Bonds

BUSI 721: Data-Driven Finance I

Kerry Back, Rice University

Coupons and Face Value

- Pay a specified coupon at regular intervals (usually semi-annually).
- And pay face value (= par value) at maturity. Last payment is coupon plus face.
- Usually in $1,000 denominations.
- Example: a 6% bond with $1,000 face value pays 3% x 1,000 = 30 every six months.

Coupon rates

- The coupon on a bond is usually set so that it can be issued at or near face value.
- This requires setting the coupon at the market interest (for a bond of its maturity and credit quality).
- Investment banks assist companies and municipalities in setting coupons and issuing bonds.
- The U.S. Treasury runs auctions - buyers bid in rates and low bidders win. The coupon is set at the marginal rate.
- Upcoming Auctions

The bond market

- Many, many different bonds outstanding. Most do not trade in any given period.
- Trade via dealers - contact a dealer to get a quote - rather than on exchanges.
- Mostly an institutional market.
- Better to buy bonds through ETFs than buy them directly, except maybe Treasury bonds through Treasury Direct.

Chevron's debt

	Weighted Average Interest Rate (%)[1]	Range of Interest Rates (%)[2]		2022 Principal		2021 Principal
Notes due 2023	1.282	0.426 - 7.250	$	1,800	$	4,800
Floating rate notes due 2023	3.384	3.121 - 3.821		800		800
Notes due 2024	3.291	2.895 - 3.900		1,650		1,650
Notes due 2025	1.724	0.687 - 3.326		4,000		4,000
Notes due 2026		2.954		2,250		2,250
Notes due 2027	2.379	1.018 - 8.000		2,000		2,000
Notes due 2028		3.850		600		600
Notes due 2029		3.250		500		500
Notes due 2030		2.236		1,500		1,500
Debentures due 2031		8.625		102		102
Debentures due 2032	8.416	8.000 - 8.625		183		183
Notes due 2040		2.978		293		293
Notes due 2041		6.000		397		397
Notes due 2043		5.250		330		330
Notes due 2044		5.050		222		222
Notes due 2047		4.950		187		187
Notes due 2049		4.200		237		237
Notes due 2050	2.763	2.343 - 3.078		1,750		1,750
Debentures due 2097		7.250		60		60
Bank loans due 2023	5.206	4.928 - 5.342		91		100
3.400% loan				—		211
Medium-term notes, maturing from 2023 to 2038	6.306	4.283 - 7.900		23		23
Notes due 2022				—		4,946

Coupons vs Yields

- The coupon rate of a bond is set at the time of its issue.
- However, what one anticipates earning on a bond varies with the market price.
  - Price < par $\Rightarrow$ coupon + capital gain
  - Price > par $\Rightarrow$ coupon - capital loss
- What one would earn per year on a bond if held to maturity (assuming no default) is called the bond yield.

Yield calculation example

- Bond trading at 90% of par
- Paying 5% coupon
- Next coupon in six months, matures in 2 years
- Do semi-annual discounting at the annual rate / 2
- Yield is $y = 2r$ where

$$0 = -90 + \frac{2.50}{1+r} + \frac{2.50}{(1+r)^2} + \frac{2.50}{(1+r)^3} + \frac{102.50}{(1+r)^4}$$

- In other words, r is the IRR of the cash flows from buying the bond at 90 and holding until maturity.

```python
import numpy_financial as npf

cash_flows = [-90, 2.5, 2.5, 2.5, 102.5]
r = npf.irr(cash_flows)
y = 2*r
print(f"The bond yield is {y:.2%}")
```

The bond yield is 10.69%

In this example, you are getting, roughly,

- 5% per year from the coupons
- a 10% capital gain in 2 years $\sim$ 5% per year
- so approximately 10% per year

Bond price is the PV of the cash flows

- A bond price is the PV of its cash flows when discounted at the yield.

$$\text{Price} = \frac{\text{coup}}{1 + y/2} + \frac{\text{coup}}{(1 + y/2)^2} + \cdots + \frac{\text{coup} + \text{face}}{(1 + y/2)^{2n}}$$

where $y = $ yield and $n = $ number of years to maturity.

Example

- 5-year bond with 6% coupon rate and 8% yield
- $1,000 face value
- calculate price

```python
years = 5
coupon = 1000 * 0.06 / 2
yld = 0.08

pv_factors = (1+yld/2)**np.arange(-1, -2*years-1, -1)
cash_flows = (coupon) * np.ones(2*years)
cash_flows[-1] += 1000
price = np.sum(PV_factors * cash_flows)

print(f"price is ${price:.2f}")
```

```
price is $918.89
```

```python
# check yield

cash_flows = np.concatenate(([-price], cash_flows))
r = npf.irr(cash_flows)
print(f"yield is {2*r:.2%}")
```

yield is 8.00%

Long-term bonds are riskier than short-term bonds

- Let y = bond yield.
- Consider a cash flow C that is n years away. Its PV is

$$PV = \frac{C}{(1 + y/2)^{2n}} = C(1 + y/2)^{-2n}$$

- How does this change when the yield changes?

$$\frac{d}{dy}C(1 + y/2)^{-2n} = -nC(1 + y/2)^{-2n-1} = -n \times \frac{PV}{(1 + y/2)}$$

- So the percent change in the value is

$$-n(1 + y/2)$$

Term structure of interest rates

- Term structure = how Treasury yields depend on maturity of bond
- Usually longer-term yields are higher
- But it varies a lot over time
- Learn Investments

Fed funds rate

- The Federal funds rate is an overnight rate that is targeted by the Federal Reserve
- The Fed borrows or lends in the market to push the equilibrium rate to the rate they want
- Long-term rates tend to move up and down with the Fed funds rate

```python
from pandas_datareader import DataReader as pdr
rates = pdr(["FEDFUNDS", "DGS10"], "fred", start=1900).dropna()
rates.columns = ["fedfunds", "10yr"]
sns.regplot(x="fedfunds", y="10yr", data=rates, ci=None, scatter_kws={"alpha"
```

Out[23]:   <AxesSubplot: xlabel='fedfunds', ylabel='10yr'>
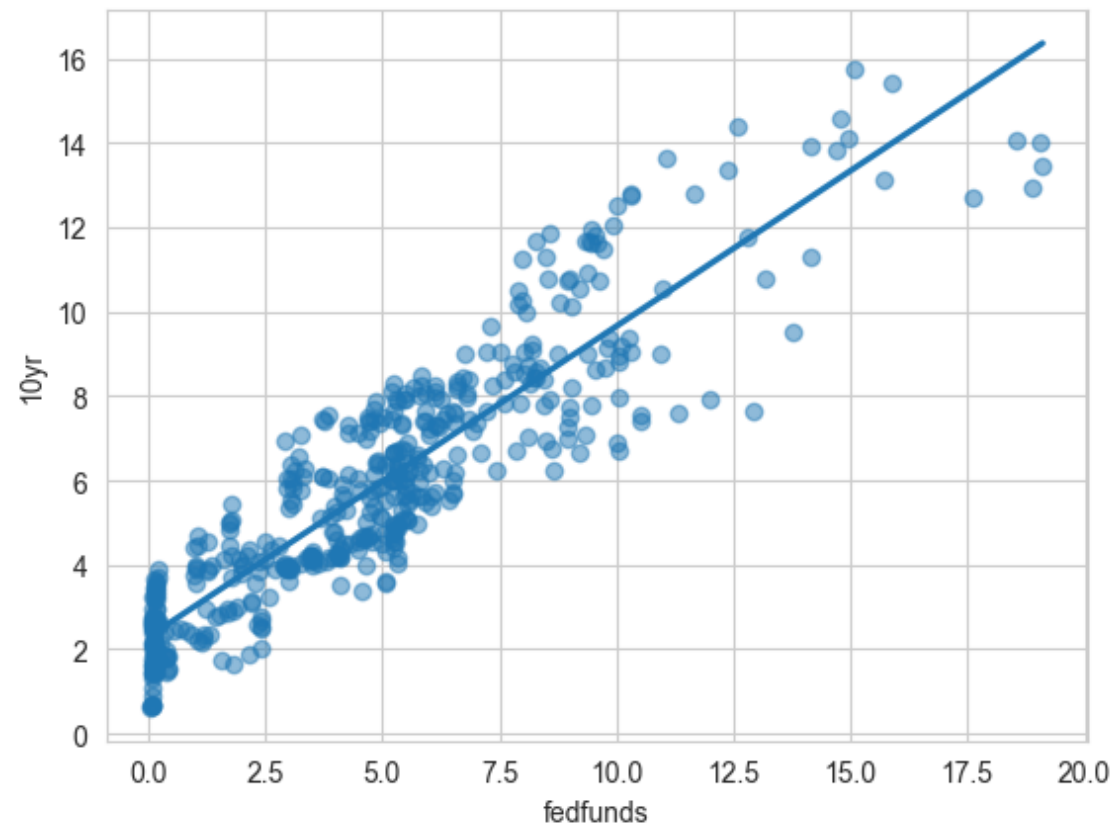
TIPS (Treasury Inflation Protected Securities)

- The Treasury issues bonds with payments indexed to inflation.
- 4% inflation $\Rightarrow$ all future coupons and the face value go up by 4%.
- This is cumulative. So each coupon and the face value are adjusted for all past inflation.
- Example: a $1,000 denomnation 2% TIPS issued today will pay 10 in today's dollars each 6 months and pay 1,000 in today's dollars at maturity.

Treasury yields and TIPS yields

- Get 10 year Treasury yields and TIPS yields from FRED (Federal Reserve Economic Data)
- Calculate the difference in yields
- Difference depends on inflation expectations

```
In [24]:  yields = pdr(["DGS10", "DFII10"], "fred", start=1900).dropna()
          yields.columns = ["Treasuries", "TIPS"]
          yields.plot()
          plt.ylabel("Yield in %")
          plt.show()
```

```
In [25]: (yields.Treasuries - yields.TIPS).plot()
         plt.ylabel("Difference in yields in %")
         plt.show()
```
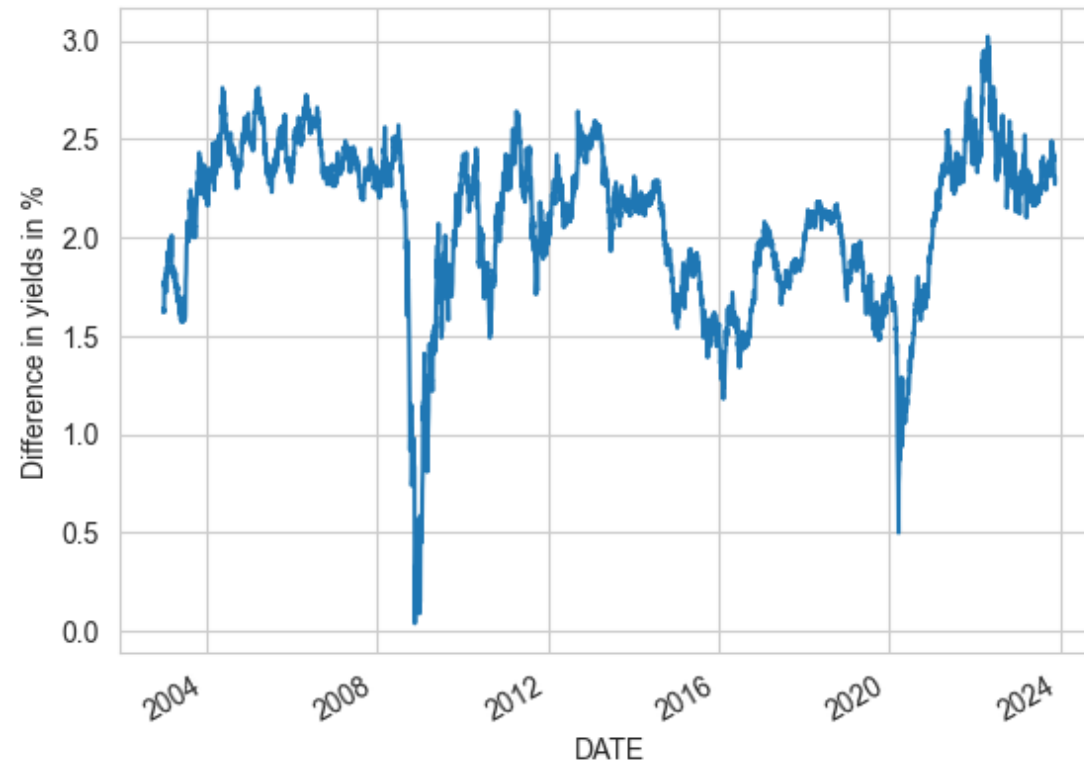
Fixed income universe

- Treasuries
- corporates
- municipals
- asset backed securities
    - mortgage backed securities
    - credit-card receivables, other receivables
    - collateralized debt obligations
- Asset backed securities enable the spreading of risks among more investors. For example, pension funds hold mortgages. Also instrumental in financial crisis.

Municipal bonds

- Municipal bonds in the U.S. are exempt from federal income tax.
- Municipal bonds are also exempt from state income taxes in the state of issue.
- So, NY investors want to hold NY municipals, California investors want to hold California municipals.
- Municipals are issued by states, cities, counties, school boards, fire districts, ...
- Tax increment financing allows limited use of municipal bonds to back private investments: sports stadiums, etc.