

# ECON 337901

# FINANCIAL ECONOMICS

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## 2 Overview of Asset Pricing Theory

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## Pricing Safe Cash Flows

A  $T$ -year discount bond is an asset that pays off \$1, for sure,  $T$  years from now.

If this bond sells for \$  $P_T$  today, the annualized return from buying the bond today and holding it to maturity is

$$1 + r_T = \left( \frac{1}{P_T} \right)^{1/T}.$$

Hence, the bond price and the interest rate are related via

$$P_T = \frac{1}{(1 + r_T)^T}.$$

## Pricing Safe Cash Flows

Since, for a  $T$ -period discount bond,

$$P_T = \frac{1}{(1 + r_T)^T},$$

the interest rate equates today's price of the bond to the present discounted value of the future payments made by the bond.

US Treasury bills, that is, US government bonds with maturities less than one year, are structured as discount bonds.

## Pricing Safe Cash Flows

A  $T$ -year coupon bond is an asset that makes an annual interest (coupon) payment of  $\$C$  each year, every year, for the next  $T$  years, and then pays off  $\$F$  (face or par value), for sure,  $T$  years from now.

US Treasury notes and bonds, with maturities of more than one year, are structured as coupon bonds.

## Pricing Safe Cash Flows

Notice that a coupon bond can be viewed as a bundle, or **portfolio** of discount bonds, since the cash flows from a  $T$ -year coupon bond can be replicated by buying

$C$  one-year discount bonds

$C$  two-year discount bonds

...

$C$   $T$ -year discount bonds

$F$  more  $T$ -year discount bonds

## Pricing Safe Cash Flows

And if both discount and coupon bonds are traded, then the price of the coupon bond must equal the price of the portfolio of discount bonds.

If the coupon bond was cheaper than the portfolio of discount bonds, one could sell the discount bonds, buy the coupon bond, and thereby profit.

If the coupon bond was more expensive than the portfolio of discount bonds, one could sell the coupon bond, buy the discount bonds, and thereby profit.

## Pricing Safe Cash Flows

Building on this insight, the price  $P_T^C$  of the coupon bond must satisfy

$$\begin{aligned} P_T^C &= CP_1 + CP_2 + \dots + CP_T + FP_T \\ &= \frac{C}{1+r_1} + \frac{C}{(1+r_2)^2} + \dots + \frac{C}{(1+r_T)^T} + \frac{F}{(1+r_T)^T} \end{aligned}$$

Today's price of the coupon bond equals the present discounted value of the future payments made by the bond.

## Pricing Safe Cash Flows

$$P_T^C = \frac{C}{1+r_1} + \frac{C}{(1+r_2)^2} + \dots + \frac{C}{(1+r_T)^T} + \frac{F}{(1+r_T)^T}$$

Note that the interest rates used to compute the present value are those on the **discount bonds**

The **yield to maturity** defined by the value  $r$  that satisfies

$$P_T^C = \frac{C}{1+r} + \frac{C}{(1+r)^2} + \dots + \frac{C}{(1+r)^T} + \frac{F}{(1+r)^T}$$

is a measure of the interest rate on the coupon bond.

## Pricing Safe Cash Flows

In fact, the US Treasury allows financial institutions to break US Treasury coupon bonds down into portfolios of separately-traded discount bonds.

These securities are called US Treasury STRIPS (Separate Trading of Registered Interest and Principal of Securities).

## Pricing Safe Cash Flows

Next, consider an asset that generates an arbitrary stream of safe (riskless) cash flows  $C_1, C_2, \dots, C_T$ , over the next  $T$  years.

To simplify the task of “pricing” this asset, we might view it as a portfolio of more basic assets: one that pays  $C_1$  for sure in one year, one that pays  $C_2$  for sure in two years,  $\dots$ , and one that pays  $C_T$  for sure in  $T$  years.

The price of the multi-period asset must equal the sum of the prices of the more basic assets.

## Pricing Safe Cash Flows

We've now reduced the problem of pricing any riskless asset to the simpler problem of pricing a more basic asset that pays  $C_t$  for sure  $t$  years from now.

But this more basic asset has the same payoff as  $C_t$   $t$ -year discount bonds. Its price  $P_t^A$  today must equal

$$P_t^A = C_t P_t = \frac{C_t}{(1 + r_t)^t},$$

the present discounted value of its cash flow.

## Application to Forward Rates

Suppose you want to borrow \$1  $n - 1$  years from now.

Repay with interest  $n$  years from now.

Lock in the “ $n$ -year forward rate”  $r_n^f$  today.

## Application to Forward Rates

Suppose you want to borrow \$1  $n - 1$  years from now.

To receive \$1  $n - 1$  years from now: buy an  $(n - 1)$ -year discount bond.

The problem is, this costs  $P_{n-1}$  today.

## Application to Forward Rates

To receive \$1  $n - 1$  years from now: buy an  $(n - 1)$ -year discount bond.

The problem is, this costs  $P_{n-1}$  today.

By selling short  $P_{n-1}/P_n$   $n$ -year discount bonds today, you'll receive

$$\left( \frac{P_{n-1}}{P_n} \right) P_n = P_{n-1}$$

to pay for the  $(n - 1)$ -year discount bond.

## Application to Forward Rates

To receive \$1  $n - 1$  years from now: buy an  $(n - 1)$ -year discount bond.

By selling short  $P_{n-1}/P_n$   $n$ -year discount bonds today, you'll have to repay  $\$(P_{n-1}/P_n)$   $n$  years from now.

$$1 + r_n^f = \frac{\text{amount repaid } n \text{ years from now}}{\$1 \text{ received } (n - 1) \text{ years from now}} = \frac{P_{n-1}}{P_n}$$

## Application to Forward Rates

$$1 + r_n^f = \frac{\text{amount repaid } n \text{ years from now}}{\$1 \text{ received } (n - 1) \text{ years from now}} = \frac{P_{n-1}}{P_n}$$

$$r_n^f = \frac{P_{n-1}}{P_n} - 1$$

Note that forward rates can be computed from discount bond prices that are observed today. No forecasting is necessary.

# Pricing Safe Cash Flows

Using discount bond prices, we can compute:

1. Interest rates on discount bonds.
2. Prices of coupon bonds.
3. Prices of more complex risk-free assets.
4. Forward rates.

## Pricing Safe Cash Flows

We've now reduced the problem of pricing any riskless asset to the simpler problem of pricing a more basic asset that pays  $C_t$  for sure  $t$  years from now.

But this more basic asset has the same payoff as  $C_t$   $t$ -year discount bonds. Its price  $P_t^A$  today must equal

$$P_t^A = C_t P_t$$

where  $P_t$  is the price of a  $t$ -year discount bond.

## Pricing Safe Cash Flows

And since the price and interest rate of the  $t$ -year discount bond are related via

$$P_t = \frac{1}{(1 + r_t)^t}$$

It is also the case that

$$P_t^A = C_t P_t = \frac{C_t}{(1 + r_t)^t}$$

the price of any safe asset equals the present discounted value of its future cash flows.

## Pricing Safe Cash Flows

$$C_t P_t = P_t^A = \frac{C_t}{(1 + r_t)^t}$$

How can we extend these pricing principles to apply to risk assets? There are two possibilities, one in each direction.

## Pricing Risky Cash Flows

Consider a risky asset, with cash flows  $\tilde{C}_1, \tilde{C}_2, \dots, \tilde{C}_T$  over the next  $T$  years that are **random variables** with values that are unknown today.

Again, we might simplify the task of pricing this asset, by viewing it as a portfolio of more basic assets, each of which makes a random payment  $\tilde{C}_t$  after  $t$  years, then summing up the prices of all of these more basic assets.

But we still have to deal with the fact that the payoff  $\tilde{C}_t$  is risky.

## Pricing Risky Cash Flows

One possibility is to break down the random payoff  $\tilde{C}_t$  into separate components  $C_{t,1}, C_{t,2}, \dots, C_{t,n}$  delivered in  $n$  different “states of the world” that can prevail  $t$  years from now.

The risky asset that delivers the random payoff  $\tilde{C}_t$   $t$  years from now can itself be viewed as a portfolio of contingent claims:  $C_{t,1}$  contingent claims for state 1,  $C_{t,2}$  contingent claims for state 2,  $\dots$ , and  $C_{t,n}$  contingent claims for state  $n$ .

## Pricing Risky Cash Flows

This **Arrow-Debreu** approach to asset pricing then computes

$$P_t^A = q_{t,1}C_{t,1} + q_{t,2}C_{t,2} + \dots + q_{t,n}C_{t,n}$$

where  $q_{t,i}$  is the price today of a contingent claim that delivers one dollar if state  $i$  occurs  $t$  years from now and zero otherwise, inferred most likely from prices of options on the S&P 500.

This approach uses contingent claims as the “basic building blocks” for risky assets, in the same way that discount bonds can be viewed as the building blocks for coupon bonds.

## Pricing Risky Cash Flows

In probability theory, if a **random variable**  $\tilde{X}$  can take on  $n$  possible values,  $X_1, X_2, \dots, X_n$ , with probabilities  $\pi_1, \pi_2, \dots, \pi_n$ , then the **expected value** of  $\tilde{X}$  is

$$E(\tilde{X}) = \pi_1 X_1 + \pi_2 X_2 + \dots + \pi_n X_n.$$

## Pricing Risky Cash Flows

More traditional approaches to asset pricing replace the random payoff  $\tilde{C}_t$  with its expected value  $E(\tilde{C}_t)$  and then “penalize” the fact that the payoff is random by discounting it at a higher rate

$$P_t^A = \frac{E(\tilde{C}_t)}{(1 + r_t + \psi_t)^t}$$

The **capital asset pricing model** (CAPM) will give us a way of determining values for the **risk premium**  $\psi_t$ .

## Two Perspectives on Asset Pricing

$$\text{Arrow-Debreu} \Leftrightarrow C_t P_t = P_t^A = \frac{C_t}{(1+r_t)^t} \Rightarrow \text{CAPM}$$

## Two Perspectives on Asset Pricing

Although all are designed to accomplish the same basic goal – to value risky cash flows – different theories of asset pricing can be grouped under two broad headings.

**No-arbitrage** theories take the prices of some assets as given and use those to determine the prices of other assets.

**Equilibrium** theories price all assets based on the principles of microeconomic theory.

# Two Perspectives on Asset Pricing

No-arbitrage theories require fewer assumptions and are sometimes easier to use.

We've already used no-arbitrage arguments, for example, to price stocks and bonds as portfolios of contingent claims and to price coupon bonds as portfolios of discount bonds.

## Two Perspectives on Asset Pricing

But no-arbitrage theories raise questions that only equilibrium theories can answer.

Where do the prices of the basic securities come from? And how do asset prices relate to economic fundamentals?

As an equilibrium theory of asset pricing, the CAPM will also help us answer these questions.

## Two Perspectives on Asset Pricing

Whereas no-arbitrage theories require only that investors prefer more to less . . .

. . . the CAPM requires us to make assumptions about how investors trade off risk versus return.

# Two Perspectives on Asset Pricing

	Arrow-Debreu	CAPM
Analytic Device	contingent claims	risk premia
Scope of Theory	no-arbitrage	equilibrium
Assumptions	more preferred to less	+ risk aversion