# Financial Risk Management

## Derivatives

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2022

# What are derivatives

A derivative is

- a financial security or contract whose value **derives** from the value of another asset / assets, known as the **underlying** (UL)
- an instrument for **transferring risk** and can therefore be used for
  - **hedging**: alter the exposure to an asset / risk you already have
  - **investment / speculation**: take on an exposure to an asset / risk

# Forward

A forward is

- an OTC (over-the-counter) contract in which two counterparties agree, with zero money down, to buy / sell the UCL at a pre-agreed *forward price* at a given *delivery date* in the future

**Example**

a forward contract to exchange 1m barrels of crude oil in 3 months at a forward price of USD 95/barrel

At the *delivery date*:

- The buyer (Long) delivers: forward price USD 95m
- The seller (Short) delivers: UL 1m barrels of crude oil

# Payoff of a forward

## Notations

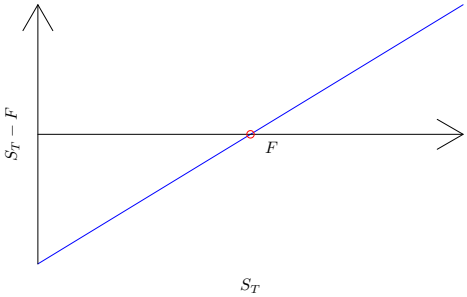
$F$: forward price

$T$: delivery date

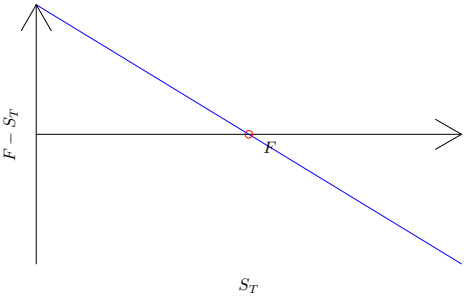
$S_T$: the spot price of the underlying on the delivery date

## Payoff diagrams

**Payoff to Long at $T$**




**Payoff to Short at $T$**



# Forwards vs Futures

Futures are **exchange-traded** version of forwards

| | **Forwards** | **Futures** |
|---|---|---|
| Buyer-seller interaction | Direct | Via exchange |
| Default-risk borne by | Individual parties | Exchange |
| Default controlled by | Collateral | Margin accounts daily "marking to market" |
| Contract terms | Tailored | Standardized |
| Unilateral reversal | Difficult | Easy |

# E-mini S&P500 Index Futures Contract

Most popular equity index futures contract in the world

- **Contract size**: \$50 $\times$ S&P500 Index price (0.2 of the standard S&P500 futures contract)
- **Contract month**: March quarterly expiration cycle (Mar, Jun, Sep, Dec)
- **Trading hours**: CME Globex (essentially around the clock from Sunday evening to late Friday afternoon)
- **Trading termination**: 8.30am on the Settlement Date (3rd Friday of the contract month)
- **Settlement procedure**: Cash settlement based on the Special Opening Quotation on Friday morning of the S&P500 Index
- **Position limits**: 20,000 S&P500 contracts or equivalent net long or short in all contract months combined

# Futures contracts - marking to market

- Similar economic effect to forwards, but, due to **marking to market**, gains and losses on futures positions are settled each day
- After **marking to market**, both sides have a zero value position with the new (end of day) futures price.
- The long receives from (pays to) the short any increase (decrease) in the futures price from the previous day

| Date | 0 | 1 | 2 | 3 | $T = 4$ |
|---|---|---|---|---|---|
| Future price | 106 | 108 | 104 | 105 | $S_T = 107$ |
| Long receives | 0 | 108-106=2 | 104-108=-4 | 105-104=1 | 107-105=2 |

- Note that $\sum$(cash flow long receives) $= 1$, equal to the payoff on a forward position where the forward price is the original futures price $S_T - F = 107 - 106 = 1$

# Fair forward price

- Consider a stock
  - currently traded at £40
  - does not pay dividends
  - with an expected return of 5% p.a.
  - risk-free rate is 2% p.a.
- How much would you **agree to** today, to pay to buy the stock a year from now?

**(a)** £40
**(b)** £40.8
**(c)** £42

# Arbitrage-free pricing

Replicate the same cashflow as a long forward contract by buying the stock today using borrowed money and repaying the borrowing with interest at $T$:

| | Today | **Delivery date** $T$ |
|---|---|---|
| **Long forward** | 0 | $S_T - F$ |
| "Cash and carry" replicating strategy: | | |
| Buy stock today | $-40$ | $S_T$ |
| Borrow £40 for 1 year at 2% | 40 | $-40.8$ |
| **Net** | 0 | $S_T - 40.8$ |

The fair forward price is 40.8; otherwise there is an arbitrage opportunity.

For example, if the actual forward price is quoted at 41.2

| | | Today | **Delivery date $T$** |
|---|---|---|---|
| **Buy low:** | Buy stock today | $-40$ | $S_T$ |
| | Borrow £40 for 1 year at 2% | 40 | $-40.8$ |
| | Net | 0 | $S_T - 40.8$ |
| **Sell high:** | Short forward | 0 | $41.2 - S_T$ |
| **Net cash flows** | | 0 | £0.4 |

# Cost of carry relationship

- Consider another stock
  - currently traded at £40
  - pays a dividend of £1 in 5 months
  - with an expected return of 5% p.a.
  - risk-free rate is 2% p.a.
- How much would you **agree to** today, to pay to buy the stock a year from now?

$$40 \times (1 + 2\%) - 1 \times (1 + 2\% \times \tfrac{6}{12}) = 39.79$$

For assets that can be traded spot and stored, forwards futures prices are linked to spot prices through the "cost of carry" relationship:

$$F = S \times (1 + r_j)^T - FV(\text{holding benefits}) + FV(\text{holding costs})$$

where

$F$: forward price

$S$: current spot price

$r_f$: risk-free rate

$T$: maturity of the contract

Holding benefits (costs) are the benefits (costs), typically cashflows, associated with holding the UL that you miss when buying in the future compared to buying now

$FV$: future value, i.e. compounded to $T$ at risk-free rate

# Forward and future – applications

- Contracts for difference (CFDs)
- Profitable alpha (futures overlay) strategies
- Commodities investing

# Contracts for difference (CFDs)

A CFD is a contract between a buyer and a seller, stipulating that:

- if the price of the UL increases, the seller pays the buyer the increase
- if the price falls, the buyer pays the seller the decrease

| Cashflows | Today | $T$ |
|---|---|---|
| to CFD buyer (long) | 0 | $S_T - S$ |
| to CFD seller (short) | 0 | $S - S_T$ |

In addition:

- the buyer pays the seller daily interst on the initial value of the UL
- the seller pays the buyer any dividends / coupons on the underlying
- margin requirements for end user

# CFDs vs forwards & futures

| Cashflows | Today | From today to $T$ | $T$ |
|---|---|---|---|
| to CFD buyer (long) | 0 | interest on $S$ | $S_T - S$ |
| to CFD seller (short) | 0 | 0 | $S - S_T$ |

# Is the forward price the expected spot price?

- is $F = \mathbb{E}[S_T]$
- Simplest setting: ignoring holding costs / benefits, using simple compounding at an annual risk-free rate $r_f$, for a 1-year forward

$$F = S \times (1 + r_f)$$

- According to standard finance theories, the (risky) UL should earn a risk premium $\pi$

$\mathbb{E}[S_T] = S \times (1 + r_f + \pi)$

therefore $F \neq \mathbb{E}[S_T]$

- Actual payoff on a long forward: $S_T - F$
- The **expected** payoff on a long forward is

$$\mathbb{E}[S_T - F] = S \times (1 + r_f + \pi) - S \times (1 + r_f) = S \times \pi$$

- The expected return on the long forward (as a percentage of the *current price of the underlying*) is the risk premium
- By going long (short) forwards / futures you assume (lay off) the risk premium on the UL

# Portable alpha strategies

- According to the CAPM, the risk premium on a stokc or portfolio is:

$\mathbb{E}(R_i) - R_f = \beta[\mathbb{E}(R_m) - R_f]$ where $\beta = \frac{\sigma_{R_i,R_m}}{\sigma^2_{R_m}}$

where:

$R_i, R_m$: the returns on the portfolio and the "market", respectively

$R_f$: the risk-free rate of return

$\mathbb{E}[]$: expected value

$\sigma_{R_i,R_m}$: the covariance between $R_i$ and $R_m$

$\sigma^2_{R_m}$: the variance of $R_m$

- The expected excess return on a stock is compensation for taking on (non-diversifiable) "market" risk

If you run the regression:

$$R_i - R_f = \alpha + \beta(R_m - R_f) + \epsilon$$

and securities are efficiently priced, alpha should not be statistically significantly different from zero

- For actively managed portfolios, if alpha is positive this is typically interpreted as evidence of stock-picking ability

Use futures overlays to create a position where you earn beta in one asset category and alpha in another:

- You have £1m to invest and a target beta of 1 wrt the S&P500
- You believe there are no alpha opportunities in S&P500 stocks but you have identified a market-neutral (zero-beta) hedge fund that you believe will generate positive alpha

To capture the S&P beta return as well as the hedge fund alpha:

- invest £1m in the "market-neutral" hedge fund
- go long £1m 1-yr S&P500 futures

# Commodity forwards / futures pricing

- The cost of carry relationship

$F = S + \text{intest cost} - \text{holding benefit} + \text{holding costs}$

- For commodities, this becomes

$F = S + \text{intest cost} - \text{convenience yield} + \text{storage costs}$

Convenience yield

- The convenicen yield (CY) is a holding benefit
- Unlike holding benefits on financial aseets (eg dividends or coupons), CY is NOT a cashflow ensured if you are long the underlying
- The CY captures the "intangible" benefits of holding the underlying spot for those who consume it / use it in production

# Investing in commodities

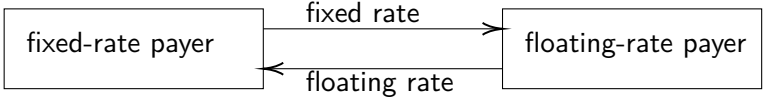
Commodities as an asset class

- low (negative) correlations with stocks and bonds
- hedge against inflation ("real return" asset class)
- exposure to emerging markets growth ("commodities super cycle")
- strong performance (relative to equities) during 2000-2007

# Swap

## Interest rate swap

Arrangement, applied to some notional principal, wherein interest at a predetermined fixed rate is exchanged for interest at a floating reference rate is exchanged for interest at a flating interest rate, with one or more regular exchanges being made for an agreed period of time



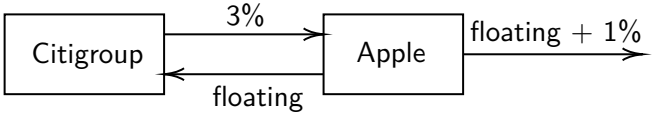
## Overnight indexed swap

Interest rate swap wherein a fixed rate of interest (the OIS rate) is exchanged for a reference rate of interest calculated from a realized overnight rate (e.g. SONIA, SOFR).

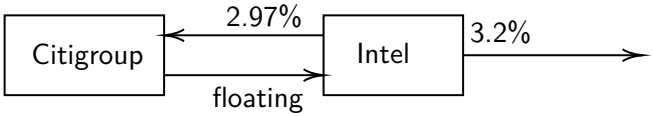
- If there is only one exchange, the OIS rate is a **risk-free zero rate** equivalent to the UL overnight rate.
- Otherwise, the OIS rates define a risk-free bond worth par.
- An OIS rate can be contrasted with a LIBOR swap, wherein the LIBOR rate for a period is known as the start of the period, so the floating rate of the first exchange is known.

# Interest rate swaps: transferring liabilities

Apple uses a swap to convert **floating**-rate borrowings to **fixed**-rate borrowings:

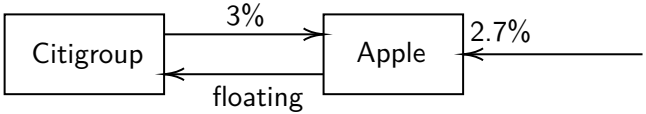



Intel uses a swap to convert **fixed**-rate borrowings to **floating**-rate borrowings:

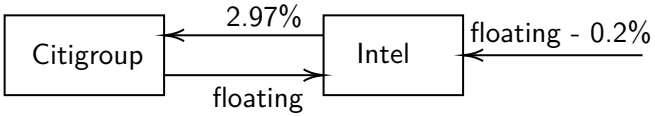


# Interest rate swaps: transferring assets

Apple converts a **fixed**-rate investment to **floating**-rate investment:




Intel converts a **floating**-rate investment to **fixed**-rate investment:

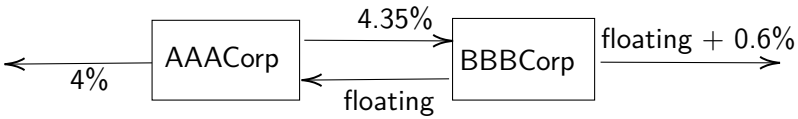


# Comparative advantage

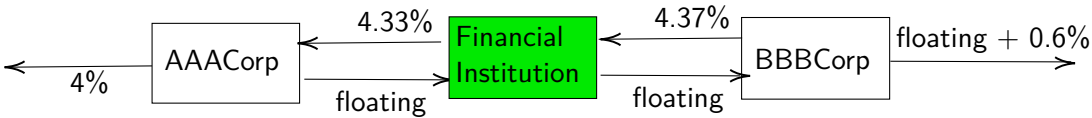
Why use swaps? One reason might be **comparative advantage**: a company might have a relative advantage to borrowing in either fixed-rate markets or floating-rate markets.

| | fixed rate | floating rate |
|---|---|---|
| AAACorp | 4.0% | floating - 0.1% |
| BBBCorp | 5.2% | floating + 0.6% |

Here, AAACorp and BBBCorp might seek to collaborate:



In practice, the swap might be **brokered** by a financial institution:



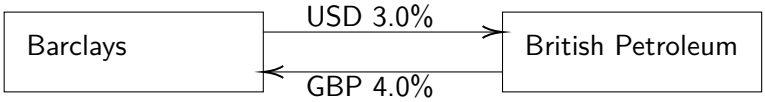

Why has comparative advantage not been arbitraged away?

The **maturities** of contracts available via fixed-rate financing are generally different than those available via floating-rate financing:

- Fixed-rate contracts are often longer than floating-rate contracts
- The spread over the reference rate can effectively be adjusted by floating-rate lenders
- Fixed-rate lenders often lack this option

# Currency swaps

**fixed-for-fixed currency swap**: arrangement wherein principal and interest payments in one currency are exchanged for principal and interest payments in another currency

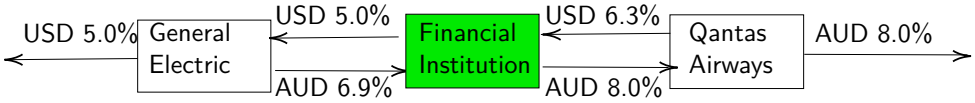



Variations:

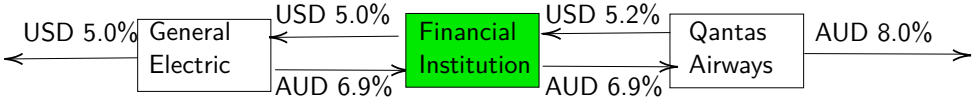
- fixed-for-floating currency swap
- floating-for-floating currency swap
- quanto (or diff swap): arrangement wherein a rate observed in one currency is applied to a principal amount in another currency

# Currency swaps: example with comparative advantage

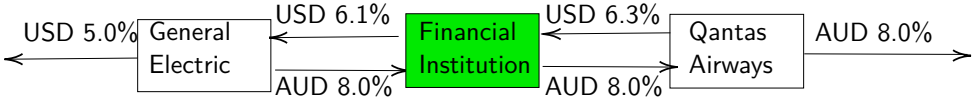
Suppose that General Electric has a **comparative advantage** to borrowing in USD and Qantas Airways has a **comparative advantage** to borrowing in AUD. Financial institution could reduce both of their costs by taking on FX risk:




It might be more cost-effective for Quantas Airways to bear some FX risk:




Or it might be more cost-effective for General Electric to bear some FX risk:



# Other swaps

**Equity swap**: agreement to exchange the total return (dividends plus gains) of an equity index for a fixed for floating rate of interest.

**Credit default swap**: agreement that generates a payment if a particular company (the reference entity) defaults

- the **protection buyer** pays the **CDS spread** (and insurance premium) over the life of the contract
- in the event of default, the **protection seller** pays an amount that would restore the value of the hypothetical portfolio of the bonds of the reference entity to the value of its principal

Options:

- entendable swap: one party can extend the swap arrangement
- puttable swap: one party can terminate the swap arrangement early
- swaption: option on a swap

# Thank you!

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# References I