IS4228
Information technology and financial services

Lecture 3

29 August, 2023

Overview

- **Valuation of bonds (risk-free and risky)**
- **Corporate bonds and sovereign bonds**
- **The determinants of interest rates**
- **Digital bonds**

Bond Terminology

- **A bond is a security sold by governments and corporations to raise money from investors today in exchange for promised future payments.**
- **The terms of the bond are described as part of the bond certificate, which indicates the amounts and dates of all payments to be made.**
- **The payments are made until a final repayment date, called the maturity date of the bond**
- **The time remaining until the repayment date is known as the term of the bond.**

Bond Terminology

- **Bonds typically make two types of payments.**
- **Coupons: the promised interest payments of a bond.**
  - The bond certificate typically specifies that the coupons will be paid periodically until the maturity date of the bond
  - The principal or face value of a bond is the notional amount we use to compute the interest payments.
- **Usually, the face value is repaid at maturity.**
  - The face value is generally denominated in standard increments such as $1000.

Coupon rate

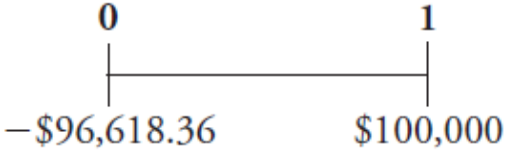
- **The amount of each coupon payment is determined by the coupon rate of the bond.**
- **This coupon rate is set by the issuer and stated on the bond certificate.**
- **By convention, the coupon rate is expressed as an APR.**
- **The amount of each coupon payment, denoted as CPN, is**

$$CPN = \frac{Coupon\ rate}{Number\ of\ payments\ per\ year} * Face\ Value$$

  - E.g., a "$1000 bond with a 10% coupon rate and semiannual payments" will pay coupon payments of $1000 * 10%/2 = $50 every six months.

Zero-Coupon Bonds

- **zero-coupon bond: the type of bond that does not make coupon payments**
  - The only cash payment the investor receives is the face value of the bond on the maturity date.
  - The simplest type of bond
  - E.g., Treasury bills, which are U.S. government bonds with a maturity of up to one year.
  - also called pure discount bond
- **E.g., a one-year, risk-free, zero-coupon bond with a $100,000 face value has an initial price of $96,618.36.**



Yield to Maturity

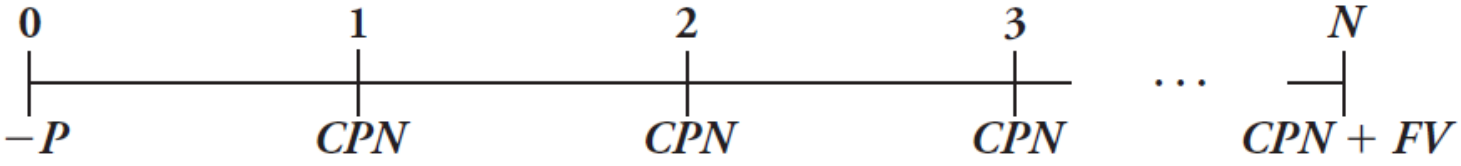
- **The yield to maturity (YTM) of a bond is the discount rate that sets the present value of the promised bond payments equal to the current market price of the bond.**
- **E.g.,** $96{,}618.36 = \frac{100{,}000}{1 + YTM_1}$
  YTM_1 = 3.5%
- **YTM for a zero-coupon bond with n periods to maturity, current price P, and face value FV solves**
  - $P = \frac{FV}{(1+YTMn)^n}$
  - $YTM_n = \left(\frac{FV}{P}\right)^{\frac{1}{n}} - 1$
  - Per-period rate of return

Risk-Free Interest Rates

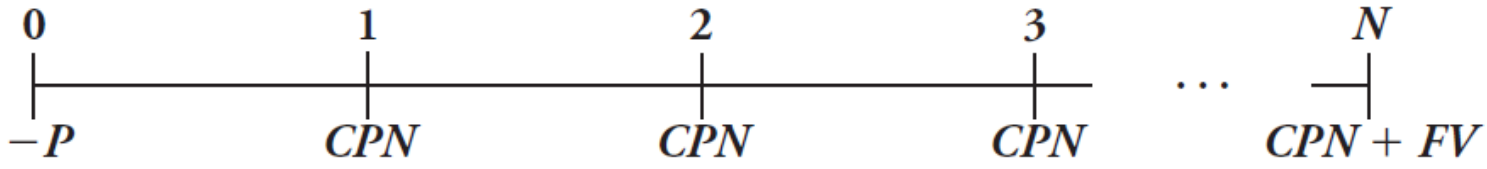
- **Competitive market interest rate r_n: available today for risk-free cash flows on date n.**
- **Default-free zero-coupon bond that matures on date n provides such a cash flow.**
- **r_n=YTM_n**
- **Practically, YTM_n of the default-free zero-coupon bonds (e.g., U.S treasuries) is actually the risk-free interest rate.**
  - a.k.a, Spot interest rates

Coupon Bonds

- **Coupon bonds pay investors their face value at maturity, as well as regular coupon interest payments.**
  - U.S. treasury notes, which have original maturities from one to 10 years
  - U.S. treasury bonds, which have original maturities of more than 10 years.



Coupon Bonds



- $\boldsymbol{P = \frac{CPN}{YTM} * \left(1 - \frac{1}{(1+YTM)^N}\right) + \frac{FV}{(1+YTM)^N}}$
  - YTM per coupon interval
- **How to solve YTM?**
  - Trial-and-error
  - RHS of the formula above is monotonically decreasing in YTM

Computing the YTM of a Coupon Bond

- **E.g., a five-year, $1000 bond with a 5% coupon rate and semiannual coupons currently trading for a price of $957.35**
  - Coupon rate is APR
- $957.35 = \frac{1000*5\%*0.5}{y} * (1 - \frac{1}{(1+y)^{10}}) + \frac{1000}{(1+y)^{10}}$
  - y = 5%? RHS=806.96<957.35 → y too large
  - y = 2%? RHS=1044.91>957.35 → y too small
  - y = 3%? RHS=957.35 Right!
  - YTM is 3% every half a year or 6% APR

Quotes of bonds

- **Bond price and YTM are one-to-one matched**
- **They can be used interchangeably**
- **Bond can be quoted by its YTM or price**
- **E.g., the bond just discussed can be quoted as**
  - having a yield of 6% (APR)
  - a price of $957.35 per $1000 face value
  - When prices are quoted in the bond market, they are conventionally quoted as a percentage of their face value, i.e., 95.735

Discounts and Premiums

- **Zero-coupon bonds trade at a discount**
  - prior to maturity, their price is less than their face value.
- **Coupon bonds may trade**
  - at a discount
  - at a premium (a price greater than their face value)
  - at par (a price equal to their face value).
- **If a bond trades at a discount → YTM>Coupon rate**
- **YTM>Coupon rate → the bond trades at a discount**
  - YTM=Coupon rate is equivalent to the bond trading at bar
  - YTM<Coupon rate is equivalent to the bond trading at a premium

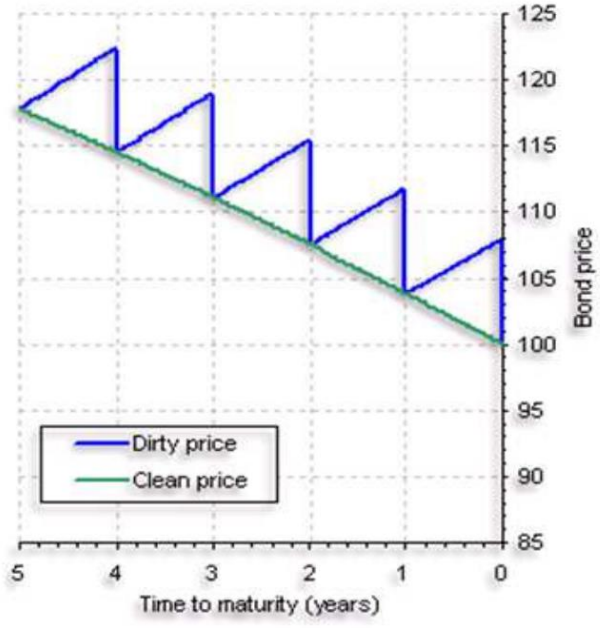
Dynamic Behavior of Bond Prices

- **Most issuers of coupon bonds choose a coupon rate so that the bonds will initially trade at, or very close to, par.**
  - Coupon rate ≈ YTM = interest rate
- **After the issue date, the market price of a bond generally changes over time**
  - As time passes, the bond gets closer to its maturity date.
  - Changes in market interest rates

Time and Bond Prices

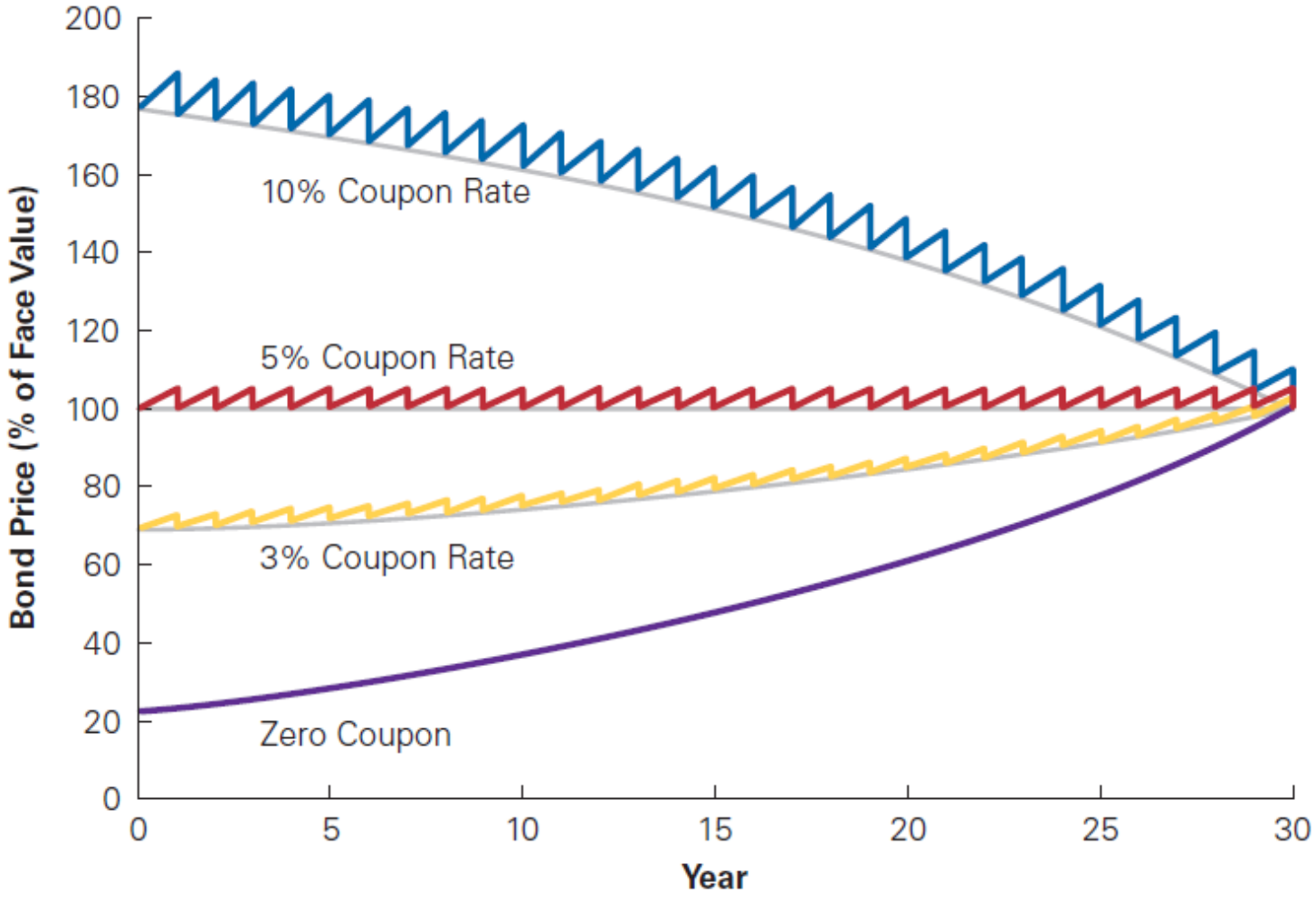
- **For zero-coupon bonds, the price will monotonically increase over time.**
  - The discount from its FV is smaller as time gets closer to maturity date.
- **E.g., a 30-year, zero-coupon bond with a yield to maturity of 5%.**
  - At issuance, the bond trades at $\$100/1.05^{30}=\$23.14$ for FV of \$100
  - Five years later, when it has 25 years until maturity, it trades at $\$100/1.05^{25}=\$29.53$ for FV of \$100

Time and Bond Prices



- **For coupon bonds, the price**
  - increases over time
  - until a coupon payment
- **Clean and dirty price of coupon bonds**
  - Dirty price: the actual cash price
  - Clean price: the bond's cash price less an adjustment for accrued interest, the amount of the next coupon payment that has already accrued
    - **Accrued interest = Coupon amount * Days since last coupon payment/Days in current coupon period**

Time and Bond Prices



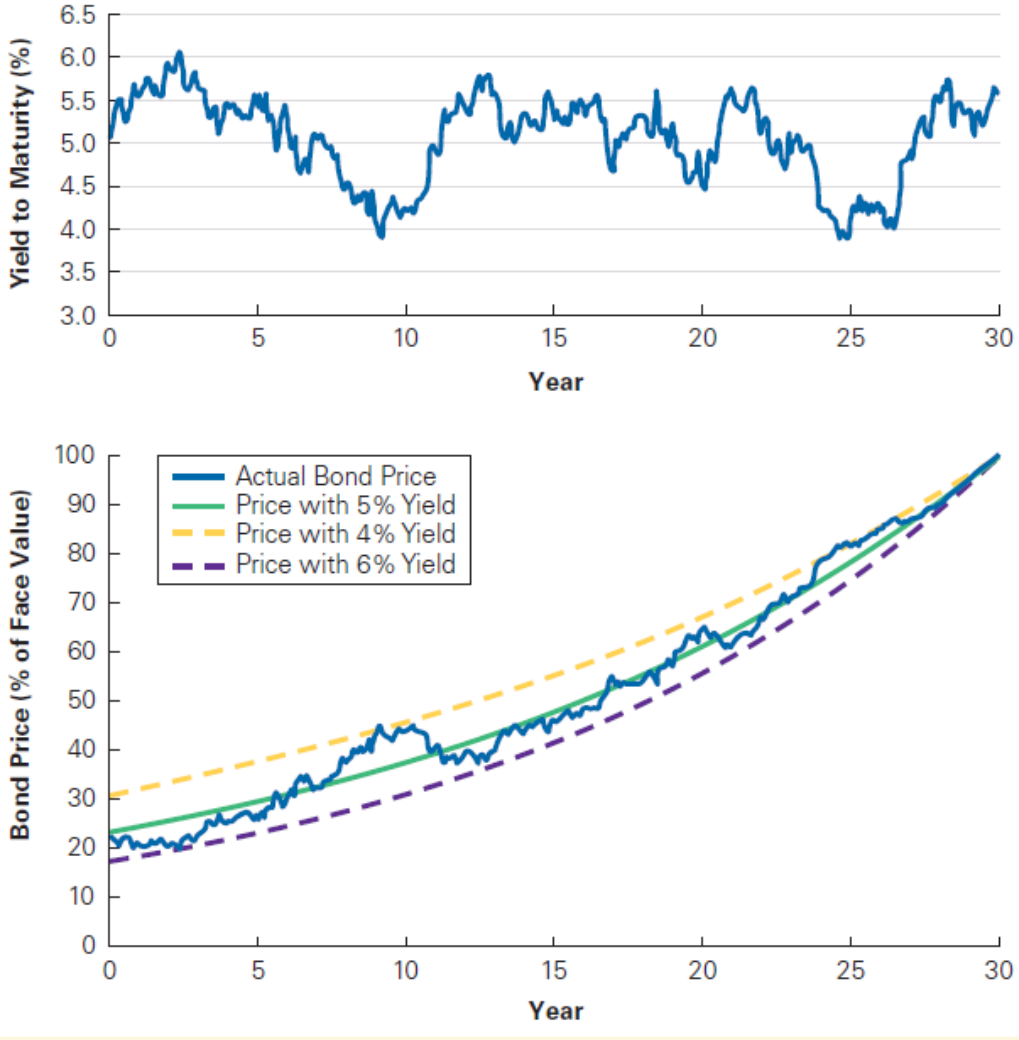
IRR of investment in bonds

- **Think about the 30-year, zero-coupon bond with a yield to maturity of 5% again**
- **What is the IRR of buying it at issuance and hold it to maturity?**
  - 5%
- **What is the IRR of buying it at issuance and sell it 5 years later?**
  - $(29.53/23.14)^{1/5}-1=5\%$
- **If a bond's yield to maturity has not changed, then the IRR of an investment in the bond equals its yield to maturity even if you sell the bond early.**
  - Also holds for coupon bonds.

Interest Rate Changes and Bond Prices

- **Consider again the 30-year, zero-coupon bond with a yield to maturity of 5%.**
  - The bond trades at $\$100/1.05^{30}=\$23.14$ for FV of \$100
- **Suppose interest rates suddenly rise so that investors now demand a 6% yield to maturity**
  - The bond trades at $\$100/1.06^{30}=\$17.41$ for FV of \$100
- **As interest rates and bond yields rise, bond prices will fall, and vice versa.**
  - Shorter-maturity zero-coupon bonds are less sensitive to changes in interest rates than are longer-term zero-coupon bonds
  - Bonds with higher coupon rates are less sensitive to interest rate changes

YTM and Bond Price Fluctuations over Time

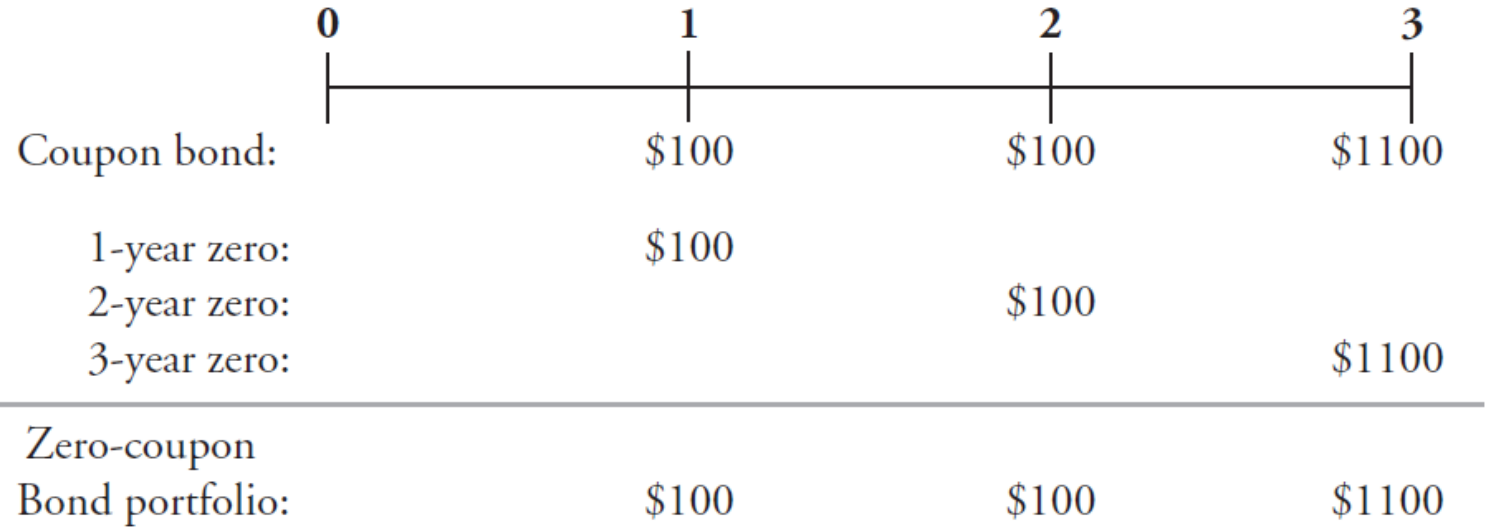


Bond Arbitrage

- **The relationship between the prices and yields of different bonds**
  - Revisit the valuation of coupon bonds
- **Construct coupon bonds with zero-coupon bonds**
- **Law of one price!**

Replicating a Coupon Bond

- **E.g., replicate a three-year, $1000 bond that pays 10% annual coupons using three zero-coupon bonds**



The yield curve

- **Bonds with different terms require different YTM.**
  - E.g., YTM_1=3.5%, YTM_2=4%, YTM_3=4.5%
- **What is the price for the coupon bond in the previous example?**
  - $P = \frac{100}{1+3.5\%} + \frac{100}{(1+4\%)^2} + \frac{1100}{(1+4.5\%)^3} = 1153$
- **Generally,**

$$\boldsymbol{P = \frac{CPN}{1+YTM_1} + \frac{CPN}{(1+YTM_2)^2} + \cdots + \frac{CPN+FV}{(1+YTM_N)^N}}$$

- $\boldsymbol{P = \frac{CPN}{YTM} * \left(1 - \frac{1}{(1+YTM)^N}\right) + \frac{FV}{(1+YTM)^N}}$
  - Does this equation still hold?
  - Which of the two equations determine the price of coupon bonds?
  - P, YTM, YTM_1, … YTM_N are all determined by market!

Treasury Yield Curves

- **The plot of the yields of coupon bonds of different maturities is called the coupon-paying yield curve.**
  - When U.S. bond traders refer to "the yield curve," they are often referring to the coupon-paying Treasury yield curve.
- **Two coupon-paying bonds with the same maturity may have different yields**
  - Different coupon rate
- **By convention, practitioners always plot the yield of the most recently issued bonds, termed the on-the-run bonds**

Coupon-paying yield curve

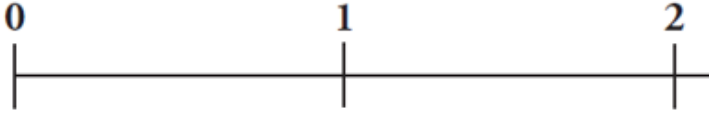
- **Zero-coupon bond yield curve provides enough information to value all other risk-free bonds.**
- **What about coupon-paying yield curve?**
- **Can any risk free bonds be replicated with the bonds on a coupon-paying yield curve?**
- **Can any zero-coupon bond be replicated with the bonds on a coupon-paying yield curve?**
- **Yes! Because the coupon bonds on the curve can span a linear space that contain all bonds.**
  - **Forget about this if you are not that familiar with linear algebra.**

Coupon-paying yield curve

- **Construct zero-coupon bonds with coupon bonds**
- **E.g., part of a coupon-paying yield curve is as follows**

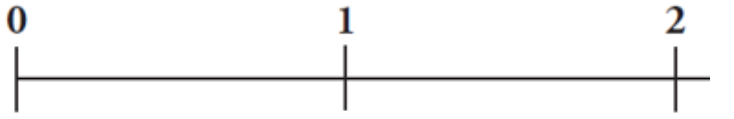
Maturity (years)	Coupon rate (annual payments)	YTM
1	0	3%
2	10%	5%

- **A two-year zero-coupon bond with FV=$1100 can be constructed by buying the two-year bond in the curve with FV=$1000 and selling the one-year bond with FV=$100**



	0	0	1100
=	0	100	1100
-	0	100	0

Coupon-paying yield curve



	0	0	1100
=	0	100	1100
-	0	100	0

- ***P(two−year zero−coupon bond with FV*=$1100)**

$$= \frac{100}{1.05} + \frac{1100}{1.05^2} - \frac{100}{1.03} = 995.88$$

- **$YTM_2=(1100/995.88)^{1/2}-1=5.10\%$**

Valuation of risky bonds

- **Most bonds are risky**
- **Risk of default: it might not pay as promised.**
  - A.k.a. Credit risk
- **E.g., A one-year, zero-coupon bond with FV of $1000, where the investors believe that it has 50% chance of default. In particular, the investors believe that they will get $900 1 year later if default. (Assume interest rate is 4%)**
  - Expected return = 50%*$1000+50%*900 = $950
  - Price = $950/(1+4%) ?
  - No

Risk premium

- **The bond above is not equivalent to 0.5 share of risk-free bond with FV=$1000 and 0.5 share of risk-free bond with FV=$900**
- **People generally don't like risk**
- **Risk aversion: preference for a sure outcome over a gamble with higher or equal expected value**
- **Risk premium: the return in excess of the risk-free**
  - a form of compensation for investors who tolerate the extra risk,

Valuation of risky bonds

- **If in the example, risk premium is 1%**
- **P = $950/(1+4%+1%) = $904.76**
- **Yield is calculated with the promised rather than the actual cash flows**
- **YTM = FV/P-1 = 10.53%**
- **The yield to maturity of a defaultable bond is higher than that of a risk-free bond**
  - Yield is higher than expected return because it is calculated with the promised cash flows
  - Risk premium

Overview

- **Valuation of bonds (risk-free and risky)**
- **Corporate bonds and sovereign bonds**
- **The determinants of interest rates**
- **Digital bonds**

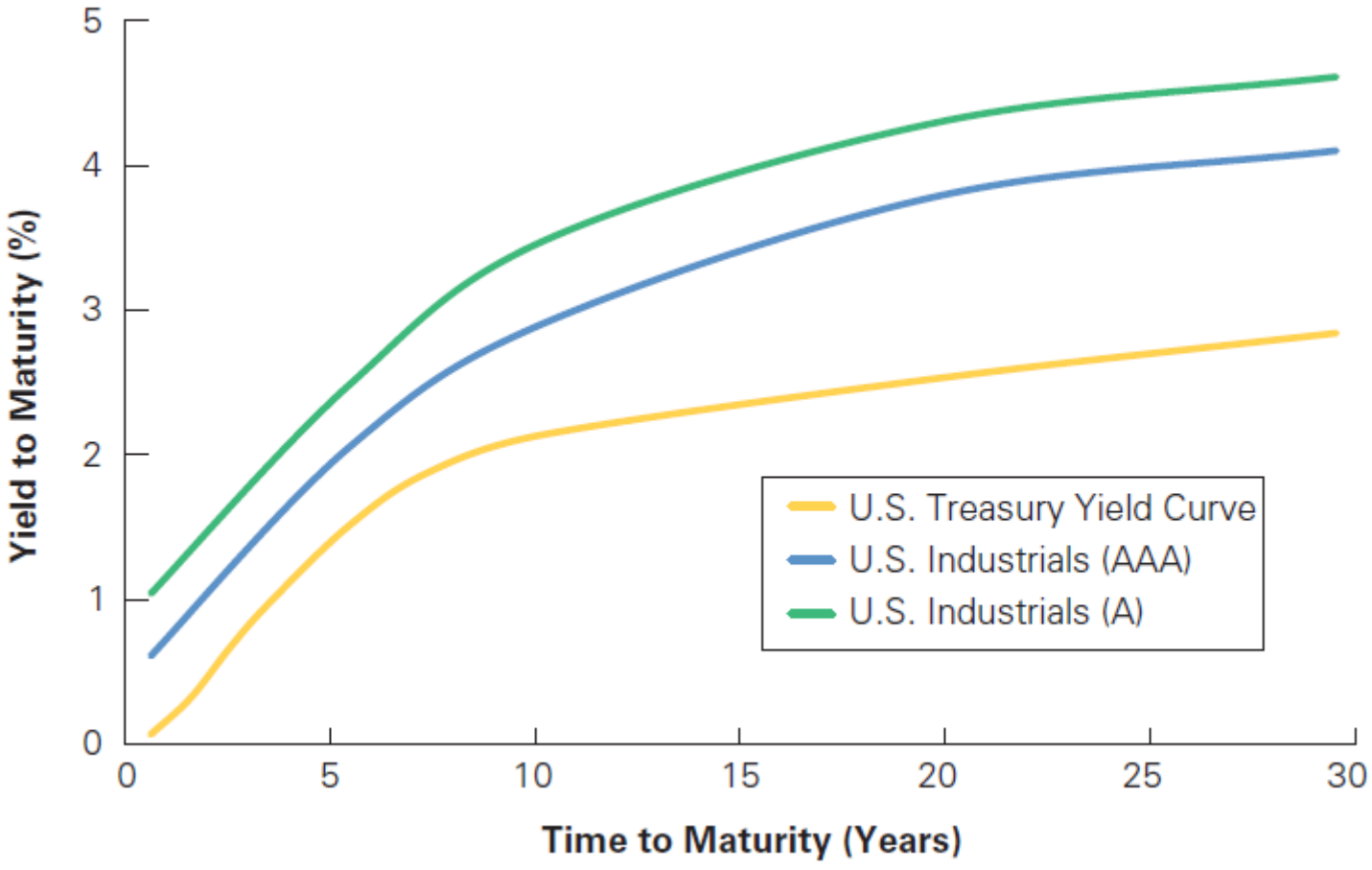
Corporate bonds

- **Corporate bonds: bonds issued by corporations**
- **Have risk of default**
- **Bond ratings: rating companies rate the creditworthiness of bonds and make this information available to investors**
  - Standard & Poor's
  - Moody's
- **Bonds are rated as AAA, AA, A, BBB, BB, B, CCC, CC, C from lowest risk to highest risk.**
- **Top four categories are often referred to as investment-grade bonds.**
- **Bottom five categories are often called speculative bonds, junk bonds, or high-yield bonds**

Definition of default by ranking companies

- **Failing to make a scheduled interest or principal payments**
- **Breaking one of its covenants**
  - a legal agreement that defines what the issuer can or cannot do over the life of the bond. E.g., a bond covenant might include a restriction on the issuer's ability to take on additional debt
- **"Distressed-debt exchange"**
  - When the issuer faces financial difficulties, its bond prices drops. The issuer may then offer to "tender" the bonds at a price above the price that the bonds trade at in the secondary market, but below the par value.

YTM of bonds with different risk ratings

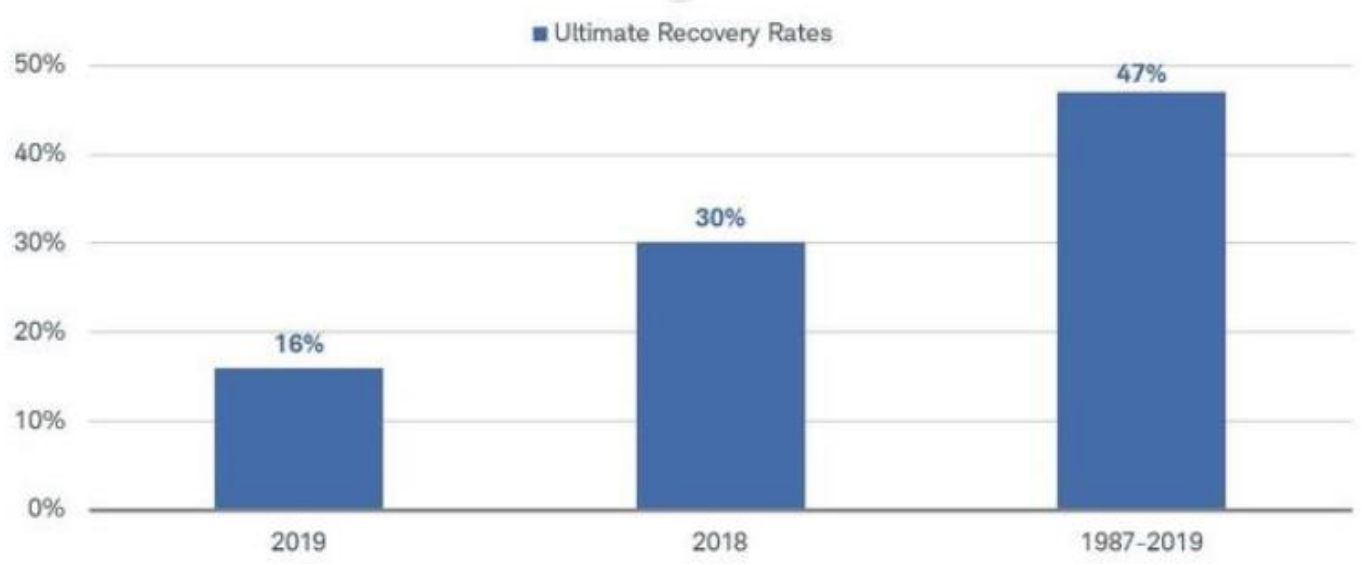


Bankruptcy

- **What happens to holders of bonds that default if the corporation files for bankruptcy protection?**
- **Chapter 11 bankruptcy**
  - The company restructure its balance sheet and “emerges” as a newly organized and restructured company.
- **Chapter 7 bankruptcy**
  - The company sells its assets—sometimes at very depressed prices—to pay off its creditors.
  - Bond holders are often below government taxes, bank loans, and other creditors like employees and suppliers, while ahead of stockholders to receive the payments.

Recovery values

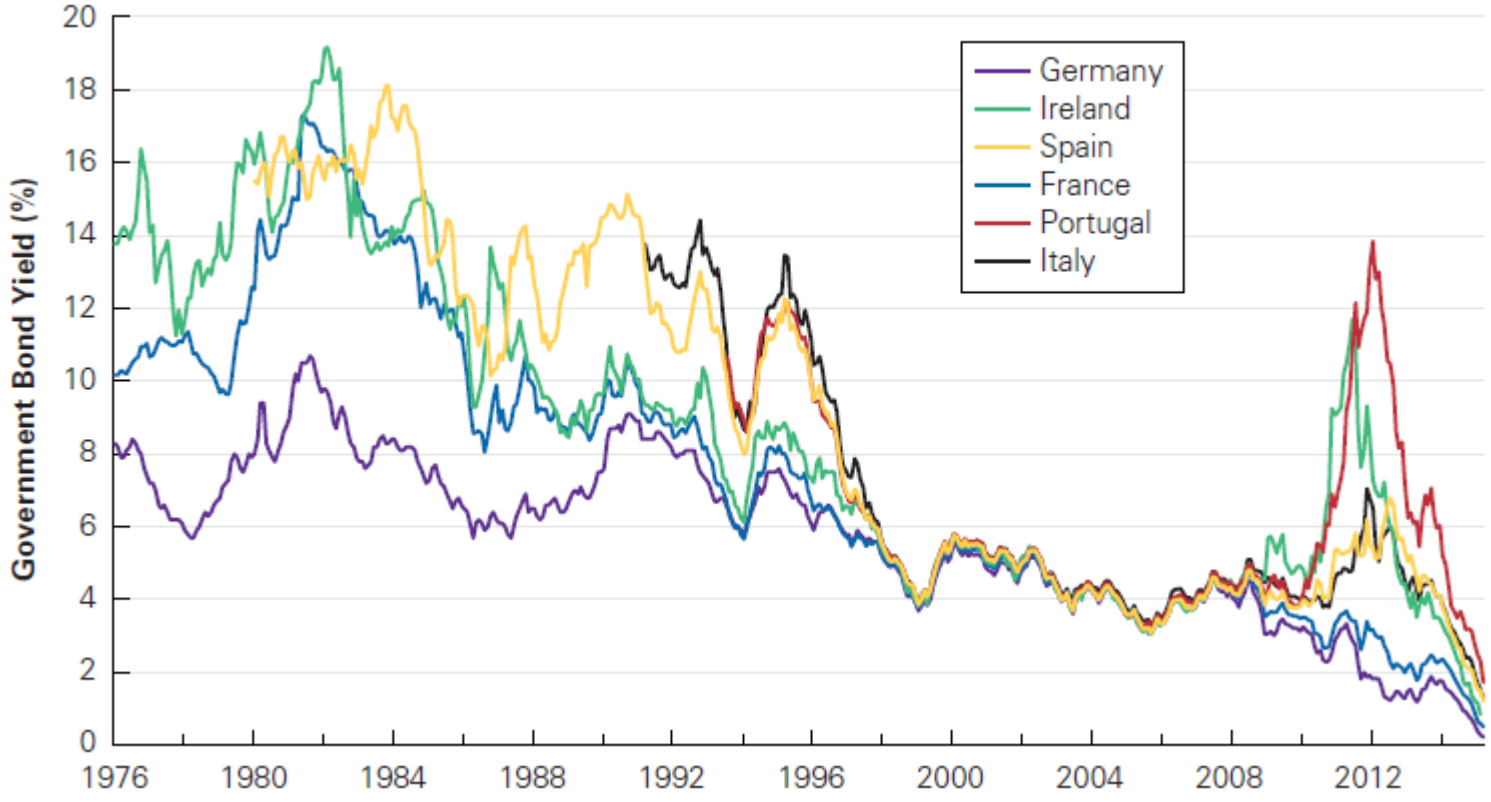
- **Vary significantly case to case**
- **Generally takes very long time (multiple years)**
- **Compensation not necessarily in cash**
  - Chapter 11 results in a newly organized company, holders of the defaulted bonds usually receive some sort of new securities as proceeds.



Sovereign Bonds

- **Sovereign bonds: bonds issued by national governments.**
- **Can be denominated in both foreign and domestic currency.**
- **Denominated in foreign currency (a currency that the bond issuer cannot "print")**
  - Risk of default
- **Denominated in domestic currency**
  - Governments can "print" money to pay the debts
  - "inflate away" the debt is generally politically preferable to an outright default.
  - Risk of exchange rate

European Government Bond Yields



How Does the Fed Influence Interest Rates?

- **Interest on Reserve Balances (IORB)**
  - As of now, banks in the U.S. are no longer required to hold any reserves. However, the Fed still pays interest on money the banks keep in reserve. The Fed calls this "interest on reserve balances" (IORB), giving banks an incentive to hold money in reserve.

  - Upper bound of overnight interest rate

How Does the Fed Influence Interest Rates?

- **Overnight Reverse Repurchases (ON RPP)**
  - Many financial institutions do not hold reserves with the Fed, so it designed the ON RRP facility to give them an option to earn interest as well. This facility sells a bank a security and then buys it back the next day at a higher price. The buyback price is set by an interest rate.

  - Lower bound of overnight interest rate

How Does the Fed Influence Interest Rates?

- **Open Market Operations (OMO)**
  - The Fed's buying or selling of securities (e.g., Treasury notes) from its member banks is called "open market operations" (OMO).
  - Tunes long-term interest rate.
- **If Fed want to raise long-term interest rate, should it buy or sell treasury notes?**

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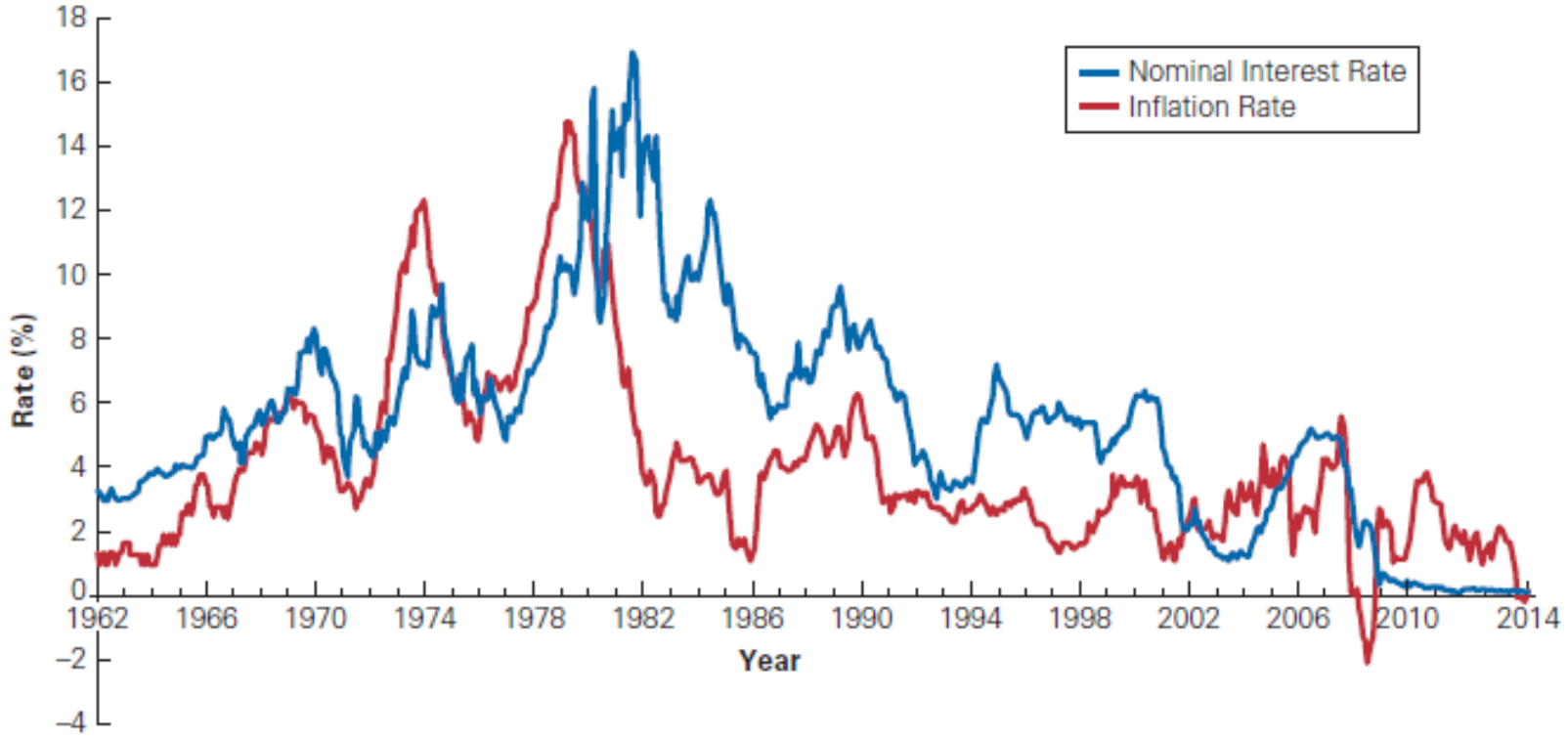
Inflation and Real Versus Nominal Rates

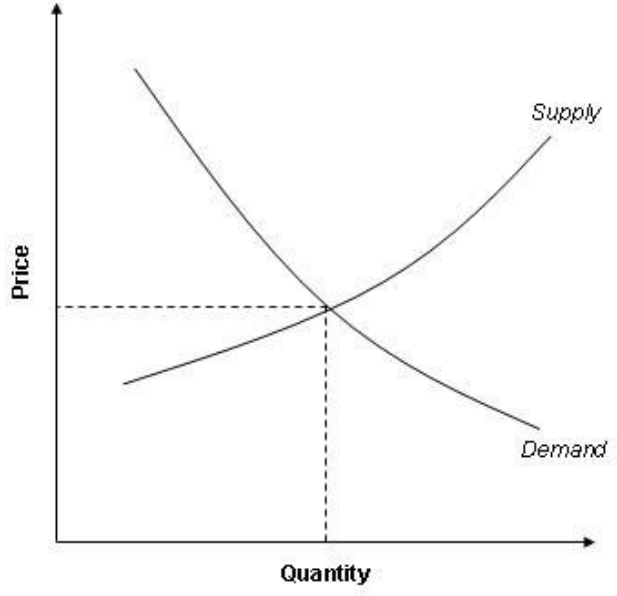
- **The interest rates that are quoted are nominal interest rates (r)**
  - the rate at which the money will grow
- **Prices of items could also grow, known as inflation (i)**
- **Real interest rate (r_r), characterize the rate of growth of purchasing power**
- **Growth of purchasing power = Growth of money/Growth of prices**
- **$1+r_r=(1+r)/(1+i)$**
- **r_r is approximately r-i**

U.S inflation rate and nominal interest rate



The determinants of interest rates

- **Interest rate**
  - the price of capital
- **Mainly determined by the supply and demand of capital**
- **Supply comes from savings**
- **Demand comes from investments**



The Yield Curve

- **Interest rates for loans or investments of different terms are usually different.**
- **The yield curve is a graph that characterizes the relationship between interest rates and terms.**
- **Practically, cash flows are discounted with these different interest rates**

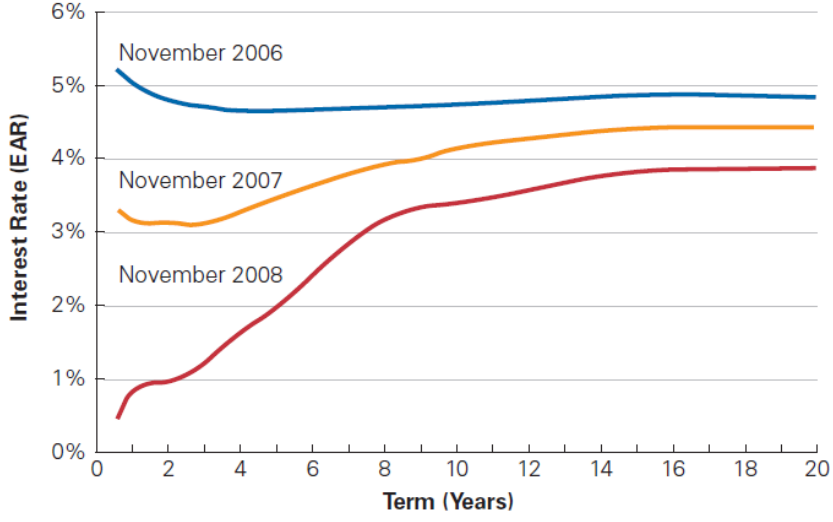
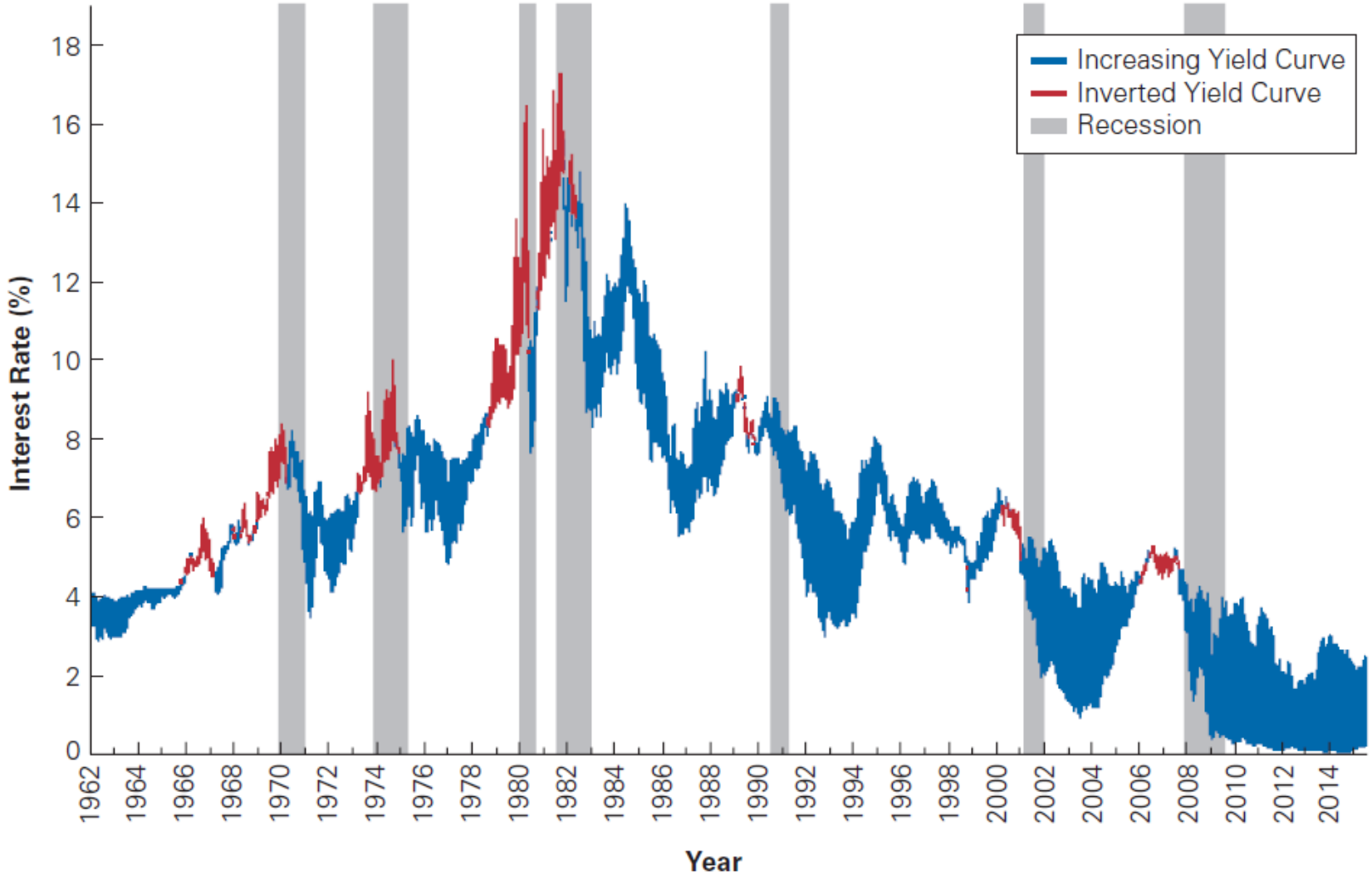


Figure: The yield curves for U.S Treasury

U.S. Interest Rates and Recessions



Interest Rate Expectations

- **Investors expect interest rate to rise in the future**

→ **short term investments (bank deposits) and then reinvest**

→ **high supply for short term capital**

- **Investors expect interest rate to fall in the future**

→ **long term investments (bank deposits)**

→ **high supply for long term capital**

- **If interest rates are expected to rise**

→ **short term rates tend to be lower than long term rates**

- **If interest rates are expected to fall**

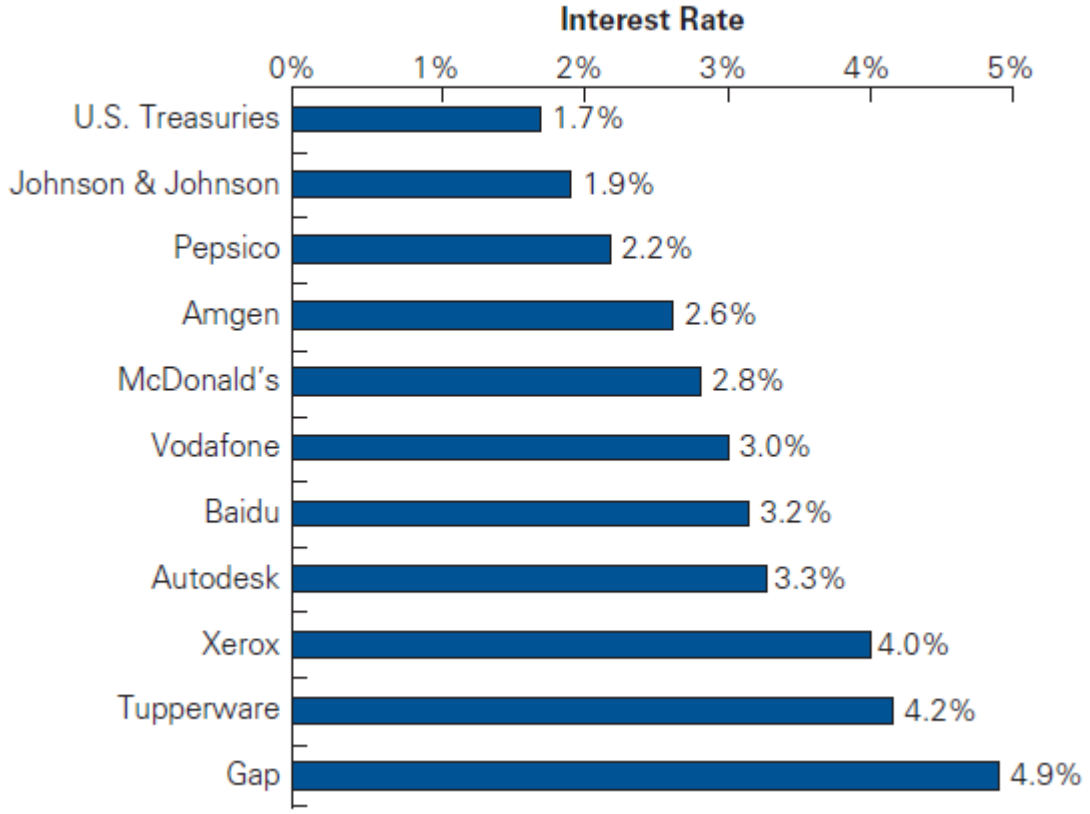
→ **short term rates tend to be higher than long term rates**

The yield curve and the economy

- **Investors value liquidity → the long term interest rates are naturally higher than short term ones**
- **If the short term ones are higher → a strong expectation that the interest rates will fall**
- **When the interest rates are higher?**
  - Think about the demand of capital
  - When the economy is booming
- **A strong expectation that the interest rates will fall reflects a strong expectation that the economy is going into a recession**

Risk and Interest Rates

- **Interest rate differs across borrowers because of the risk of default**



Subprime mortgage crisis

- **Some loans, such as adjustable rate mortgages (ARMs), have interest rates that are not constant over the life of the loan.**
- **ARMs were the most common type of so-called “subprime” loans made to homebuyers with poor credit histories.**
- **These loans often featured low initial rates, aptly named teaser rates.**
- **Prior to 2007, while interest rates remained low and home prices were high (and increasing), such borrowers were able to avoid default simply by refinancing their loans into new loans that also featured low initial teaser rates.**
- **But as mortgage rates increased and housing prices began to decline in 2007, this strategy for keeping their loan payments low was no longer possible.**

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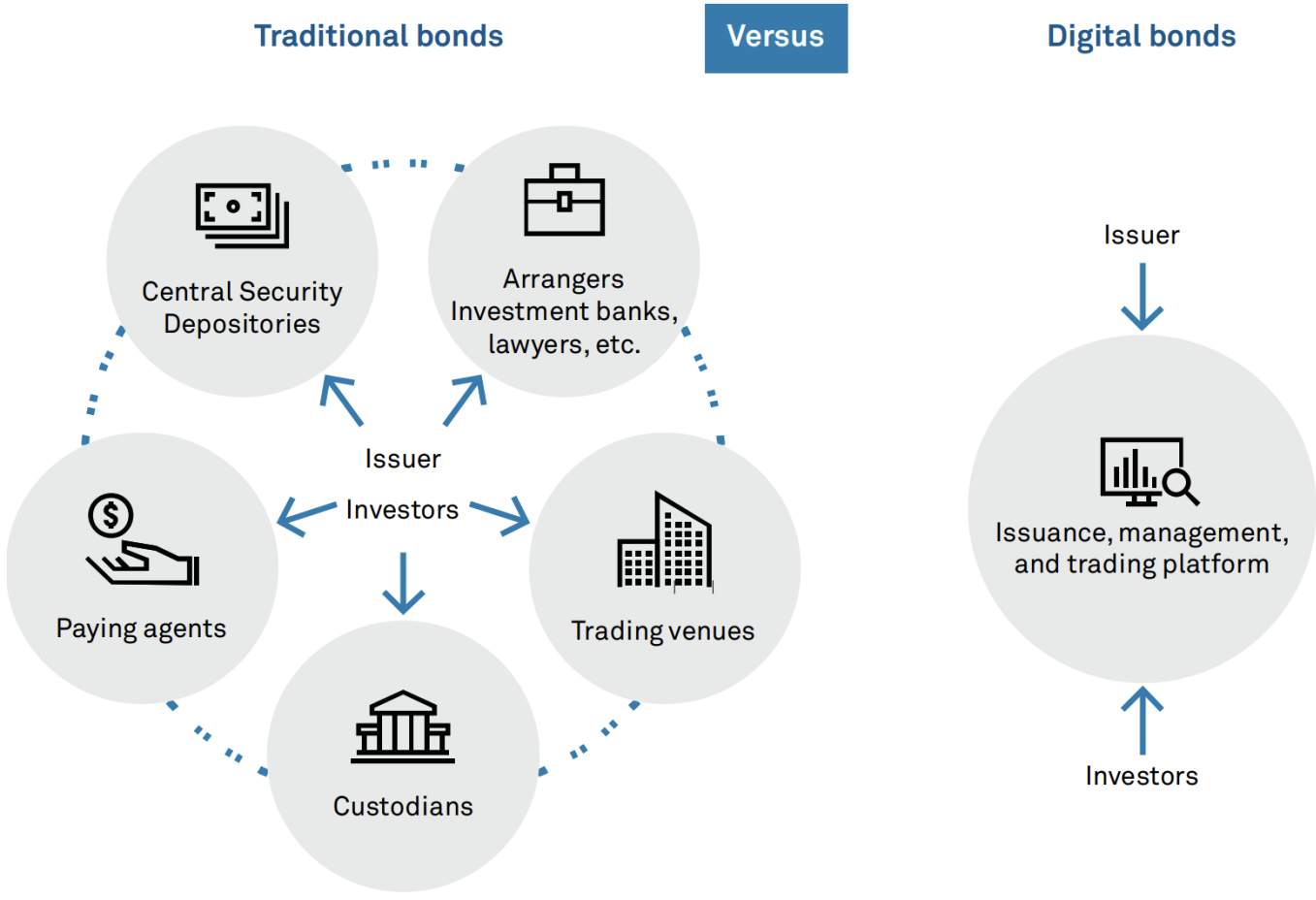
Digital bonds

- **Digital bonds are financial instruments that are created and managed on decentralized systems.**
- **They help issuers raise disintermediated funding more efficiently than through traditional bonds, thanks to the lower number of intermediaries involved.**
- **Digital bonds can also provide access to a wider pool of investors and improved pricing with instantaneous settlement.**

Digital bonds



Source: S&P Global Ratings.

Digital bonds

- **The legal documents underpinning the digital bonds must be verifiable and executable.**
- **In most cases, these documents are standardized as part of the offering of the issuance platforms.**
- **The management of the instrument should also be secured, which is typically achieved using blockchain technology.**

Digital bonds

	Traditional bonds	Digital bonds
Time to market	Few weeks	Few hours to less than one week assuming the use of dedicated platforms
Diversification of investors' base	Global	Access to new class of investors
Trading	Electronic and over-the-counter, which could create some inefficiencies	Electronic and more efficient
Recourse mechanisms	Can be lengthy and inefficient	Efficient if based on smart contract

Digital bonds

- **Challenges**
  - Credit
  - Regulations
  - Security

Thank you!

Reminder: the second individual assignment is due before next lecture. (6:30 PM, 5 Sept)