,157.7	1,370.2	720.7	233.2	7,165.3
334.9	2,140.0	2,092.0	1,379.9	419.5	262.4	6,628.8
337.5	2,215.4	1,365.3	1,479.3	377.4	309.6	6,084.5
403.1	2,122.5	1,710.0	1,489.3	513.5	255.2	6,493.4
445.8	2,169.4	1,863.9	1,510.1	673.0	207.6	6,869.7

Pricing Stocks

Discounted Dividend Model

- Basic PV formula, assuming knowledge of
  - Expected future dividends
  - Future dividends' risk (discount rate)
- Notation:
  - P_t: stock price at date t (ex-dividend)
  - D_t: expected cash dividend at t
  - r_t: risk-adjusted discount rate for cash flow at t

$$P_t = \sum_{k=1}^{\infty} \frac{D_{t+k}}{(1 + r_{t+k})^k}$$

Example: Amgen Revisited*

- EPS estimate (next year): $12.84
- Payout ratio p: 37.94%
- ROE: 26.65%
- Cost of capital r: 12.55%
- EPS growth: 6.77% or 16.58%??

$$\begin{aligned} D_1 &= p \times \text{EPS}_1 \\ &= 0.3794 \times \$12.84 \\ &= \$4.87 \end{aligned}$$

$$\begin{aligned} g &= b \times \text{ROE} \\ &= (1-p) \times \text{ROE} \\ &= 0.6206 \times 0.2665 \\ &= 16.48\% \end{aligned}$$

$$P_0 = \frac{D_1}{r-g} = \frac{\$4.87}{0.1255 - 0.0677} = \$84.82$$

- Maybe cost of capital is wrong? Use inverse relation:

$$r = g + \frac{D_0}{P_0}(1+g) = 6.77\% + 2.76\% \times 1.0677 = 9.72\%$$

$$P_0 = \frac{D_1}{r-g} = \frac{\$4.87}{0.0972 - 0.0677} = \$165.26$$

*All data are as of 2/10/17 and from finance.yahoo.com unless otherwise indicated.

Multi-Stage Growth Models

Simplified Corporate Life-Cycle

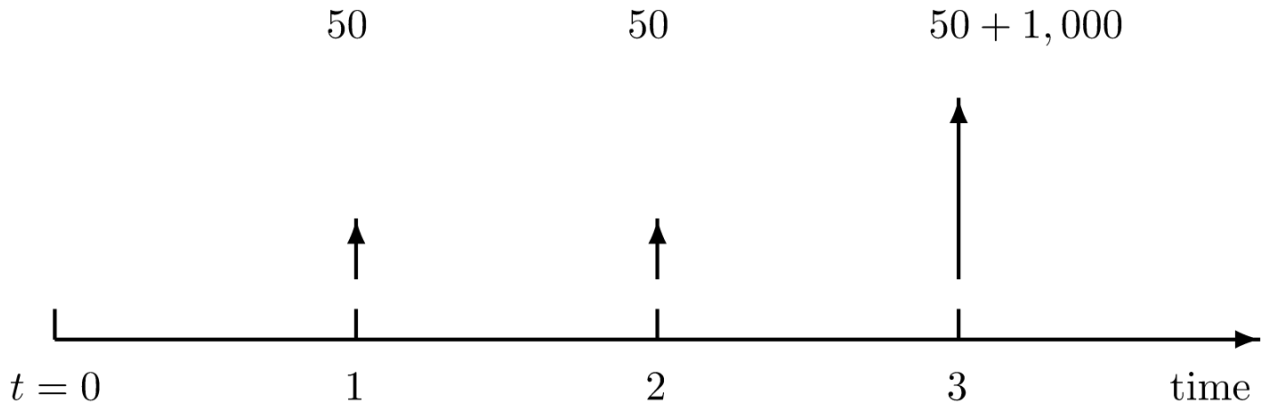
- **Growth stage**: rapidly expanding sales, high profit margins, and high growth in earnings per share, many new investment opportunities, low dividend payout ratio.
- **Transition stage**: growth rate and profit margin reduced by competition, fewer new investment opportunities, high payout ratio.
- **Maturity stage**: earnings growth, payout ratio and average return on equity stabilizes for the remaining life of the firm.

Bond Pricing

Bond Cash Flow

- Maturity
- Coupon
- Principal

Example. A 3-year bond with principal of $1,000 and annual coupon payment of 5% has the following cash flow:



Bond Pricing

Components of Valuation

- Time value of principal and coupons
- Risks: inflation, credit, timing (callability), liquidity, currency
- First consider riskless debt only
  - U.S. government debt (is it truly riskless?)
- Consider risky debt later

Discount Bonds

Pure Discount Bond

- No coupons, single payment of principal at maturity
- Bond trades at a "discount" to **face value**
- Also known as **zero-coupon bonds** or **STRIPS***
- Valuation is straightforward application of NPV

$$P_0 = \frac{F}{(1+r)^T}$$

- Note: (P_0, r, F) is "over-determined"; given two, the third is determined
- Now what if r varies over time?
  - Different interest rates from one year to the next
  - Denote by r_t the **spot rate of interest** in year t

*Separate Trading of Registered Interest and Principal Securities

Discount Bonds

Example: 2/10/2017

U.S. Treasury Strips — **Source: WSJ**

Friday, February 10, 2017

U.S. zero-coupon STRIPS allow investors to hold the interest and principal components of eligible Treasury notes and bonds as separate securities. STRIPS offer no interest payment; investors receive payment only at maturity. Quotes are as of 3 p.m. Eastern time based on transactions of $1 million or more. Yields calculated on the ask quote.

Maturity	Bid	Asked	Chg	Asked yield
Treasury Bond, Stripped Principal				
2017 May 15	99.797	99.799	0.004	0.80
2017 May 15	99.863	99.866	0.005	0.53
2017 Aug 15	99.663	99.668	0.001	0.66
2018 May 15	98.804	98.816	-0.017	0.95
2018 Nov 15	98.232	98.249	-0.014	1.01
2019 Feb 15	97.872	97.892	-0.017	1.07
2019 Aug 15	96.679	96.703	-0.024	1.34
2020 Feb 15	95.701	95.729	-0.045	1.46
2020 Feb 29	95.691	95.720	-0.040	1.44
2020 May 15	95.031	95.062	-0.048	1.56
2043 Aug 15	44.269	44.385	-0.089	3.09
2043 Nov 15	44.023	44.139	-0.086	3.08
2044 Feb 15	43.476	43.591	-0.069	3.10
2044 May 15	43.097	43.213	-0.058	3.10
2044 Aug 15	42.661	42.777	-0.053	3.11
2044 Nov 15	42.278	42.393	-0.052	3.12
2045 Feb 15	41.863	41.979	-0.040	3.12
2045 May 15	41.544	41.659	-0.048	3.12
2045 Aug 15	41.235	41.351	-0.020	3.12
2045 Nov 15	40.904	41.020	-0.008	3.12
2046 Feb 15	40.610	40.726	-0.005	3.12
2046 May 15	40.325	40.442	0.014	3.12
2046 Aug 15	40.090	40.207	-0.013	3.11
2046 Nov 15	39.923	40.040	0.005	3.10

$$\frac{1}{(1+r_{0,3})^3} = 0.95729$$

$$r_{0,3} = 1.46\%$$

Discount Bonds

If *r* Varies Over Time

- Denote by R_t the **one-year spot rate of interest** in year t

$$P_0 = \frac{F}{(1+R_1)(1+R_2)\cdots(1+R_T)}$$

- But we don't observe the entire sequence of future spot rates today!

$$P_0 = \frac{F}{(1+R_1)(1+R_2)\cdots(1+R_T)} = \frac{F}{(1+r_{0,T})^T} \quad , \quad r_{0,T} \equiv \text{Today's } T\text{-Year Spot Rate}$$

- Today's **T-year spot rate is** an "average" of one-year future spot rates
- $(P_0, F, r_{0,T})$ is over-determined

Discount Bonds

Suppose We Observe Several Discount Bond Prices Today

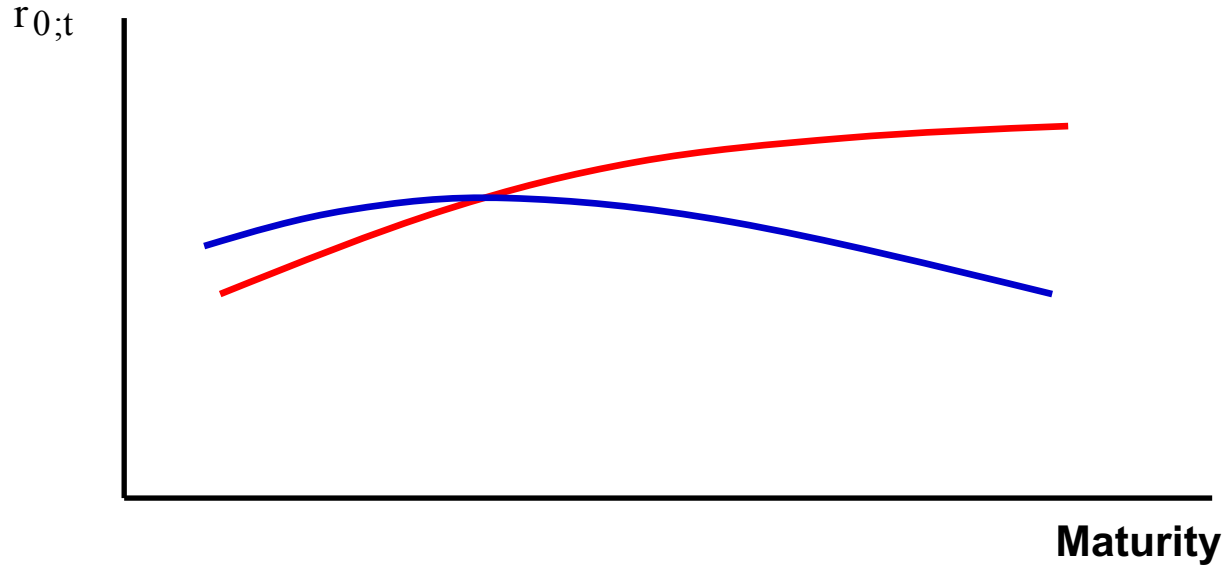
$$
\begin{aligned}
P_{0,1} &= \frac{F}{(1+R_1)} \quad \rightarrow \quad r_{0,1} \\
P_{0,2} &= \frac{F}{(1+R_1)(1+R_2)} \quad \rightarrow \quad r_{0,2} \\
P_{0,3} &= \frac{F}{(1+R_1)(1+R_2)(1+R_3)} \quad \rightarrow \quad r_{0,3} \\
&\vdots \\
P_{0,T} &= \frac{F}{(1+R_1)(1+R_2)(1+R_3)\cdots(1+R_T)} \quad \rightarrow \quad r_{0,T}
\end{aligned}
$$

$$
\{P_{0,1}, P_{0,2}, \ldots, P_{0,T}\} \quad \rightarrow \quad \{r_{0,1}, r_{0,2}, \ldots, r_{0,T}\}
$$

Term Structure of Interest Rates

Discount Bonds

Term Structures Contain Information About Future Interest Rates



- What are the implications of each of the two term structures?

Discount Bonds

Term Structures Contain Information About Future Interest Rates

$$P_{0,1} = \frac{F}{(1+R_1)}$$

$$P_{0,2} = \frac{F}{(1+R_1)(1+R_2)}$$

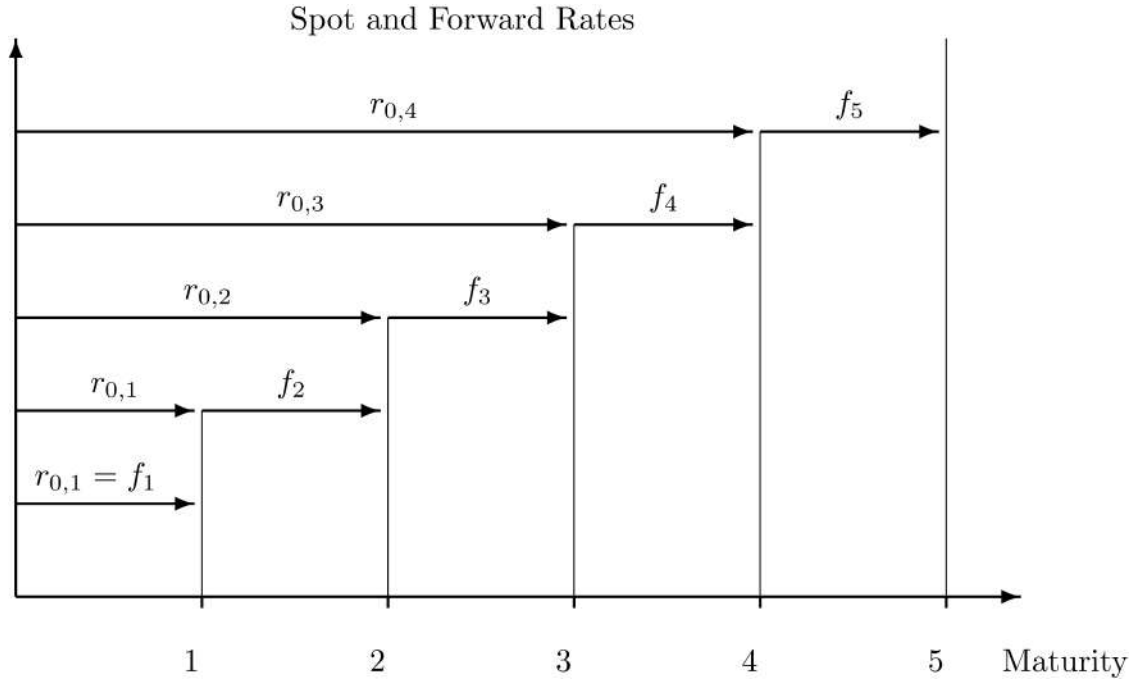
$$\frac{P_{0,1}}{P_{0,2}} = \frac{F}{(1+R_1)} \frac{(1+R_1)(1+R_2)}{F} = (1+R_2)$$

- Implicit in current bond prices are forecasts of future spot rates!
- These current forecasts are called **one-year forward rates**
- To distinguish them from spot rates, we use new notation:

$$\frac{P_{0,t-1}}{P_{0,t}} = 1 + f_t = \frac{(1+r_{o,t})^t}{(1+r_{o,t-1})^{t-1}}$$

Discount Bonds

Term Structures Contain Information About Future Interest Rates



Discount Bonds

More Generally:

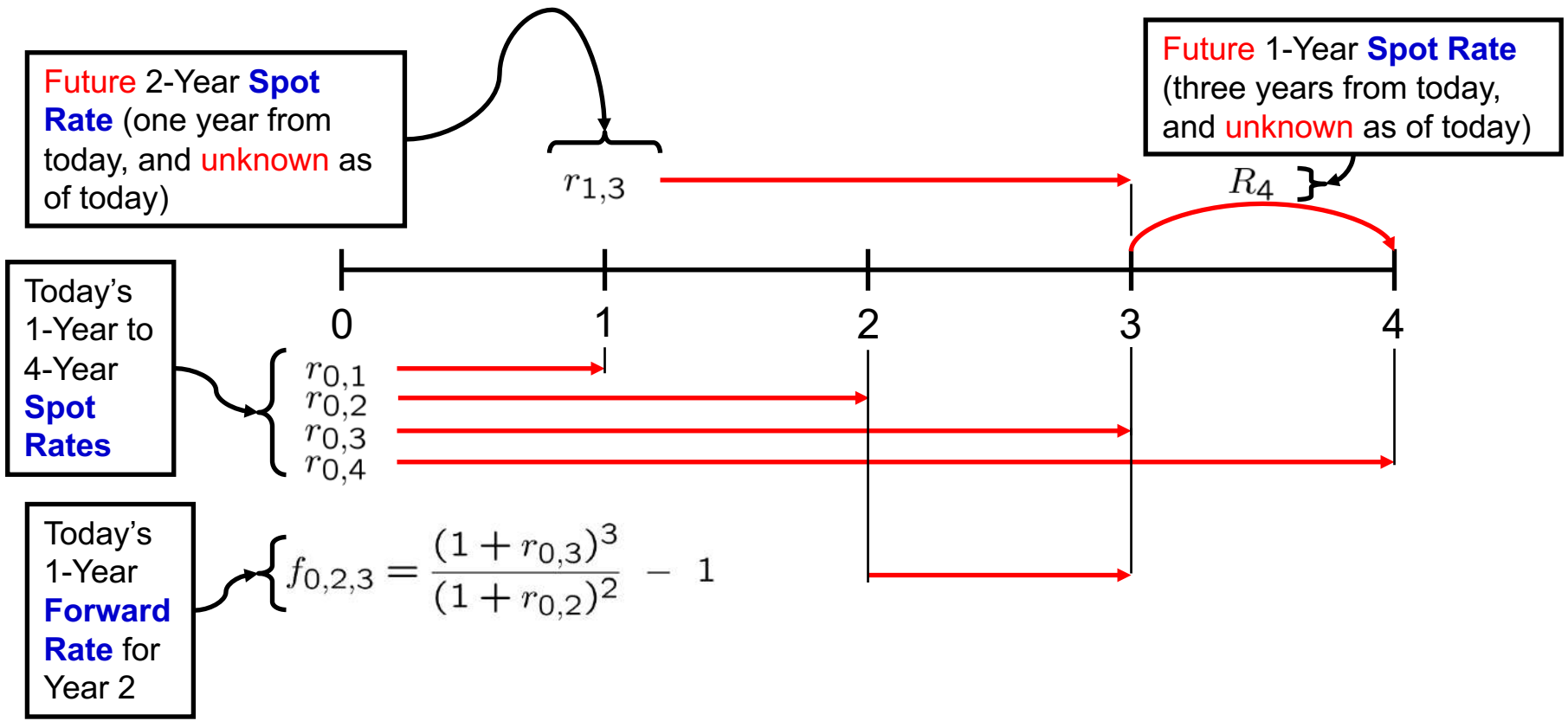
- **Forward interest rates** are today's rates for transactions between two future dates, for instance, t_1 and t_2.
- For a forward transaction to borrow money in the future:
  - Terms of transaction are agreed on today, $t = 0$
  - Loan is received on a future date t_1
  - Repayment of the loan occurs on date t_2
- Note: future spot rates can be (and usually are) different from current corresponding forward rates

Discount Bonds

Summary of Terminology:

- **Today's Spot Rate:** current interest rate for a loan "on the spot"
  - Known as of today (date 0)
  - Written as $r_{0,1}$, $r_{0,2}$,…
- **Forward Rate:** current interest rate for a future loan
  - Known as of today (date 0)
  - Written as f_2, f_3,… for one-period loans
  - Written as $f_{0,3,7}$ for a 4-year loan beginning in year 3
- **Future Spot Rate:** rate for a future loan (unknown as of today)
  - Unknown as of today (date 0)
  - Written as R_1, R_2,… for future one-period loans
  - Written as $r_{2,7}$ for a 5-year loan beginning in year 2

Discount Bonds



Discount Bonds

Example: Suppose that discount bond prices are as follows:

t	1	2	3	4
P_t	0.9524	0.8900	0.8278	0.7629
$r_{0,t}$	0.05	0.06	0.065	0.07

You need to borrow $20MM one year from now for a Phase II trial lasting three years. What rate should you expect for this forward loan?

All you need is the year-1 three-year forward rate $f_{1,4}$:

$$(1+f_{0,1,4})^3 = \frac{(1+r_{0,4})^4}{(1+r_{0,1})} = \frac{(1.07)^4}{(1.05)}$$

$$f_{0,1,4} = \left(\frac{(1.07)^4}{(1.05)}\right)^{1/3} - 1 = 7.68\%$$

Discount Bonds

Example (cont):

Strategy:

- Buy 20,000,000 of 1-year discount bonds at date 0, which costs:

$$(20{,}000{,}000)(0.9524) \quad = \quad \$19{,}047{,}619$$

- Finance this by **(short)selling*** these many 4-year discount bonds:

$$\$19{,}047{,}619/0.7629 \quad = \quad 24{,}967{,}543$$

- This creates a liability in year 4 in the amount of $24,967,543

*A **shortsale** is a particular financial transaction in which an individual can sell a security that s/he does not own by borrowing the security from another party, selling it and receiving the proceeds, and then buying back the security and returning it to the original owner at a later date, possibly with a capital gain or loss.

Discount Bonds

Example (cont):

- Cash flows from this strategy (in millions of dollars):

Position	Year 0	Year 1	Year 2	Year 3	Year 4
Long 1-Year Bond	−19.048	20.000	0	0	0
Short 4-Year Bond	19.048	0	0	0	−24.968
Total	0	20.000	0	0	−24.968

- The yield for this strategy or "synthetic bond return" is given by:

$$\left(\frac{24{,}976{,}543}{20{,}000{,}000}\right)^{1/3} - 1 = 7.68\%$$

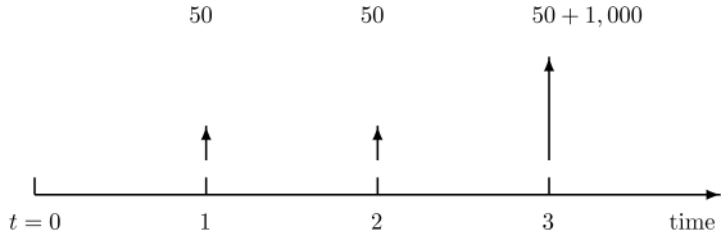
Coupon Bonds

Cash Flows

- Intermediate payments in addition to final principal payment
- Coupon bonds can trade at discounts or premiums to face value
- Valuation is straightforward application of NPV

Example:

- 3-year bond of $1,000 par value with 5% coupon



Coupon Bonds

Valuation of Coupon Bonds

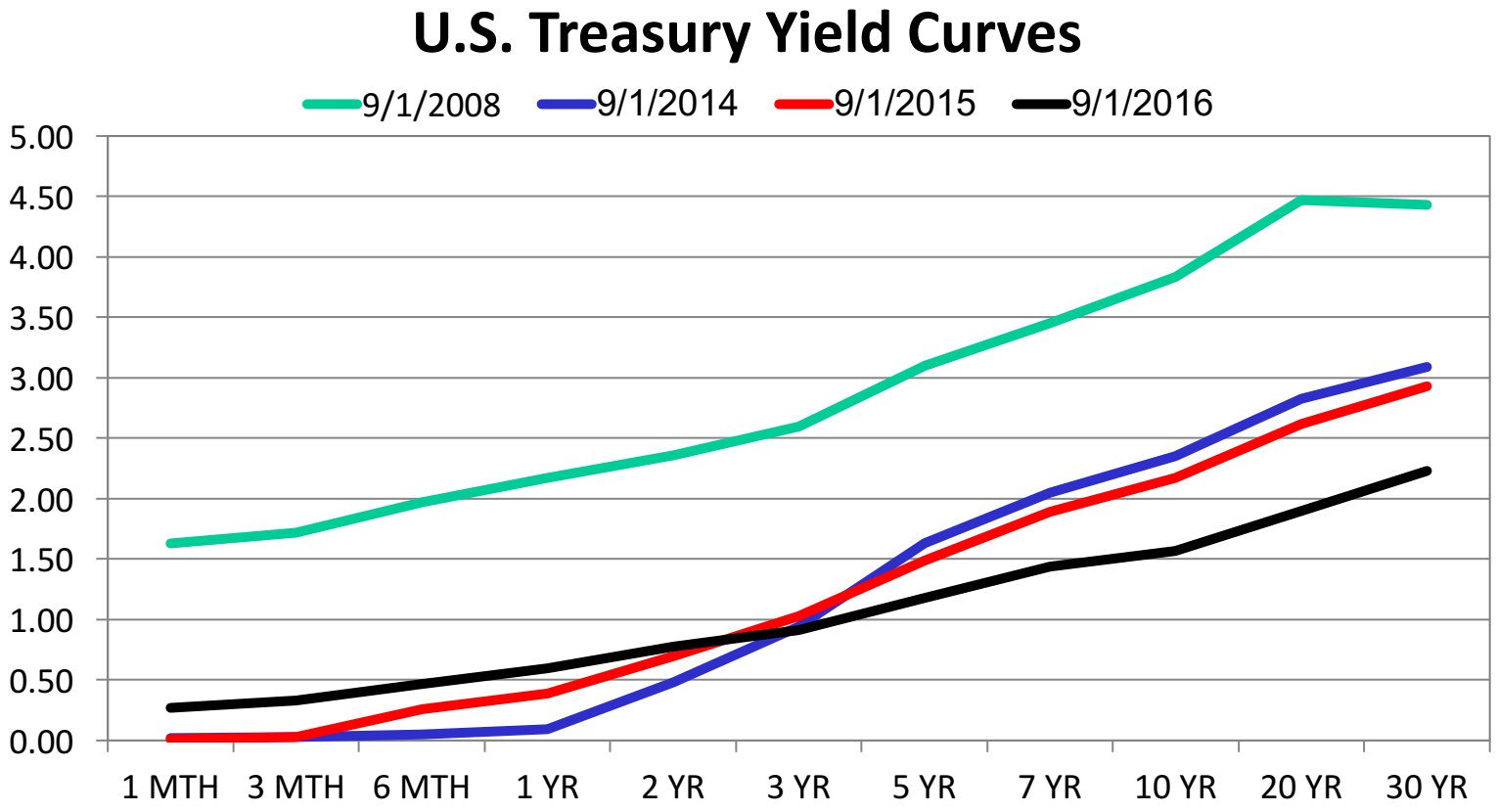
$$P_0 = \frac{C}{(1+R_1)} + \frac{C}{(1+R_1)(1+R_2)} + \cdots + \frac{C+F}{(1+R_1)\cdots(1+R_T)}$$

- Since future spot rates are unobservable, summarize them with *y*

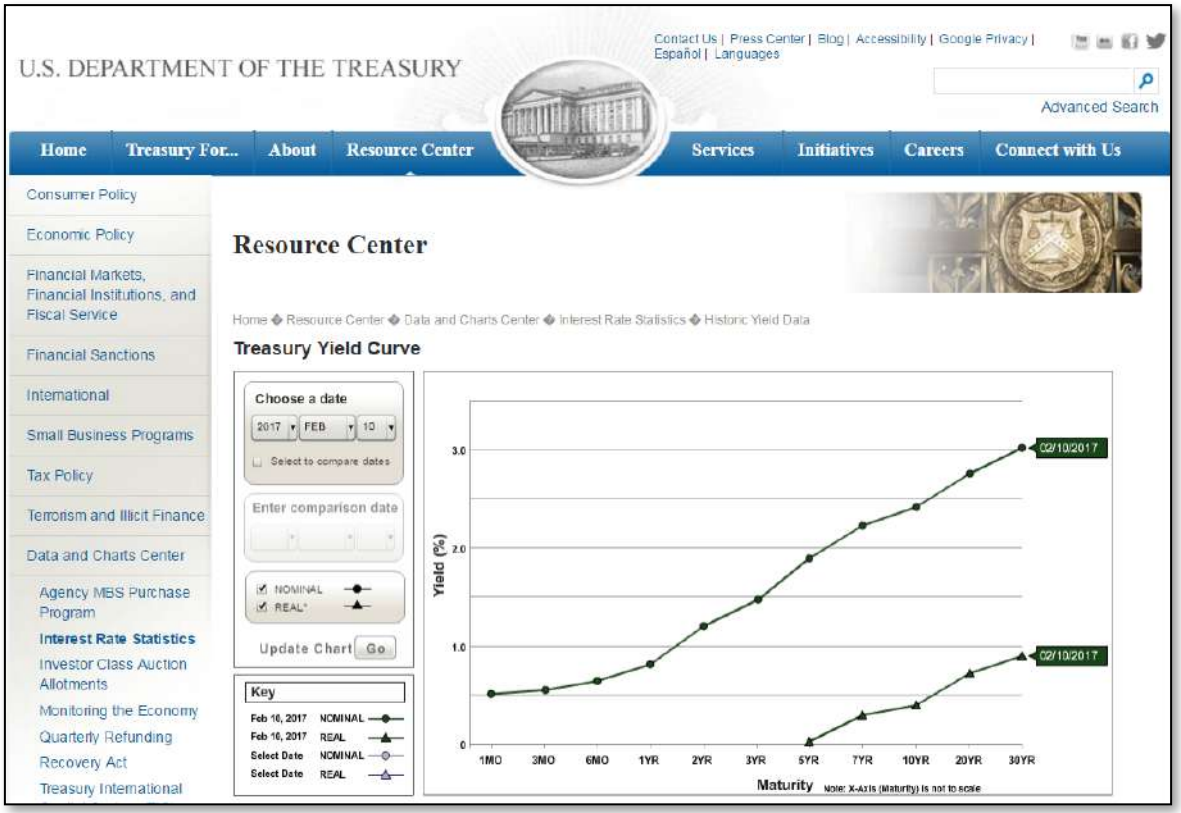
$$P_0 = \frac{C}{(1+y)} + \frac{C}{(1+y)^2} + \cdots + \frac{C+F}{(1+y)^T}$$

- *y* is called the **yield-to-maturity** (**YTM**) of a bond; a complex average of all future spot rates
- There is usually no closed-form solution for *y*; numerical methods must be used to compute it (T^{th}-degree polynomial), and (P_0, *y*, *C*) is over-determined (any two determines the third)
- For pure discount bonds, the YTM's are the current spot rates, and a graph of coupon-bond *y* against maturities is called the **yield curve**

Coupon Bonds



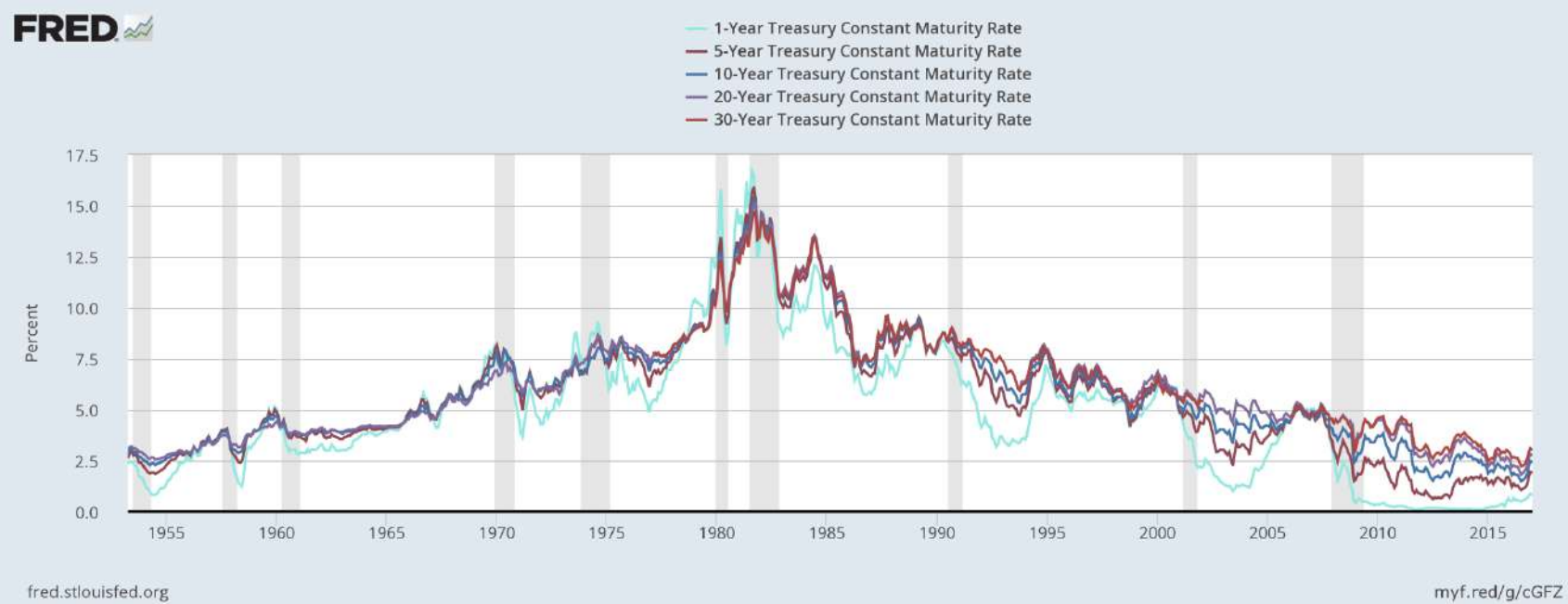
Coupon Bonds



Coupon Bonds

Constant Maturity U.S. Treasury Yields

April 1953 to January 2017



Corporate Bonds

PR Newswire
a CISION company

February 3, 2017

Axovant Sciences Announces $55.0 Million Venture Debt Financing from Hercules Capital

NEWS PROVIDED BY
Axovant Sciences →
Feb 03, 2017, 07:00 ET

BASEL, Switzerland, Feb. 3, 2017 /PRNewswire/ -- Axovant Sciences (NYSE: AXON), a leading clinical-stage biopharmaceutical company focused on the treatment of dementia, today announced that it has entered into a $55.0 million debt financing agreement with Hercules Capital, Inc. (NYSE: **HTGC**) ("Hercules"), a leader in customized debt financing for companies in life sciences and technology-related markets.

"This financing provides Axovant additional flexibility to pursue its mission of developing comprehensive solutions for patients with dementia," stated Vivek Ramaswamy, Chief Executive Officer of Axovant Sciences. "We are excited to be working with the Hercules team that has a long history of supporting innovative life sciences companies."

"Hercules is pleased to enter into this financing partnership with Axovant at this important stage to allow it to continue to advance and expand its pipeline and achieve its growth objectives," said Scott Bluestein, Chief Investment Officer at Hercules Capital. "This investment in Axovant provides another example of our ability to finance life sciences companies through multiple stages of development and through various value inflection points."

The full amount of the $55.0 million loan was funded upon closing. The loan will mature on March 1, 2021. Payments under the loan are interest only for a period of 18 months, followed by equal monthly installments of principal and interest thereafter. The interest-only period may be extended to 24 months contingent upon Axovant achieving of certain clinical development milestones. In connection with the debt financing, Axovant issued Hercules a warrant to purchase up to 274,086 of its common shares at an exercise price of $12.04 per share.

Corporate Bonds

Non-Government Bonds Carry Default Risk

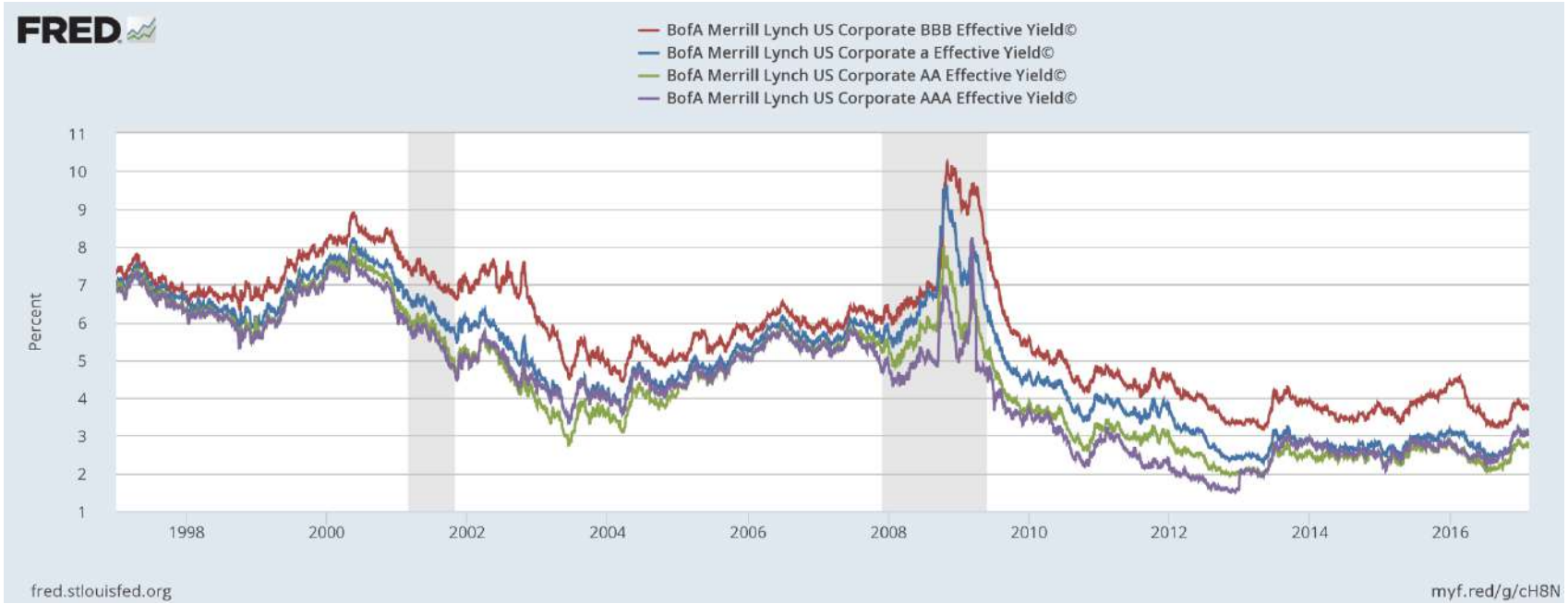
- A **default** is when a debt issuer fails to make a promised payment (interest or principal)
- Credit ratings by rating agencies (e.g., Moody's and S&P) provide indications of the likelihood of default by each issuer.

Credit Risk	Moody's	S&P	Fitch
Investment Grade			
Highest Quality	Aaa	AAA	AAA
High Quality (Very Strong)	Aa	AA	AA
Upper Medium Grade (Strong)	A	A	A
Medium Grade	Baa	BBB	BBB
Not Investment Grade			
Somewhat Speculative	Ba	BB	BB
Speculative	B	B	B
Highly Speculative	Caa	CCC	CCC
Most Speculative	Ca	CC	CC
Imminent Default	C	C	C
Default	C	D	D

Corporate Bonds

BofA Merrill Lunch Corporate Bond Effective Yield Indexes

Dec 31, 1996 to Feb 10, 2017



Corporate Bonds

What's In The Premium?

- Expected default loss, tax premium, systematic risk premium (Elton, et al., 2001)
  - 17.8% contribution from default on 10-year A-rated industrials
- Default, recovery, tax, jumps, liquidity, and market factors (Delianedis and Geske, 2001)
  - 5-22% contribution from default
- Credit risk, illiquidity, call and conversion features, asymmetric tax treatments of corporates and Treasuries (Huang and Huang, 2002)
  - 20-30% contribution from credit risk
- Liquidity premium, carrying costs, taxes, or simply pricing errors (Saunders and Allen, 2002)

Default Risk

Decomposition of Corporate Bond Yields

- **Promised YTM** is the yield if default does not occur
- **Expected YTM** is the probability-weighted average of all possible yields
- **Default premium** is the difference between promised yield and expected yield
- **Risk premium** (of a bond) is the difference between the expected yield on a risky bond and the yield on a risk-free bond of similar maturity and coupon rate

Example: Suppose all bonds have par value $1,000 and

- 10-year Treasury STRIPS is selling at $463.19, yielding 8%
- 10-year zero issued by XYZ Inc. is selling at $321.97
- Expected payoff from XYZ's 10-year zero is $762.22

Default Risk

- For the 10-year zero issued by XYZ:

$$\text{Promised YTM} = \left(\frac{1000.00}{321.97}\right)^{1/10} - 1 = 12\%$$

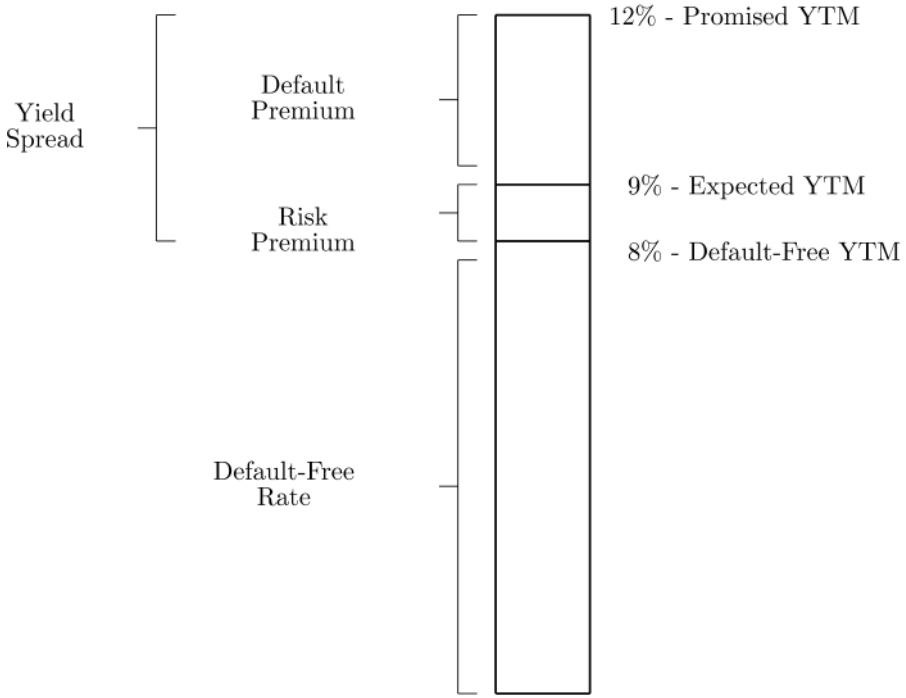
$$\text{Expected YTM} = \left(\frac{762.22}{321.97}\right)^{1/10} - 1 = 9\%$$

$$\begin{aligned}\text{Default Premium} &= \text{Promised YTM} - \text{Expected YTM} \\ &= 12\% - 9\% = 3\%\end{aligned}$$

$$\begin{aligned}\text{Risk Premium} &= \text{Expected YTM} - \text{Default-free YTM} \\ &= 9\% - 8\% = 1\%\end{aligned}$$

Default Risk

Decomposition of Corporate Bond Yields



Default Risk

Moody's Cumulative Default Rates, 1920–2015

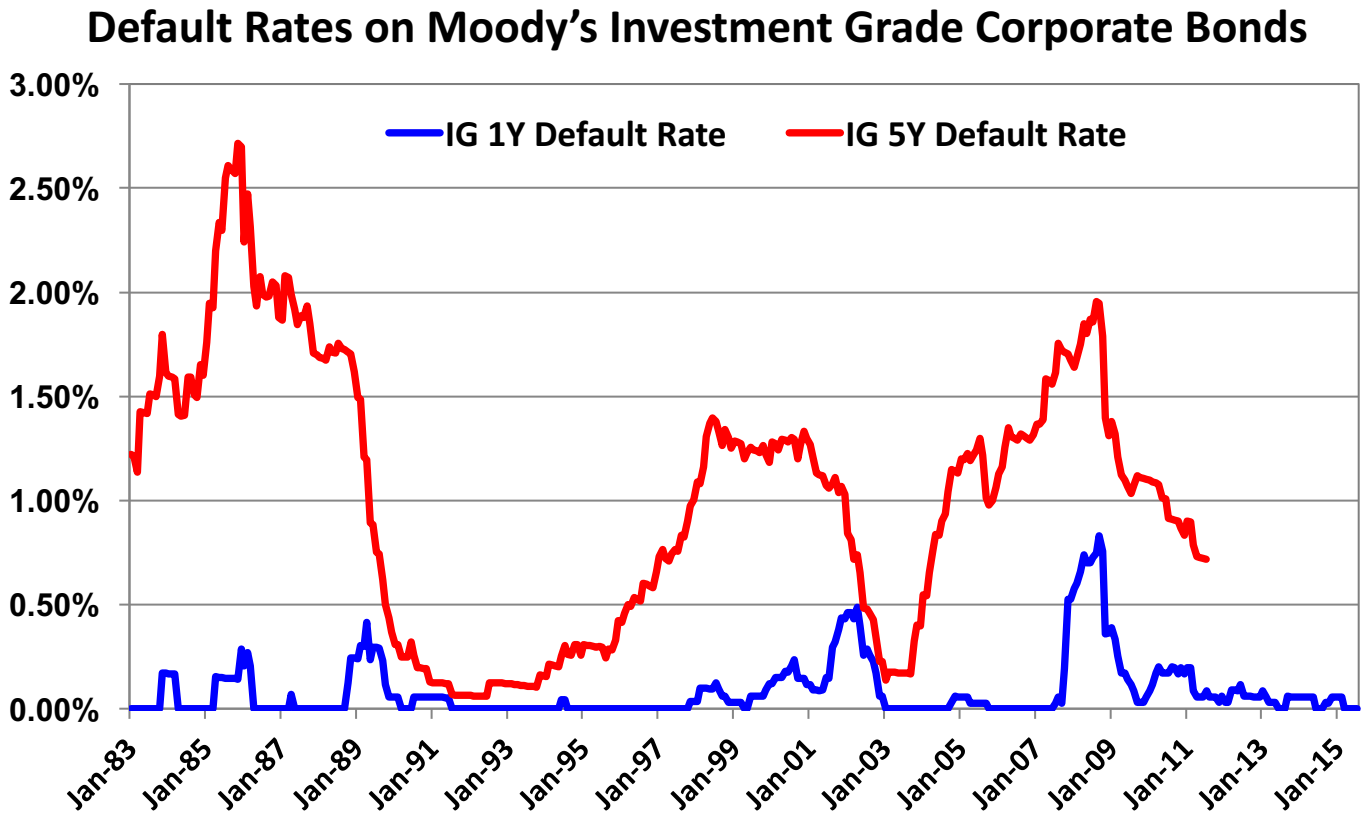
EXHIBIT 32

Average Cumulative Issuer-Weighted Global Default Rates by Letter Rating, 1920-2015*

Rating	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Aaa	0.000	0.008	0.027	0.075	0.144	0.219	0.313	0.442	0.578	0.737	0.872	0.984	1.102	1.136	1.168	1.231	1.293	1.345	1.404	1.444
Aa	0.063	0.183	0.289	0.443	0.680	0.956	1.236	1.503	1.750	2.026	2.343	2.689	3.031	3.357	3.601	3.790	3.960	4.163	4.413	4.623
A	0.089	0.266	0.541	0.848	1.182	1.543	1.923	2.306	2.728	3.157	3.601	4.036	4.435	4.837	5.301	5.713	6.047	6.377	6.690	7.006
Baa	0.274	0.771	1.345	1.979	2.635	3.292	3.919	4.567	5.246	5.922	6.605	7.306	8.012	8.645	9.222	9.832	10.433	10.984	11.506	12.035
Ba	1.245	2.926	4.795	6.752	8.650	10.464	12.124	13.720	15.261	16.889	18.318	19.727	21.080	22.289	23.448	24.555	25.637	26.680	27.639	28.534
B	3.545	8.010	12.470	16.495	20.068	23.165	26.006	28.411	30.524	32.293	33.850	35.280	36.685	38.091	39.391	40.659	41.812	42.746	43.463	43.990
Caa-C	10.441	18.290	24.447	29.306	33.277	36.429	38.938	41.105	43.136	45.016	46.900	48.771	50.449	52.152	53.948	55.718	57.372	58.974	60.500	62.017
Inv Grade	0.149	0.423	0.758	1.134	1.544	1.971	2.396	2.827	3.277	3.736	4.209	4.687	5.149	5.579	5.995	6.388	6.744	7.087	7.425	7.755
Spec Grade	3.689	7.413	10.890	14.003	16.756	19.162	21.304	23.204	24.949	26.602	28.068	29.478	30.829	32.097	33.310	34.480	35.592	36.615	37.526	38.354
All rated	1.473	2.977	4.375	5.629	6.748	7.741	8.629	9.438	10.208	10.949	11.646	12.326	12.974	13.573	14.145	14.687	15.183	15.647	16.083	16.494

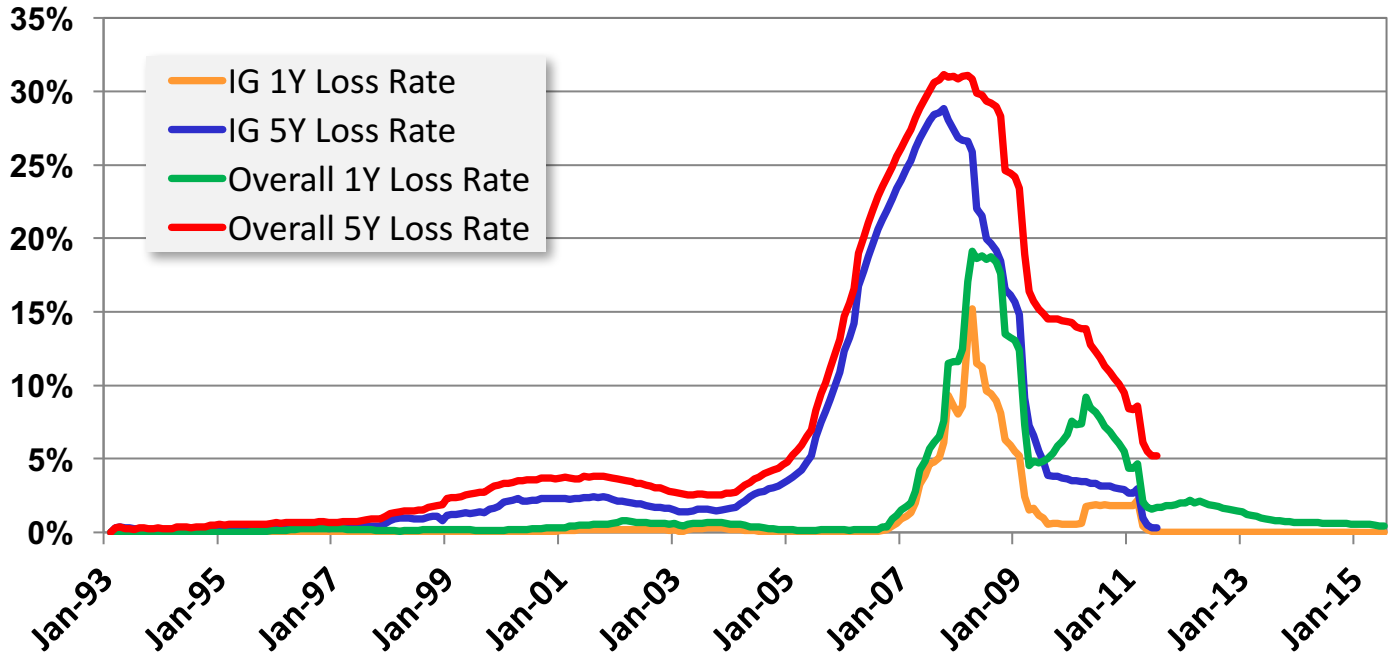
* Data in percent.

Default Risk

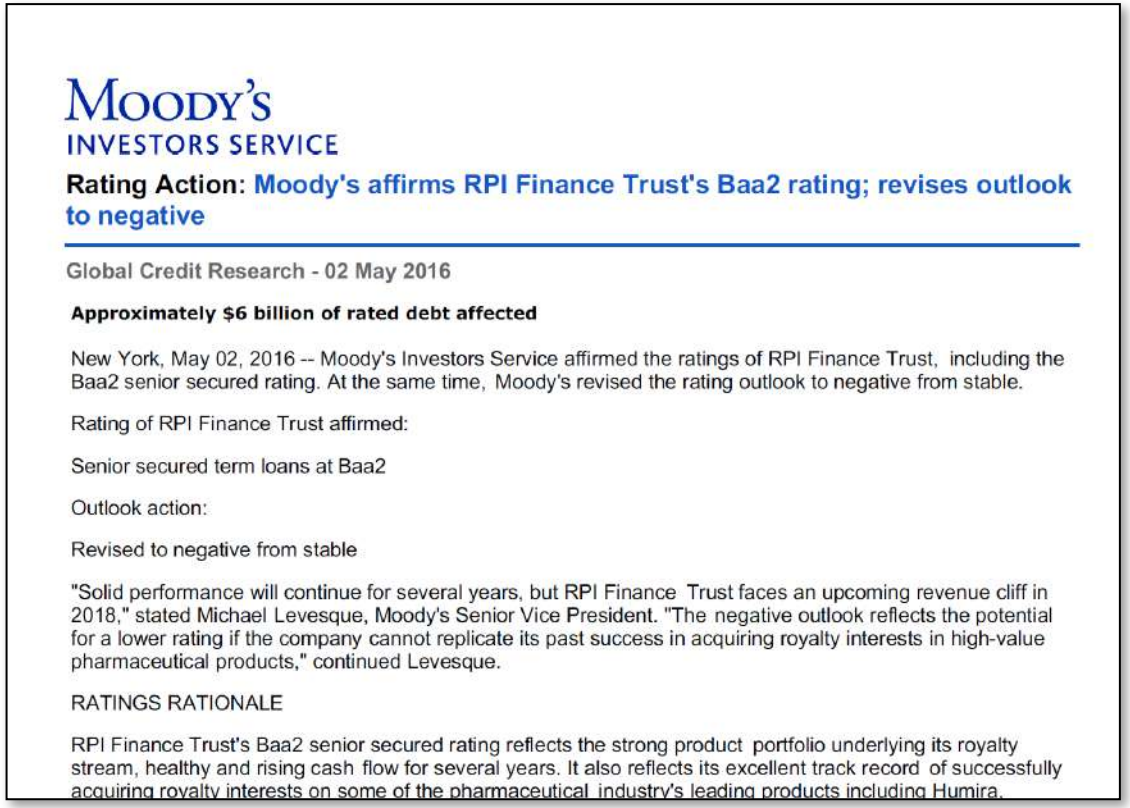


Default Risk

Loss Rates on Global Structured Finance Deals (overall vs Moody's investment grades)



Default Risk



MOODY'S
INVESTORS SERVICE

Rating Action: Moody's affirms RPI Finance Trust's Baa2 rating; revises outlook to negative

Global Credit Research - 02 May 2016

Approximately $6 billion of rated debt affected

New York, May 02, 2016 -- Moody's Investors Service affirmed the ratings of RPI Finance Trust, including the Baa2 senior secured rating. At the same time, Moody's revised the rating outlook to negative from stable.

Rating of RPI Finance Trust affirmed:

Senior secured term loans at Baa2

Outlook action:

Revised to negative from stable

"Solid performance will continue for several years, but RPI Finance Trust faces an upcoming revenue cliff in 2018," stated Michael Levesque, Moody's Senior Vice President. "The negative outlook reflects the potential for a lower rating if the company cannot replicate its past success in acquiring royalty interests in high-value pharmaceutical products," continued Levesque.

RATINGS RATIONALE

RPI Finance Trust's Baa2 senior secured rating reflects the strong product portfolio underlying its royalty stream, healthy and rising cash flow for several years. It also reflects its excellent track record of successfully acquiring royalty interests on some of the pharmaceutical industry's leading products including Humira.