

# 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

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

The contract is an *obligation* of both parties to transact, designed to protect both the buyer and the seller from price fluctuations in the future.

# Investment assets and consumption assets

**Investment asset:** asset normally held for investment purposes

- ▶ financial assets: stocks, bonds
- ▶ precious metal: gold, silver

**consumption asset:** asset NOT normally held for investment purposes

- ▶ industrial metals: copper, aluminium
- ▶ agricultural products: orange juice, pork bellies
- ▶ energy products: natural gas, heating oil

## 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

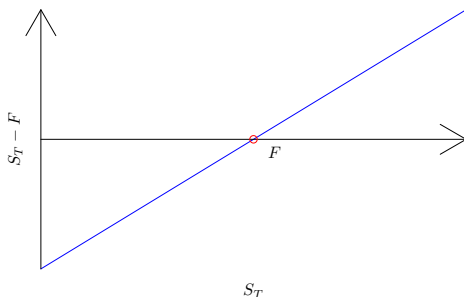
$F$ : forward price

$T$ : delivery date

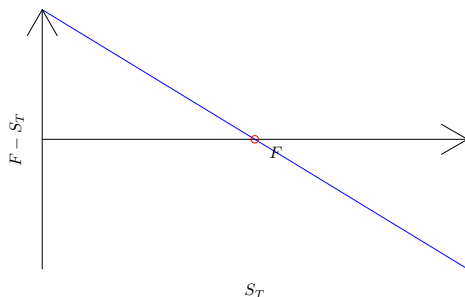
$S_T$ : the spot price of the underlying on the delivery date

## Payoff diagrams

Payoff to Long at  $T$



Payoff to Short at  $T$



# 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 $T$
<b>Long forward</b>	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
<b>Net</b>	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 $T$
<b>Buy low:</b>	Buy stock today	-40	$S_T$
	Borrow £40 for 1 year at 2%	40	-40.8
	Net	0	$S_T - 40.8$
<b>Sell high:</b>	Short forward	0	$41.2 - S_T$
<b>Net cash flows</b>		0	£0.4

## Holding benefits / costs

- ▶ 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?

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

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

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

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

**Futures contract:** fungible, standardized contract for delivery of a specific commodity at a specific delivery or maturity date for an agreed-upon price (the **futures price**), to be paid at contract maturity

**Futures market:** market for trading **futures contracts** wherein buyers and sellers in a centralized futures exchange (wherein some flexibility is sacrificed for **liquidity**)

The **futures exchange** establishes features of the contract:

- ▶ **size** of the contract: mass, volume, number of units
- ▶ acceptable **grade** of the commodity
- ▶ contract **delivery dates**
- ▶ nature of **settlement**: cash, warehouse receipts

The trader with the **long position** (the buyer) commits to purchasing the commodity on the delivery date.

The trader with the **short position** (the seller) commits to delivering the commodity on the delivery date.

# Forwards vs Futures

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

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

# The clearinghouse

**Clearinghouse:** designated intermediary between a buyer and a seller in a financial market that validates and finalizes the transaction, ensuring that both the buyer and the seller honor their contractual obligations.

- ▶ Traders on both sides face the **clearinghouse** rather than each other.
- ▶ The **clearinghouse** bears the risk of non-performance by any trader.
- ▶ Contracts are therefore **fungible**: traders can reverse a position by entering the countervailing position with the clearinghouse.

# Examples of futures contract

## Commodities:

- ▶ agricultural: oats
- ▶ metals: copper, gold
- ▶ energy: crude oil

## Financial assets:

- ▶ foreign currencies: euro
- ▶ interest rates
- ▶ equity indices
- ▶ single stocks

Delivery can be specified as **physical** or **cash-settled**.

- ▶ Cash settlement provides the trader with the same profit that would result from directly purchasing the units in the spot market.



# E-mini S&P500 Index Futures Contract

Most popular equity index futures contract in the world

- ▶ **Contract size:**  $\$50 \times \text{S\&P500 Index price}$  (0.2 of the standard S&P500 futures contract which has a multiplier of \$250)
- ▶ **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  $\sum(\text{cash flow long receives}) = 1$ , equal to the payoff on a forward position where the forward price is the original futures price  $S_T - F = 107 - 106 = 1$
- ▶ **Convergence property**: at maturity, the futures price and spot price must converge;  $F_T = P_T$

# Normal backwardation and contango

The terms **normal backwardation** and **contango** describe the state of a futures market:

- ▶ In **normal backwardation**, the futures price is less than the expected future spot price,  $F_0 < \mathbb{E}(S_T)$
- ▶ In **contango**, the futures price is greater than the expected future spot price,  $F_0 > \mathbb{E}(S_T)$

In practice, these terms are sometimes used with reference to the current spot price rather than the expected future spot price.

# Margin and open interest

**Margin:** a good-faith deposit to guarantee contract performance

**Marking to market:** daily settling (realizing) of gains and losses with the clearinghouse

**Maintenance margin:** minimum quantity that a trader must hold in reserve with the clearinghouse

- ▶ Margin safeguards the position of the clearinghouse.
- ▶ If the mark-to-market value of the trader's account falls below the maintenance margin, the trader receives a **margin call**.
- ▶ A **margin call** requires the trader to replenish the margin account to the maintenance margin. Otherwise, the position is reduced to a size commensurate with the remaining funds (the trader is **bought in** by the exchange).

**Open interest:** the number of contracts outstanding

- ▶ The position of the clearinghouse always nets out to zero.

# Hedging and speculation

**Hedgers** use futures to insulate themselves (**hedge**) against price movements in the underlying asset.

- ▶ Example: both airplane manufacturers and bauxite miners might seek to hedge their exposure to the price of aluminium.

**Speculators** use futures to profit from movements in futures prices.

- ▶ Speculators take **long** position if they expect an increase in price and a **short** position if they expect a decrease in price.
- ▶ Usually, **transaction costs** in future markets are considerably smaller than in markets for the UL.
- ▶ Speculators also gain the advantage of **leverage** because margin requirements are generally much less than the value of the UL.

# 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

# 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 convenience yield (CY) is a holding benefit, the value of holding a physical asset to keep a production process running or to profit from temporary local shortages
- ▶ Unlike holding benefits on financial assets (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



## 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

## Interest rate futures: estimating forward interest rates

interest rate futures can be used to bootstrap zero curves (e.g. Sterling Overnight Index Average, or SONIA):

$$R_F = \frac{R_2 T_2 - R_1 T_1}{T_2 - T_1}$$

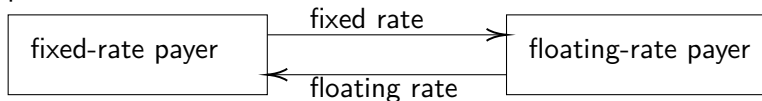
$$R_2 = \frac{R_F(T_2 - T_1) + R_1 T_1}{T_2}$$

$R_1, R_2$ : zero rate for maturities  $T_1, T_2$  respectively

$R_F$ : forward rate applicable to the period from  $T_1$  to  $T_2$

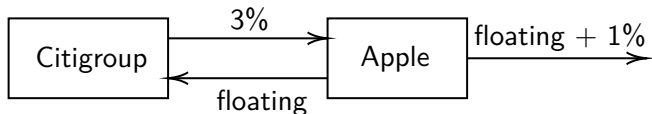
## Interest rate swap

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 floating interest rate, with one or more regular exchanges being made for an agreed period of time

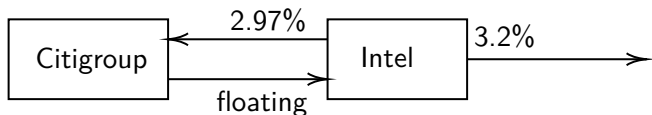


# Interest rate swaps: transferring liabilities

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

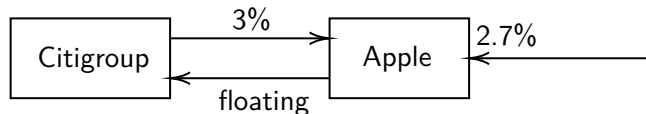


Intel uses a swap to convert **fixed**-rate borrowings to **floating**-rate borrowings:

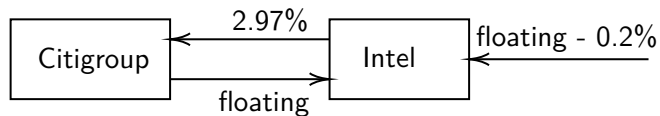


## Interest rate swaps: transferring assets

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



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

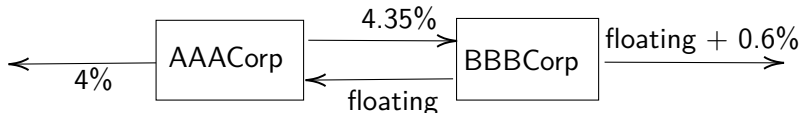


## Comparative advantage

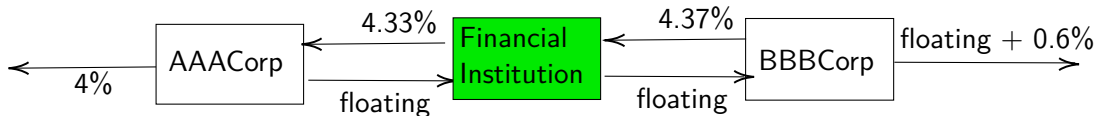
Why use swaps? One reason might be **comparative advantage**: a company might have a relative advantage to borrowing in either fixed-rate markets or floating-rate markets.

	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:



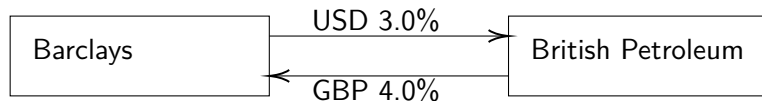
Why has comparative advantage not been arbitrated away?

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



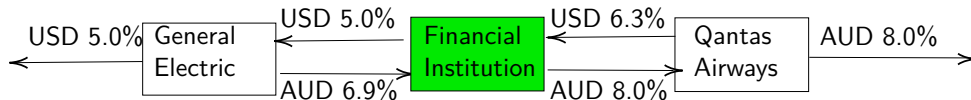
Variations:

- ▶ 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

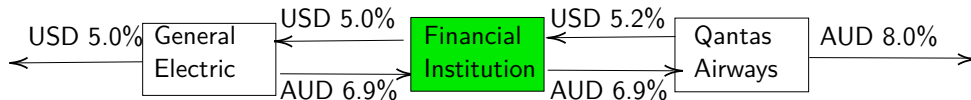


# Currency swaps: example with comparative advantage

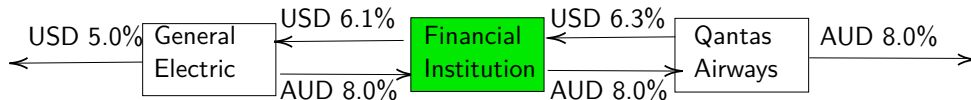
Suppose that General Electric has a **comparative advantage** to borrowing in USD and Qantas Airways has a **comparative advantage** to borrowing in AUD. Financial institution could reduce both of their costs by taking on FX risk:



It might be more cost-effective for Qantas 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:

- ▶ **extendable 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!

## Contact

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