DEUTSCHE BUNDESBANK

Financial Instruments

Fixed Income Instruments,
Equity Instruments,
Derivatives
Structured Products
Credit Derivatives

Programme

DEUTSCHE BUNDESBANK

- **Spot Market Products**
- **Forward Market Products**
- **Structured Capital Market Products**
- **Credit Derivatives**

Basics and fundamentals

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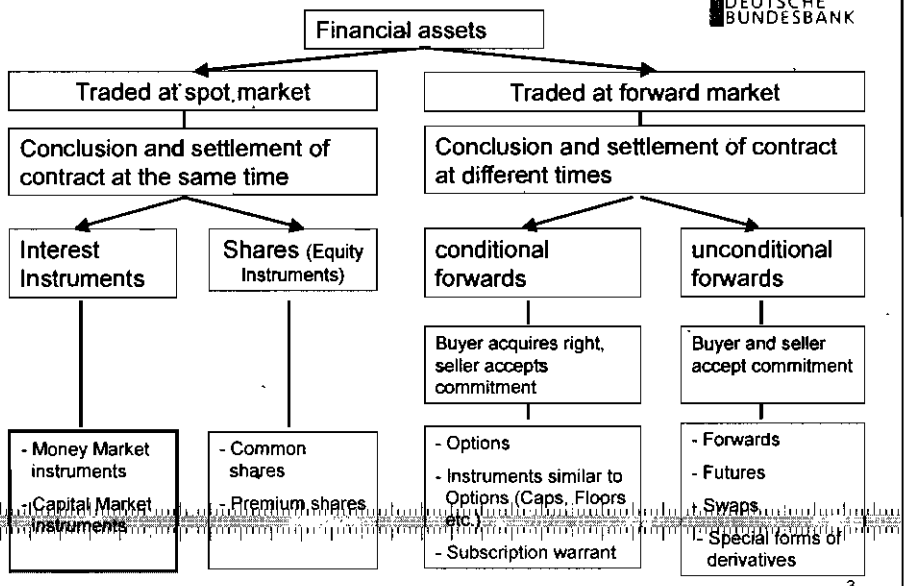

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Basics and fundamentals

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- **Fixed income securities are securities with specified payment dates and amounts, generating direct access to cash-flows of enterprises, banks or government. Typical fixed income securities are:**
  - Money market instrument (short term)
  - Capital market instruments (long term)
  - Equity instruments
- **Fixed income securities are traded on spot market, settlement of contract immediately after conclusion of business, in general after 2 working days**

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Basics and fundamentals

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- **Derivates are securities where payment dates and amounts may vary according maturity and/or amount, Typical derivative instruments are:**
  - Forwards/Futures
  - Options
  - Swaps
- **Derivatives are traded at forward market, settlement after a contracted period (in future)**

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Basics and fundamentals

DEUTSCHE BUNDESBANK

- **Fixed income securities:**
  - Money market instruments: Short term (up to 1 year)
  - In General three national issuers:
    - Government: - Treasury bills / ECB Debt certificates
      - Federal funds
      - Repurchase agreements
    - Commercial Banks: - Certificates of deposit
      - Bankers' acceptances
    - Corporations: - Commercial papers

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Basics and fundamentals

DEUTSCHE BUNDESBANK

- **Government (The Central Bank)**
  - Core institution of the money market
  - Steering general level of interest rates with:
    - open market operations:
      - reverse transaction (Repurchase agreements)
      - outright transaction (Sales of T-Bills/ECB Debt Certificates)
    - Standing facilities: Overnight lending and -depositing
    - Minimum reserves (Europe)/ Federal funds (US)

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Basics and fundamentals

DEUTSCHE BUNDESBANK

- **Government (The Central Bank)**
  - Most important vehicle: purchase and sale of government securities

    Central Bank as a Market partner
    - Treasury-Bills: raising money by selling bills to the public, directly from government, at auction (Tender-procedure) or on secondary market, highly liquid instrument repurchase guaranteed anytime by government, bear no interest rate but are discounted, quoted by yield on discount
    - ECB-Debt certificates: Treasury bills of ECB (EU-Based money market operation)

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Basics and fundamentals

DEUTSCHE BUNDESBANK

- **Government (The Central Bank)**
  - Repurchase agreements
    - Traditional short term loan (EU limited to 1 week, US usually overnight)
    - Increasingly used as long-term loan, either revolving or with fixed maturity
    - Commitment by seller of security to buy it back from buyer at specified date for specified price
    - collateralised loan with government securities (as collateral, i.e. T-Bills)

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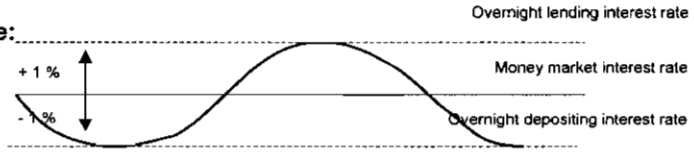
Basics and fundamentals

DEUTSCHE BUNDESBANK

- **Government (The Central Bank)**
- **Standing facilities: Overnight lending and –depositing**
- **Minimum reserves (Europe)/ Federal funds (US)**

set by Central Bank **set by market**

- **In Europe:**



- **In US: Federal funds tradable at market, interest rate as result of market operations**

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Basics and fundamentals

DEUTSCHE BUNDESBANK

- **Commercial Banks**
  - Addressee of monetary policy, interest rates relative to money market transactions of Central Bank. Instruments:
    - Certificate of Deposit (CD): Time deposit, not withdraw able until maturity, can be traded between banks/investors, highly marketable if extremely short-term, classical instrument to finance bank's lending, fixed or floating interest rate, paid periodically or at maturity, interest based on money market rate.

Basics and fundamentals

DEUTSCHE BUNDESBANK

- **Commercial Banks**
  - Banker's acceptance:
    - Drafts guaranteed by issuing bank
    - Often used as a guarantee between domestic producer and foreign buyer
    - Traded on discount basis in US and on money market basis in Europe
    - Purchase price calculated accordingly to T-Bills
    - Price reflects the risk that neither Bank nor importer honour the commitment

Basics and fundamentals

DEUTSCHE BUNDESBANK

- **Corporations**
  - Commercial paper:
    - Unsecured short term debt,
    - Maturity ranging from 2 to 270 days
    - Traded on discount basis in US and on money market basis in EU
    - Slightly more risky than banker's acceptance as no bank guarantees for commitment at maturity date
    - Corporations typically use CPs for short-term fund-raising or interim financing (revolving) for long-term projects
    - Interim financing more risky due to uncertainty of development of interest rates

Basics and fundamentals

DEUTSCHE BUNDESBANK

- **Fixed income securities:**
  - Capital market instruments: Long term (more than 1 year)
    Duration: 1 to 10 years (note) or 10 to 30 years (bond)
  - In General two national issuers:
    - Government: - Treasury notes and bonds
      - Municipal notes and bonds
    - Private sector: - Corporate bonds (banks and corporations)
  - Capital market instruments more standardised than money market instruments
  - Interest rate (coupon) defined by market transactions

Basics and fundamentals

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- **Characteristics of bonds/notes**
- **Purpose: classification**
  - Issuers name (e.g. Bundesrepublik Deutschland)
  - Issuers type (e.g. sector of issuer, oil industry)
  - Issuing market (e.g. US-domestic market, EU domestic market)
  - Issuers domicile
  - Currency denomination
  - Type of guarantee (e.g. underlying collateral as security)
  - Maturity date
  - Coupon type (e.g. fixed interest rate, floating interest rate, step up)

Basics and fundamentals

DEUTSCHE BUNDESBANK

- **Characteristics of bonds/notes**
  - Coupon frequency (annually, semi-annually)
  - Day count type (360 or 365 days)
  - Announcement date (day when bond/note first offered)
  - Interest accrual date (date when interest starts to count)
  - Settlement date (Maturity)
  - First coupon date (date of first payment of interest, not starting to count)
  - Issuance price (Percentage of nominal value, paid at issuance)
  - Spread at issuance (Relation to benchmark bond/ note)

Basics and fundamentals

DEUTSCHE BUNDESBANK

- **Characteristics of bonds/notes**
  - Identifying code (i.e. ISIN: International securities Identification Number, CUSIP Committee on Uniform Securities Identification Procedures)
  - Rating
  - Total amount issued
  - Minimum amount purchasable
  - Nominal Value
  - Redemption value (i.e. Value of repurchase at date of maturity)

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Basics and fundamentals

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- **Example for Description of an US T-Bond**
  - Coupon rate 3,5%
  - Maturity date 11.05.2006
  - Semi-annual coupon
  - Actual day account basis
  - Issued amount equal to 20 Mio. USD
  - Minimum amount that can be purchased is 1.000 USD
  - Bond was issued at 05.05.2001 on the US market
  - Interest began to accrue from this date on
  - The price at issuance was 99,469 %
  - First coupon date is 05.11.2001 (1/2 year after issuance)
  - Rating is AAA

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Basics and fundamentals

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- **Example for Description of an Elf Aquitaine Corporate Bond**
  - Coupon rate 4,5%
  - Bond was issued at 23.03.2001 on the Euro market
  - Maturity date 23.03.2009
  - Annual coupon
  - First coupon date is 23.03.2002 (1 year after issuance)
  - Issued amount equal to 1 Bio. Euro
  - Minimum amount that can be purchased is 1.000 Euro
  - Interest began to accrue from date of issuance on
  - The price at issuance was 98,666 %
  - Spread at issuance 39 basis points over French government T-Bond
  - Rating is AAA

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Basics and fundamentals

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- **Types of bonds/notes**
  - Treasury bonds and notes
  - Federal Agency Debt (in US) Bundesobligationen (in Germany)
  - International Bonds
  - Municipal Bonds
  - Mortgage backed securities
  - Corporate bonds (special form: convertible bond)

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Basics and fundamentals

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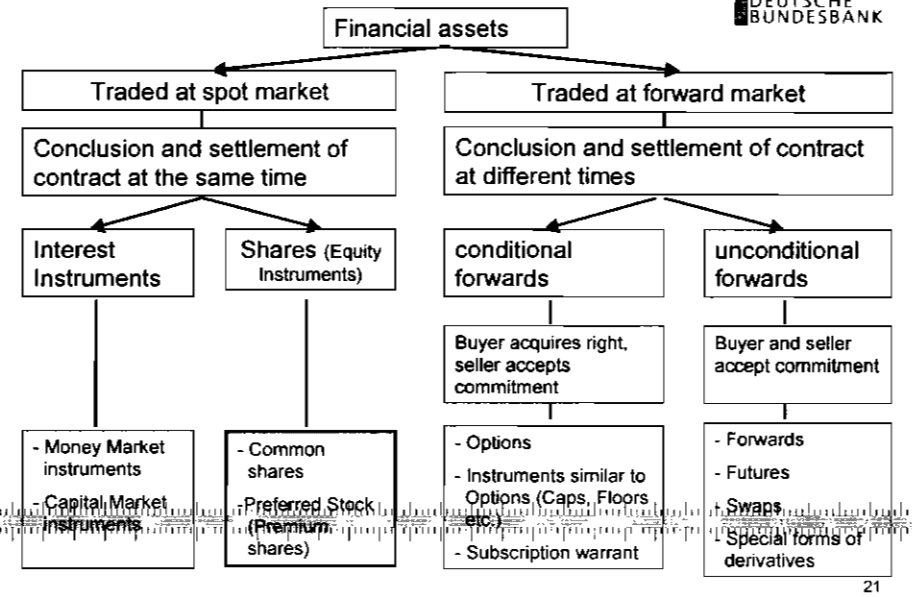

Basics and fundamentals

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- **Equity Securities**
  - Common stock as ownership shares:
    - Representation of ownership of an enterprise
    - Each share gives right to vote on any matter of corporate governance
    - Entitlement to access to annual results, liability in case of insolvency (?)
    - Direct Access to assets and liabilities of an enterprise
    - Separation of Management and ownership
      - Core element of every successful economy
      - Agency problem

Basics and fundamentals

DEUTSCHE BUNDESBANK

- **Characteristics of common stock:**
  - Residual claim:
    - Stockholders are last line who have claim on assets and income
    - In case of going concern of enterprise access to share of profit after settlement of all other fixed income claims
    - Decision of Management to pay dividends to shareholder or to accumulate dividends to increase value of capital
    - In case of liquidation shares generally prove worthless
  - Limited liability
    - Loss limited to original investment
    - Only failure of unincorporated business leads to private liability

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Basics and fundamentals

DEUTSCHE BUNDESBANK

- **Preferred stock**
  - Comparable to bond, promise to pay fixed income to holder, regardless of economic situation of enterprise
  - No voting power regarding the management
  - Unpaid dividend is cumulated and must be paid before any other dividend paid
  - Unpaid dividend bear interest, if these cannot be paid, bankruptcy proceedings are set off.
  - Despite contractual obligation to pay interest, preferred stock dividends are not tax-deductible, neither are interests; received preferred stock dividends are tax-free by 70% (in US and EU)

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Basics and fundamentals

DEUTSCHE BUNDESBANK

- **Preferred stock**
  - In case of bankruptcy, settlement of preferred stock after settlement of bonds/notes, before common stock
  - Price of preferred stock at stock exchange lower than corporate bonds, because
    - due to dividend exclusion in case of bankruptcy in comparison to bonds
    - No participation during management-decision processes
    - Private enterprises cannot use tax redemption for received dividends on preferred stock
  - Issuance comparable to corporate bonds, callable (redeemable) by issuing corporation, conversion into common stock at specified conversion ratio possible

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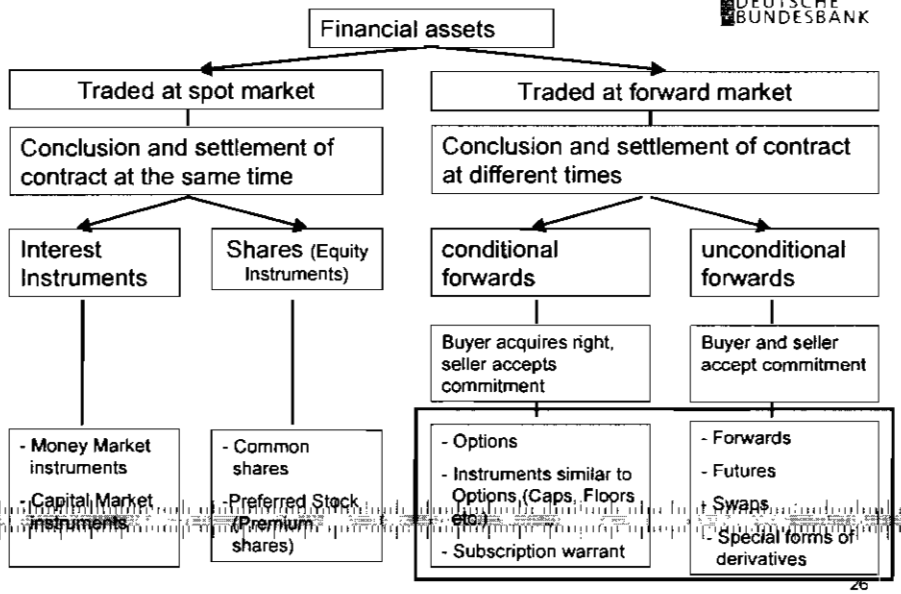
Basics and fundamentals

DEUTSCHE BUNDESBANK



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Basics and fundamentals

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- **Derivatives traded at the forward market (Forward transactions)**
  - Unconditional transaction: fulfilment of business is not linked to a condition, both sides have to fulfil the contract
    Example: Delivery of a specified good at a fixed date for a fixed price
  - Conditional transaction: one party has right to ask for fulfilment or waive contract
    Example: Chance to buy € for specified exchange-rate, if at maturity market value is more favourable for option-holder he can waive option

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Basics and fundamentals

DEUTSCHE BUNDESBANK

- **Derivatives:**
  - Forwards: Contract initiated at one time, performance/settlement occurs in a subsequent time, prior fixture of volume and price, binding for both sides, contract details subject to individual negotiation
    Example: purchase/sale of grain in spring time to be fulfilled in autumn
  - Futures: comparable to Forwards, highly standardised and closely specified concerning price, volume, contract details; guarantee by clearing house

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Basics and fundamentals

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- **Derivatives:**
  - Example for futures: Contract about the sale/purchase of specified contract (i.e. noted at stock or commodity exchange)

→ Important:
- Futures and Forwards are similar products
- Difference only in institutional setting,
- principles for pricing and use are almost identical

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Basics and fundamentals

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- **Derivatives:**
  - Options: Right to sell/purchase agreed amount of goods for fixed price, differentiation between active and passive (silent) market partner, general differentiation between:
    - call option (right to purchase underlying good)
    - put option (right to sell underlying good)
  - seller of option is "option writer", receiving payment for offering option

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Basics and fundamentals

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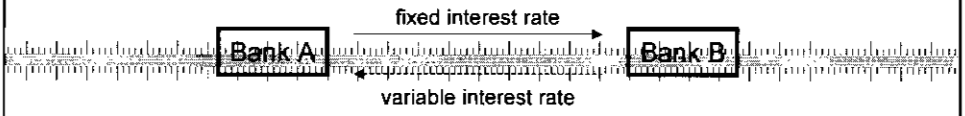
- **Derivatives:**
  - Options on futures: Option that takes a futures contract as underlying good
    Example: option about futures contract about delivery of grain in ½ year for fixed price with option to waive contract if price-development is unfavourable.
  - Swaps: agreement between two ore more parties to exchange sequence of cash flows over a period in the future
    Example: Exchange of variable interest rates against fixed interest rates



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Market-Organisation

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- **Market organisation for Futures contracts: Safeguards for transactions**
  - "Mark to Market" System: Percentage of future to be deposited at clearing house, daily settlement
  - Types of Margins
    - Initial Margin: Initial deposit to be paid before trading of any future contract, equal to maximum daily price fluctuation, for most contracts approx. 5 % of underlying commodity's value.
    - Maintenance Margin: if value of funds on deposit with broker reaches a certain level, additional money has to be delivered to fill up the difference between current price level and future price level, normally 75% of initial margin.
    - Variation Margin: Additional amount that is used to fill the difference between "Initial Margin" and "Maintenance Margin"

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Market-Organisation

DEUTSCHE BUNDESBANK

- **Margins and daily settlement**

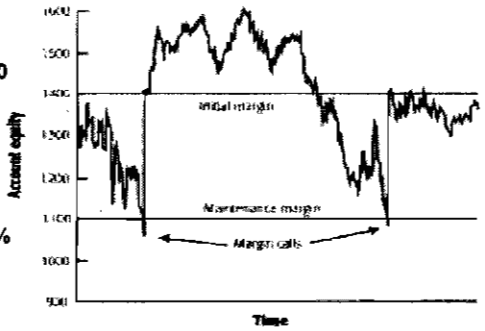
  Example: Oil futures contract of 1000 barrel to be purchased in one month for 28 Euro per Barrel

  Initial Margin: 1,400 € (i.e 5% of 28,000 € value of underlying asset)

  Maintenance Margin: 1,100 € (i.e. 75% of Initial Margin, representing price per barrel of 22 €)

  One week before settlement. price per barrel drops to 21 €, value of deposit now 1,050 €

  Variation Margin to be paid: 350 € (in cash)



Payment(s) at date of settlement:

- **Value of oil contract: 28,000 €**
- **Return of deposits: 1,400 € (Initial Margin)**
  350 € (Variation Margin)

Net payment: 26,250 €

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Market-Organisation

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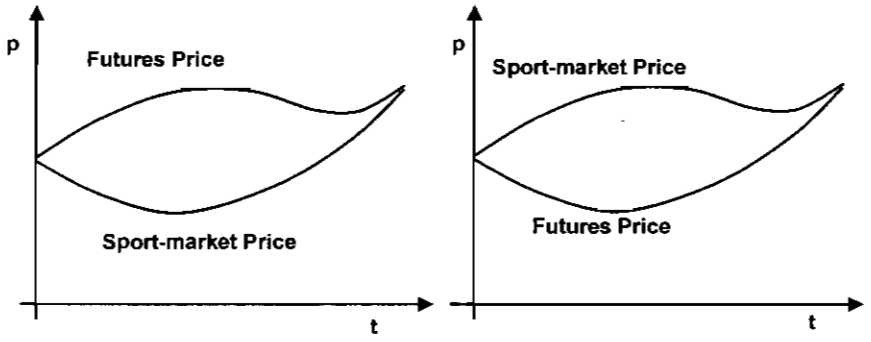
- Convergence of prices at Spot-market and **Futures**-market
  (without consideration of arbitrage)



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Market-Organisation

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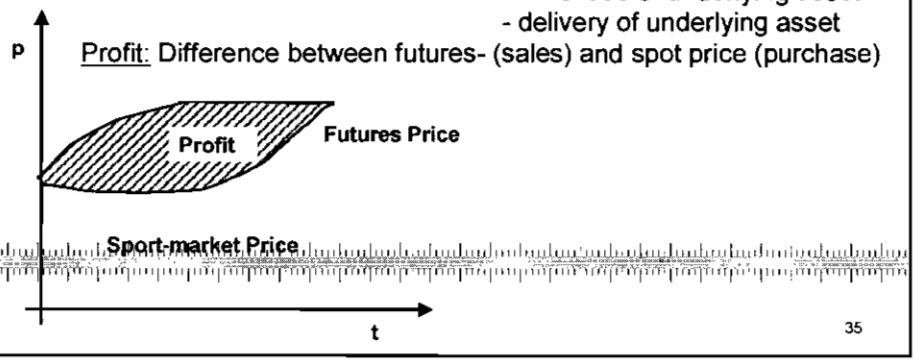
- Convergence of prices at Spot and Futures-market → why?

  → Possibility to gain profit from arbitrage

  Example1: Price at Futures-market higher than at Spot-market

  Option of a seller of contract: - Selling contract at market
  - Purchase of underlying asset
  - delivery of underlying asset

  Profit: Difference between futures- (sales) and spot price (purchase)



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Market-Organisation

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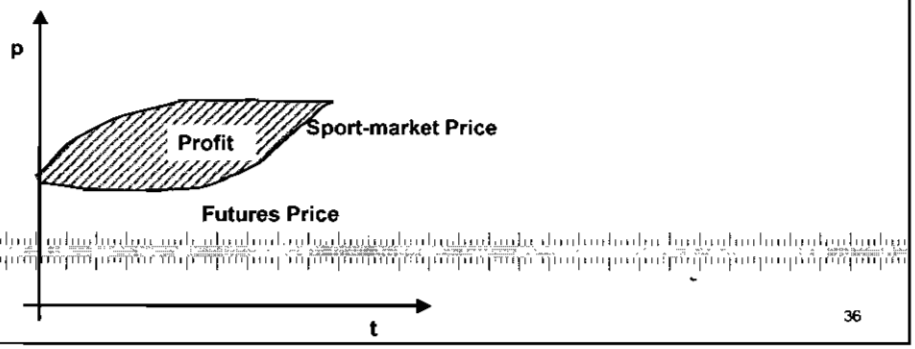
Example 2: Price at Spot -market higher than at Futures -market

Option of the buyer of the contract: - Purchase contract at market
- Purchase of underlying asset
- wait for delivery by counterpart

Profit: Difference between spot- (sales) and futures-price (purchase)



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Market-Organisation

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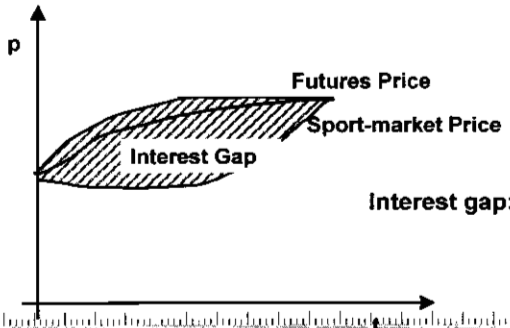
Impact of Arbitrage:

→ Arbitrage always leads to equalising of prices



Interest gap: - Price for storage of goods
- lost interest gains

Market-Organisation

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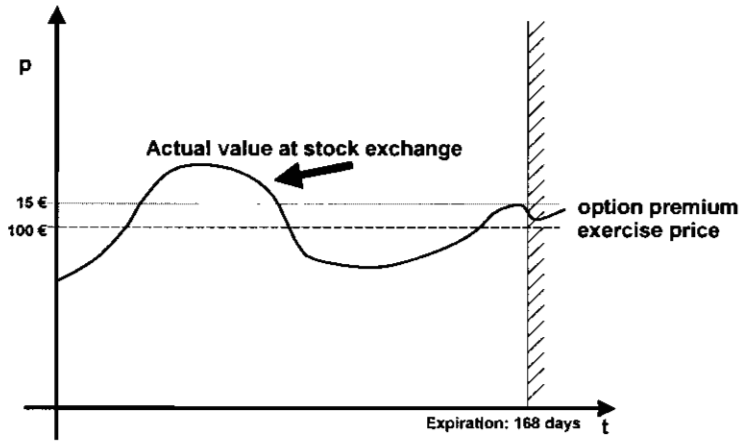
- **Market organisation for Options**
  - Options traded only at organised exchanges
  - In contrary to Forwards/Futures buyer of an option has to pay for the instrument (option premium)
  - Two fundamental kind of options:
    - American option permits the owner to exercise at any time before or at expiration
    - European option permits owner to exercise only at date of expiration
    - → American option allows a higher degree of variations and more possibilities to gain profits
    - → American option more valuable if desirable for option holder to exercise before date of expiration, else no difference in value

Market-Organisation

DEUTSCHE BUNDESBANK



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Market-Organisation

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- **Market organisation for Options**
  - As in case of Futures, trade is exercised via Clearing-house
  - Both sides do not trade directly but via the registered members of a stock exchange (example: "Ring" at the London Metals Exchange)
  - Trade papers (purchase and sales agreement of Option) are matched if records of both sides agree (regarding exercise price, option premium, expiration date); if not, trade is a **"Outtrade"** and exchange works to solve the disagreement
  - Options cannot be bought on credit, buyer of the option (put and call) has to pay the full price (option premium) at the morning of next working day.
  - If seller sells call option with a deposit in background: **"Covered Call"**, if no deposit in background: **"uncovered call"** or **"naked call"**

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Market-Organisation

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- **Market organisation for Options**
  - Differentiation of **"in the money"** and **"out of the money"**
    - in the money: current stock price higher than exercise price
    - out of the money: current stock price lower than exercise price
  - As in case of Futures clearing house is asking for margins to be paid by seller of option
  - Initial Margin to be defined according to exercise price at date of sales of option: - in the money: Initial margin 100% of proceeds from selling the option plus 20% of value of underlying stock
    - out of the money: Initial margin 100% of proceeds from selling the option plus 20% of value of underlying stock minus the amount the option is out of the money.

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Market-Organisation

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- **Market organisation for Options: examples**
  - "Initial Margin in the money":
    current stock price: 105 €
    exercise price: 100 €
    option premium: 6 €
    Initial Margin: 27 €
  - "Initial Margin out of the money":
    current stock price: 95 €
    exercise price: 100 €
    option premium: 6 €
    Initial Margin: 20 €
  - In case of "Initial Margin out of the money" negative values possible

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Effectiveness of Derivatives

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	Long-Position	Short-Position
Call-Option	Long-Call	Short-Call
Put-Option	Long-Put	Short-Put

- Long-Call: Purchase of a Purchase option
  (Option holder = active part)
- Short-Call: Sale of a Purchase option
  (Option writer = passive part)
- Long-Put: Purchase of a Sales option
  (Option holder = active part)
- Short-Put: Sale of a Sales option
  (Option writer = passive part)

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Effectiveness of Derivatives

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Call-Option

Call-option holder = Buyer of Call-Option, having "Long Call"	Call-option writer = seller of Call-Option, having "Short Call"
has	
Right but no obligation to buy underlying asset	Obligation to sell underlying asset upon demand of call option holder

Put-Option

Put-option holder = Buyer of Put-Option, having "Long Put"	Put-option writer = seller of Put-Option, having "Short Put"
has	
Right but no obligation to sell underlying asset	Obligation to buy underlying asset upon demand of put option holder

of

underlying asset:	Specified amount of Shares, Gold, Oil etc
exercise price:	for the value of a pre-defined price
expiry:	until a specified date of expiry

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Effectiveness of Derivatives

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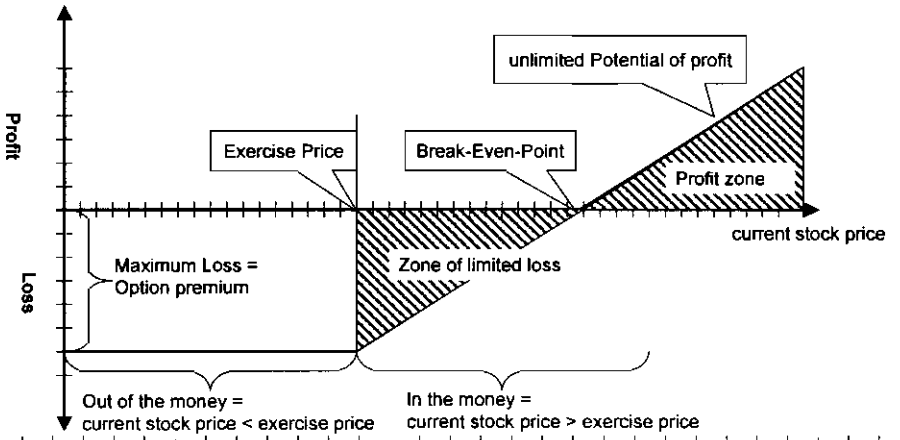
Long-Call



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Effectiveness of Derivatives

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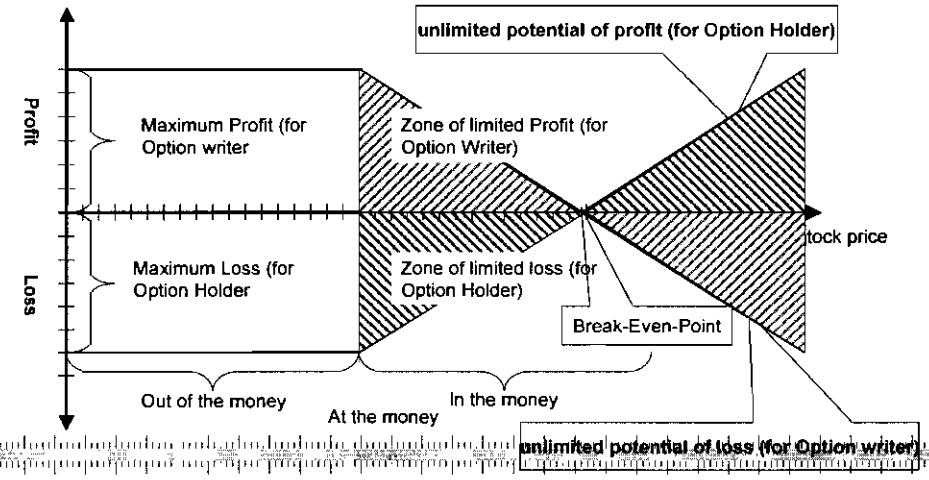
Long-Call / Short-Call



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Effectiveness of Derivatives

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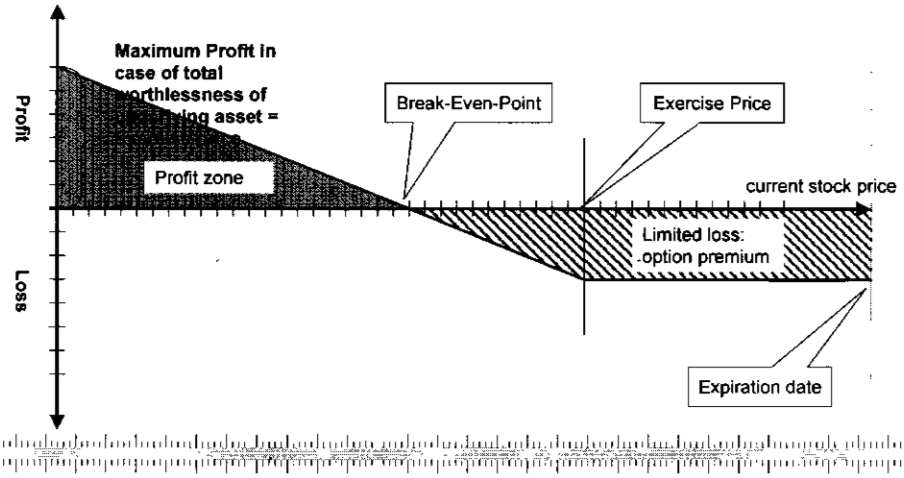
Long-Put



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Effectiveness of Derivatives

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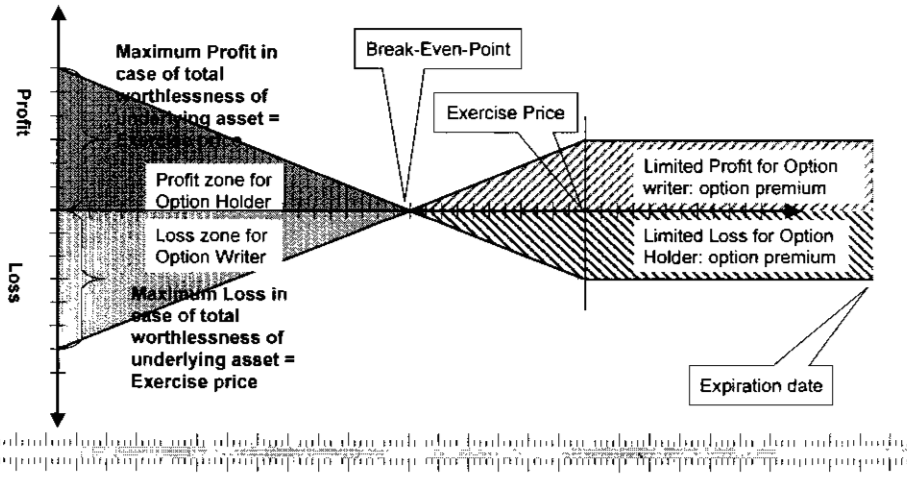
Long-Put/Short-Put



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Effectiveness of Derivatives

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Risks - Opportunities:

- **Long-Call:** Risk limited to Option Premium, Opportunities unlimited
- **Short-Call:** Risk unlimited, Opportunities limited to Option Premium
- **Long-Put:** Risk limited to Option Premium, Opportunities limited to exercise price
- **Short-Put:** Risks limited to exercise price, Opportunities limited to Option Premium
- **Performance Risk not existent due to market regulation**

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Effectiveness of Derivatives

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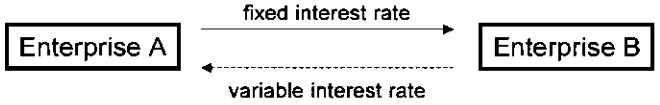
Summary:

- **Agreement between two or more parties to exchange a sequence of cash flows over a period in future**
- **Plain Vanilla Interest Swap: Enterprise A pays to Enterprise B money according to a prior fixed interest rate on virtual capital, whereas Enterprise B pays Enterprise A money according to a variable interest rate on the same amount of virtual capital**



- **Variable interest (at least in Europe) generally related to LIBOR (London Interbank Offer Rate)**

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Effectiveness of Derivatives

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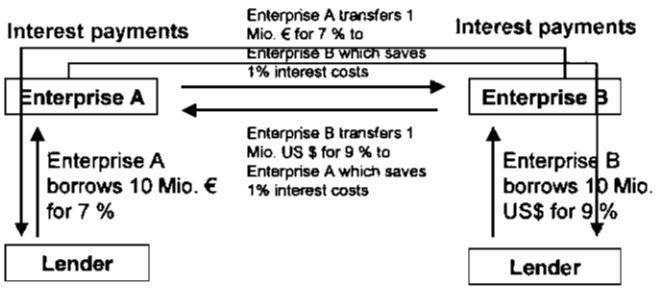
Fixed for fixed currency swaps



Comparative advantage of one enterprise in regard to the other

- For German enterprise (Enterprise A): US$ rate 10% and € rate 7%
- For American enterprise (Enterprise B): US$ rate 8% and € rate 9%
- Exchange rate between US$ and €: 1 US$ = 1 €
- Exchange of borrowings

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Effectiveness of Derivatives

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Basic pre-requisite of a "Fixed for fixed currency swap":

- both parties enjoy comparative advantages that the other respective party is interested.
- Both parties have a relatively equal financial soundness
- Market is inefficient possibility to generate → arbitrage profits
- Costs of transaction considerably high

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Effectiveness of Derivatives

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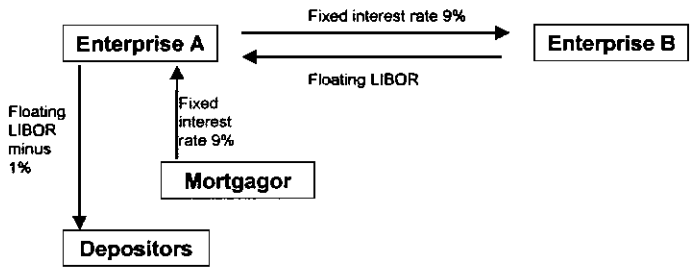
Converting a fixed rate asset into a floating rate asset



Necessity to generate sufficient liquidity

- **Business of a Saving and Loans Associations (Enterprise A): Loan to construction company for fixed rate, Deposit rate is flexible.**
- **Problem: If flexible rate rises higher than fixed rate loss as a consequence**
- **Solution: Offering fixed interest rate to Enterprise B and and receiving floating LIBOR interest rate in return.**

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Effectiveness of Derivatives

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Converting a fixed rate asset into a floating rate asset

Pre-requisite of a conversion of a fixed rate asset into a floating rate asset

- Continuous and synchronised inflow of cash
- Interest to find a market partner with concern to accept suitable (opposite) interest agreements
- Financial soundness of the Mortgagor
- Fungibility of the underlying assets (i.e. mortgage agreement)

- Considerably high risk due to individuality and lack of market regulation

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Effectiveness of Derivatives

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Forex Derivatives

- **Forex Market as total of all transactions related to Foreign exchange**
- **Consisting of: - Spot transactions (Exchange of currency units according to actual exchange rate)**
  - Forward transactions (Exchange of currency units with a fixed exchange rate in future, Forwards, Futures and Options on foreign currencies)
  - Swap transactions (amalgamation of Spot transactions and Forward transactions)
- **Forward transactions as issue of Derivatives**

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Effectiveness of Derivatives

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- **Forex-Forward rate can be noted and traded as "Outright Contract"**
  - with notation of explicit exchange rate

    or
  - Swap-rate-margin / percentage of Swap rate margin
  - Important: Swap-rate in Forex-Derivatives is defined as between Forward currency rate and spot market rate.
  - REPORT: Forward rate > Spot market rate
  - DEPORT: Forward rate < Spot market rate

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Effectiveness of Derivatives

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- **DEPORT**
  - When interest rate of foreign currency higher than domestic interest rate.
  - Here Swap rate is negative and to be deduced from Spot market rate
- **REPORT**
  - When interest rate of foreign currency lower than domestic interest rate.
  - Here Swap rate is positive and to be added to Spot market rate

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Effectiveness of Derivatives

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- **Classical instrument of Forex Derivatives: Foreign currency Hedging**
- **Taking offsetting position in Foreign currency,**
- **Example:**
  - Sales of goods From "Country X" to Germany, payment terms 30 days, to be paid in Euro.
  - Problem: Risk of devaluation of Euro against domestic currency.
  - Solution: Taking a credit in Germany at conclusion of business for 30 days terms, paid by customer,
  - Standardised instrument is foreign currency hedge
- **Calculation of price for hedging instrument relates to Report/Deport as result for expected international interest rate developments**

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Effectiveness of Derivatives

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Credit Derivatives

- Aim: separation of credit risk and ownership of receivable, bond and other credit instruments
- Details of contract to be negotiated individually, at large contract between
- In general trading "over the counter"
- In Europe minimum size of transaction about 5 Mio. Euro
- Transfer of credit risk either over whole duration of validity/contract or a shorter period
- Similarity to credit insurance (without depositing of securities)

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Effectiveness of Derivatives

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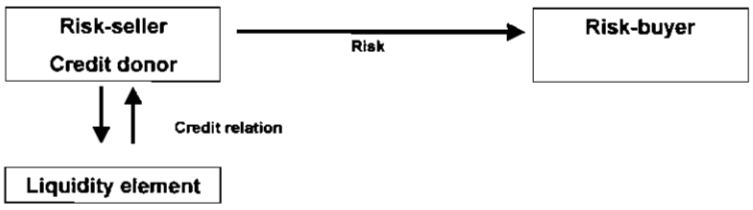
Plain Vanilla arrangement



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Effectiveness of Derivatives

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- **Contract items are:**
  - underlying asset (credit itself)
  - reference asset (scale to measure the extent of default, i.e. Rating)
  - credit event (definition of default, i.e. case of non-payment, downgrade of rating)
  - credit event payment
    - cash settlement (fixed percentage of nominal value of underlying asset - or - difference between nominal value of fixed asset and its current market value
    - physical settlement (in case of bonds: payment in reference-stocks)
    - binary settlement (fixed payment, regardless actual credit-loss)

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Effectiveness of Derivatives

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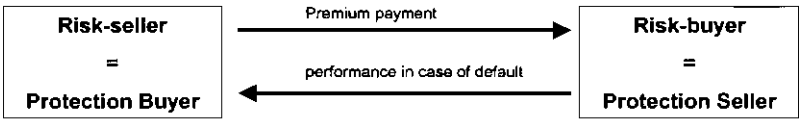

- **Credit Default Swap:**
  - Obligation of risk-buyer to pay in case of pre-specified risk event
  - Protection-buyer agrees to pay risk premium according to risk structure of underlying asset
  - Useful for ordinary credit relations

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Effectiveness of Derivatives

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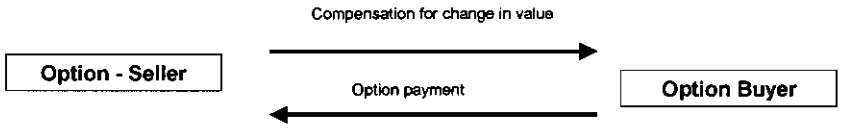

- **Credit Spread Option:**
  - Buyer acquires the right to purchase (call option) of sell (put option) reference asset within limited time.
  - So no coverage of underlying asset itself but of diverging development of reference
  - Example: Underlying asset is payment of rent, compensation not for default, but for loss of market value in relation to average value of fund of rental payments
  - Useful for credit funded investment

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Effectiveness of Derivatives

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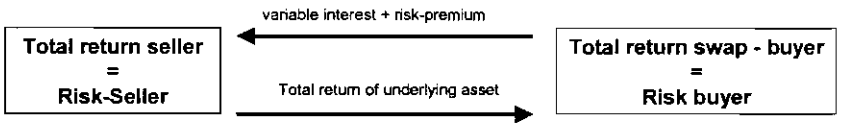

- **Total Return Swap:**
  - Total value of underlying asset including changes of value created through interests (not only credit related changes)
  - Variable interest reflecting changes in market value
  - Payments not linked to credit event but as a periodical compensation payment. If market value below contracted value then compensation payment from risk-buyer, else from risk seller
  - Useful for bonds and similar investments

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Effectiveness of Derivatives

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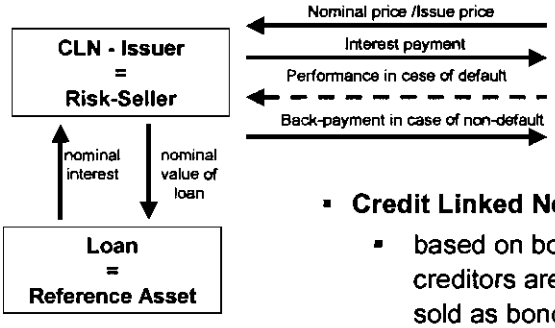

- **Credit Linked Notes:**
  - based on bonded loans: Loans to creditors are made fungible and sold as bond to risk buyer
- Risk buyer receives interest payment
- In case of non-performance of creditor back-payment of non-defaulted part of loan only
- Tradable for asset backed Securities

Mathematics of Financial Instruments

DEUTSCHE BUNDESBANK

- **Option pricing: The Black-Scholes-Option Pricing Formula**

  a) The plain Call-Option

  S = Stock price

  X = Strike price

  r = Risk-free interest rate

  T = Time to expiration (years)

  σ = Price- Volatility of underlying asset

  N = Normal distribution

$$c = S * N(d_1) - X * e^{-rt} * N(d_2)$$

with

$$d_1 = \frac{\ln(\frac{S}{X}) + (r + \frac{\sigma^2}{2}) * T}{\sigma\sqrt{T}}$$

and

$$d_2 = \frac{\ln(\frac{S}{X}) + (r - \frac{\sigma^2}{2}) * T}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T}$$

Mathematics of Financial Instruments

DEUTSCHE BUNDESBANK

- **Option pricing: The Black-Scholes-Option Pricing Formula**

  a) **The plain Call-Option**

  Components of the formula:

  d_1: Probability that stock price may vary through time

  d_2: Probability that Option may be exercised at maturity

  $X*e^{-rT}$: Discounting of Strike-price to maturity

  N: Normal distribution to cover probabilities and developments of prices based on historical experience

Mathematics of Financial Instruments

DEUTSCHE BUNDESBANK

- **Option pricing: The Black-Scholes-Option Pricing Formula**

  a) **The plain Call-Option, Example:**

  European Call-Option, three month (i.e. ¼ year) to expiry, with Stock-Price of 60€ and Strike-Price of 65€, price volatility of 30% and a risk-free interest-rate of 8%. Price to purchase the option?

Components
S = Stock price = 60€
X = Strike price = 65€
r = interest rate = 8%
T = expiration = 0,25 y
σ = Volatility = 30%

Purchase price of Option: 2,13 €

If

$$d_1 = \frac{\ln(\frac{60}{65}) + (0,08 + \frac{0,30^2}{2}) * 0,25}{0,3\sqrt{0,25}} = -0,3253$$

and

$$d_2 = d_1 - 0,30\sqrt{0,25} = -0,4753$$

as well as

$$N(-0,3253) = 0,3725$$

and

$$N(-0,4753) = 0,3173$$

so is

$$c = 60 * 0,3725 - 65 * e^{-0,08*0,25} * 0,3173 = 2,1334$$

Mathematics of Financial Instruments

DEUTSCHE BUNDESBANK

- **Option pricing: The Black-Scholes-Option Pricing Formula**
  b) The plain Put-Option

S = Stock price
X = Strike price
r = Risk-free interest rate
T = Time to expiration (years)
σ = Price- Volatility of underlying asset
N = Normal distribution

$$p = X * e^{-rt} * N(-d_2) - S * N(-d_1)$$

with

$$d_1 = \frac{\ln(\frac{S}{X}) + (r + \frac{\sigma^2}{2}) * T}{\sigma\sqrt{T}}$$

and

$$d_2 = \frac{\ln(\frac{S}{X}) + (r - \frac{\sigma^2}{2}) * T}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T}$$

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Mathematics of Financial Instruments

DEUTSCHE BUNDESBANK

- **Option pricing: The Black-Scholes-Option Pricing Formula**
  b) The plain Put-Option, Example:
  European Call-Option, three month (i.e. ¼ year) to expiry, with Stock-Price of 60€ and Strike-Price of 65€, price volatility of 30% and a risk-free interest-rate of 8%. Price to purchase the option?

Components
S = Stock price = 60€
X = Strike price = 65€
r = interest rate = 8%
T = expiration = 0,25 y
σ = Volatility = 30%

Purchase price of Option: 2,13 €

If

$$-d_1 = \frac{\ln(\frac{60}{65}) + (0,08 + \frac{0,30^2}{2}) * 0,25}{0,3\sqrt{0,25}} = +0,3253$$

and

$$-d_2 = d_1 - 0,30\sqrt{0,25} = +0,4753$$

as well as

$N(0,3253) = -0,3725$

and

$N(+0,4753) = -0,3173$

$$p = 65 * e^{-0,08*0,25} * (-0,3173) - 60 * (-0,3725) = 2,1334$$

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Mathematics of Financial Instruments

DEUTSCHE BUNDESBANK

- **Option pricing: The Black-Scholes-Option Pricing Formula**

  Computer algorithm (calculation with Excel):

  d_1 = (log(S/X) + (r+v^2/2)*T/(v*Sqr(t))

  d_2 = d1-v*Sqr(T)

  p = X*Exp(-r*T)*CND($-d_2$)-S*CND($-d_1$)

  or

  c = S*CND(d_1)-X*Exp(-r*T)*CND(d_2)

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Mathematics of Financial Instruments

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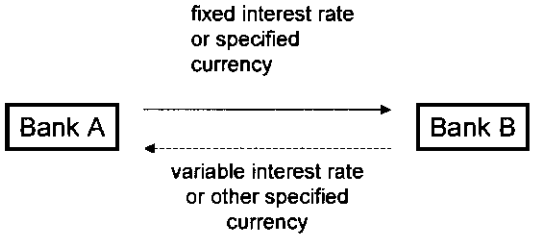
- **Swap pricing:**

  Swap = Exchange of cash-flows of same size but with different conditions on interest and/or currency rates



Problem for Swap pricing: finding the "fair" price for the swap arrangement

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Mathematics of Financial Instruments

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- **Swap pricing:**

→ Conditions/Price for Interest Swaps:

- Euribor or Libor for fixed part of contract
- Agreement on flexible part of contract by negotiation
- Equal treatment of both sides, both parties have same structure of risks and chances

→ Conditions/Price for Currency Swaps:

- Both parts of contract are flexible, due to daily fixing of exchange rates
- Swap Pricing as a method to find suitable balance for chances and risks on both sides

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Mathematics of Financial Instruments

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- **Swap pricing:**

→ Conditions/Price for Currency Swaps:

- Calculation of Swap-rates based on forward contracts
- Unconditional contract to deliver one currency (e.g. €) against another currency (e.g. $)
- Price of forward contracts relate to actual spot exchange rate (e.g. 1 € = 1,24 $)
  Determined by interest rates in currency areas
  Calculation of Spot-Rate

$$F = E_0 * \frac{(1+r_\$)}{(1+r_€)}$$

→ One-period Swap is one-period forward contract, fair swap-rate given by parity relationship

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Mathematics of Financial Instruments

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- **Swap pricing:**

→ Conditions/Price for Currency Swaps:

- Example:
  Actual exchange rate: 1,24 $ for 1 €
  Interest rate USA: 4,5%
  Interest rate Euro-Area: 2,5%

  Forward Price for one period: $F_1 = 0,81 * \frac{(1+0,025)}{(1+0,045)} = 0,79$

  Swap-rate for one Period = 0,79 € for 1 $ or 1,27 $ for 1 €

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Mathematics of Financial Instruments

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- **Swap pricing:**

→ Conditions/Price for Currency Swaps:

- Forward price for two periods, no changes in interest rates considered

$$F = E_0 * \frac{(1+r_\$)}{(1+r_€)}$$

- Result: two different forward rates for the two different periods calculated

$$F_2 = E_0 * \left[\frac{(1+r_\$)}{(1+r_€)}\right]^2$$

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Mathematics of Financial Instruments

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- **Swap pricing:**

→ Conditions/Price for Currency Swaps:

- Example:

  Actual exchange rate: 1,24 $ for 1 €

  Interest rate USA: 4,5%

  Interest rate Euro-Area: 2,5%

  Forward Price for first period: 0,79 € for 1 $ or 1,27 $ for 1 €

$$F_1 = 0{,}81 * \frac{(1+0{,}025)}{(1+0{,}045)} = 0{,}79$$

Forward Price for second period: 0,80 € for 1 $ or 1,25 $ for 1 €

$$F_2 = 0{,}81 * \left[\frac{(1+0{,}025)}{(1+0{,}045)}\right]^2 = 0{,}80$$

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Mathematics of Financial Instruments

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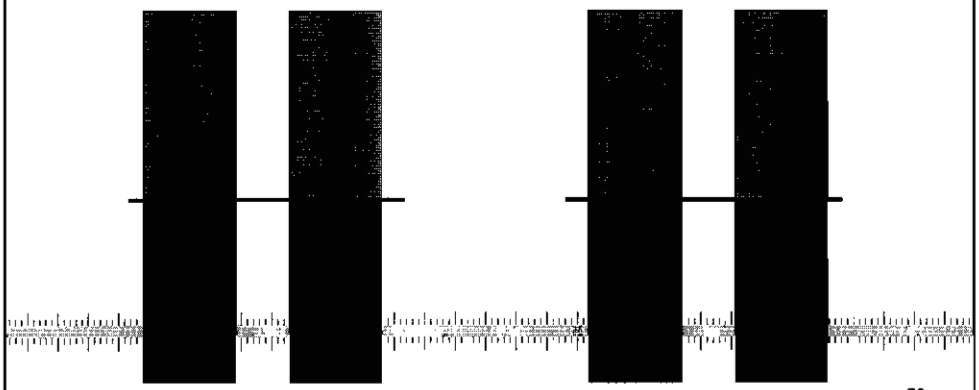
- **Swap pricing:**

Two forward contracts, each priced independently

Two-year Swap arrangement



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Mathematics of Financial Instruments

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- **Swap pricing:**

→ Conditions/Price for Currency Swaps:

- How would be the price for one single two year period instead of two individual contracts covering two consecutive years?

→ Constant USD/Euro-Exchange-rate

- Precondition: The costs of the two-year swap must be equal to two consecutive one-year swaps

$$\frac{F_1}{1+r_1}+\frac{F_2}{(1+r_2)^2}=\frac{F^*}{1+r_1}+\frac{F^*}{(1+r_2)^2}$$

- Result:
  Swap price for 2 years =
  0,795 € for 1 $
  or 1,26 $ for 1 €

with

$$\frac{0,79}{1,045}+\frac{0,80}{1,045^2}=\frac{F^*}{1,045}+\frac{F^*}{1,045^2}$$

leads to

$$F^* = 0,794889$$

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Mathematics of Financial Instruments

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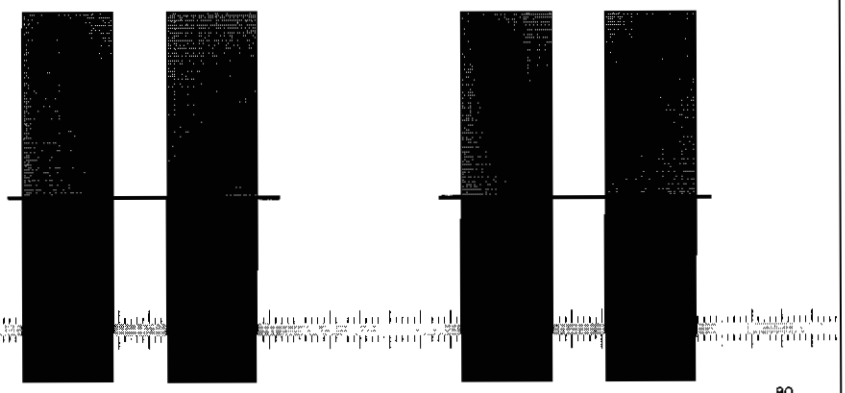
- **Swap pricing:**

Two forward contracts, each priced independently

Two-year Swap arrangement



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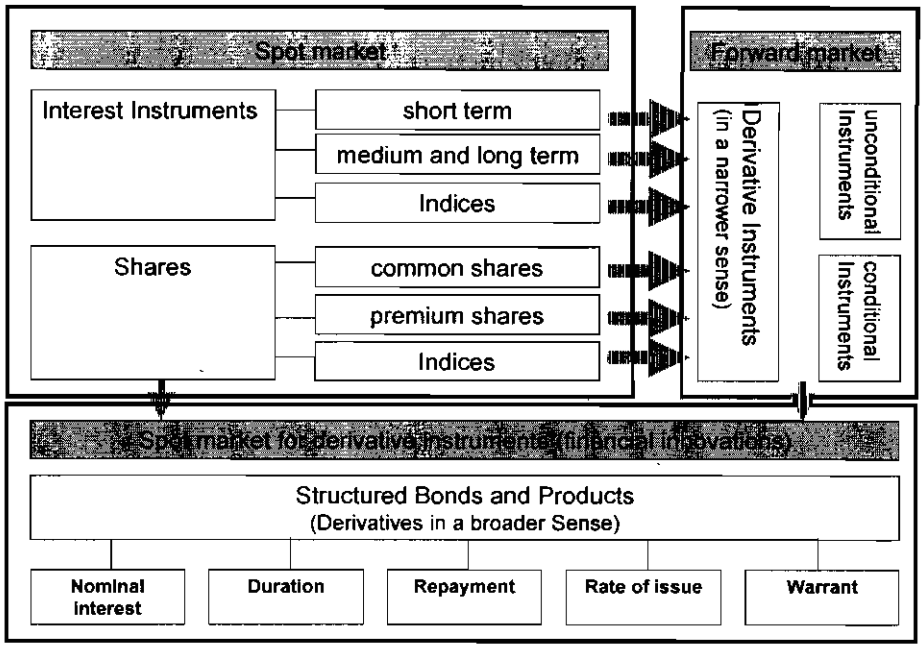

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Structured Capital Market Products

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- **Swaption**
  - Right of buyer to enter into a specific Swap-relation
  - Differentiation of Payer- and Receiver Swaption
  - Buyer of Payer Swaption acquires option to enter into Swap-agreement as payer of fixed interest rate
  - Buyer of Receiver Swaption acquires option to enter into Swap-agreement as receiver of fixed interest rate

Swaption type	fixed rate	variable rate
purchase of receiver swaption	right to receive	right to pay
purchase of payer swaption	right to pay	right to receive
sales of receiver swaption	potential obligation to pay	potential obligation to receive
sales of payer swaption	potential obligation to receive	potential obligation to pay

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Structured Capital Market Products

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- **Swaption**
  - Pricing by Black- Scholes formula of European option on Futures
  - Stock-style: Payment of option premium at conclusion of contract
  - Future-style: Payment of option premium during execution period of contract, Specialty: risk-free interest rate assumed as Zero

$$c = e^{-rT} * \left[F * N(d_1) - X * N(d_2)\right]$$

or

$$p = e^{-rT} * \left[X * N(-d_2) - F * N(-d_1)\right]$$

with d_1 and d_2 as defined before, but "S" replaced by "F"

  - Exercise only when interest rate favorable

Structured Capital Market Products

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- **Swaption**
  - Payer Swaption, Example:
    Right to enter in 1 year into payer Swap and pay fixed interest rate of 3,57%
    Cash settlement: Payment of cash value at maturity if then current interest rate is favourable (i.e. above 3,57%)
    Swap settlement: Entry into the Swap-contract, execution of more than 90% of the contracts by Swap settlement, motivated by hedging
  - Price of Swaption expensive, when yield curve steep, Speculation on rising forward rates
  - Price of Swaption inexpensive, when yield curve flat or inverse, Speculation on decreasing forward rates

Structured Capital Market Products

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- **Swaption**
  - Calculation of risks/chances based on volatility (Vega).
  - The higher volatility, the more expensive is Swaption
  - Definition of "high" volatility due to historical data

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EUR ATM Swaption Straddles - Implied Volatilities

Please call +44 (0)20 7588 7558 for further details

	1Y	2Y	3Y	4Y	5Y	6Y	7Y	8Y	9Y	10Y	15Y	20Y	25Y	30Y
1M Opt	18.6	17.0	15.7	14.4	13.9	12.7	12.1	11.5	11.0	10.5	9.9	9.5	9.3	9.1
3M Opt	19.0	17.7	16.2	14.9	13.9	13.3	12.7	12.2	11.7	11.3	10.6	10.2	9.9	9.6
6M Opt	19.2	17.4	15.6	14.6	13.6	13.	12.6	12.1	11.6	11.2	10.5	10.2	9.9	9.7
1Y Opt	17.8	16.1	14.9	14.0	13.3	12.	12.3	11.9	11.5	11.2	10.6	10.2	10.0	9.8
2Y Opt	16.1	14.6	13.8	13.1	12.6	12.2	11.9	11.6	11.3	11.0	10.4	10.1	9.9	9.8
3Y Opt	14.9	13.8	13.0	12.4	12.	11.8	11.6	11.3	11.1	10.8	10.3	9.9	9.8	9.7
4Y Opt	14.0	13.2	12.5	12.	11.7	11.5	11.3	11.1	10.8	10.6	10.1	9.8	9.6	9.5
5Y Opt	13.5	12.7	12.1	11.6	11.4	11.2	11.0	10.8	10.7	10.5	10.0	9.6	9.5	9.3
7Y Opt	12.6	11.9	11.5	11.0	10.8	10.6	10.4	10.3	10.1	10.0	9.5	9.3	9.2	9.0
10Y Opt	11.7	11.0	10.5	10.2	10.0	9.9	9.8	9.7	9.6	9.5	9.1	8.9	8.8	8.7
15Y Opt	10.0	9.9	9.5	9.4	9.3	9.2	9.2	9.2	9.2	9.2	9.0	8.9	8.8	8.7
20Y Opt	9.6	9.4	9.1	9.1	9.1	9.2	9.2	9.2	9.2	9.2	9.0	8.9	8.7	8.6
25Y Opt	10.1	9.7	9.4	9.3	9.2	9.2	9.2	9.1	9.1	9.1	9.1	8.9	8.7	8.5
30Y Opt	9.9	9.6	9.2	9.2	9.2	9.2	9.2	9.3	9.3	9.3	9.1	8.9	8.5	8.3

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Structured Capital Market Products

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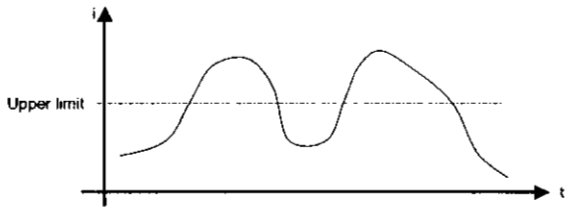
- **Cap**
  - Agreement between seller and buyer of cap, if market interest rate increases a pre-fixed level, compensation (i.e. difference between upper limit and current rate) to be paid to buyer of cap



  - Chance of buyer to take advantage of decreasing interest rate
  - Limitation of costs of financing, especially in a credit-relation

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Structured Capital Market Products

DEUTSCHE BUNDESBANK

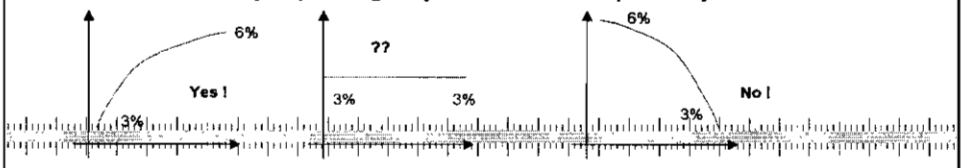
- **Cap**
  - Evaluation of Financial Instrument by decomposition into components (Stripping)

    Components of a credit contract with capped interest rate:

    Credit contract, variable interest rate

    \+ Cap (e.g. on 7%)

    ➔ Compensation payment to Debtor
  - Reasonability depending on yield curve and expectancy of forward rates



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Structured Capital Market Products

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- **Cap**
  - Pricing of the cap by Black- Scholes Formula

$$MV_{Cap} = P(0,T) * \left[F * N(d_1) - K * N(d_2) \right]$$

with d_1 and d_2 defined as before

With

- P = Discount rate
- F = Forward rate
- X = Strike-Price (i.e. the upper limit)
- N = Normal distribution

  - If yield curve decreases, cap looses value
  - Note: materially a cap is a bundle of options to be exercised anytime during maturity (i. e. American options) ➔ Caplets

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Structured Capital Market Products

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- **Cap**

  Worst case: Decrease of Euribor, decrease of Forward rate: Cap looses significant value, due to falling yield curve

  Best case: Rise of Euribor, rise of Forward rate: Cap gains value significantly, yield curve flattens

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Structured Capital Market Products

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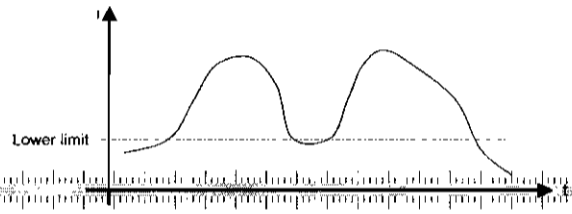
- **Floor**
  - Converse Cap, Contract about a lower level of a floating/flexible interest rate
  - Calculation via the Black – Scholes Option Pricing formula

  Worst case: Rise of Euribor (cash-rate), rise of Forward rate: Cap looses significant value, due to steeper yield curve

  Best case: Fall of Euribor (cash-rate), fall of Forward rate: Cap gains value significantly, yield curve flatter



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Structured Capital Market Products

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- **Summary:**
  Swaptions, Caps, Floors are vulnerable to changes of the yield curve, impact of short term and/or long term interest rates

Instrument	Yield curve steeper	Yield curve flatter
Purchase Cap	+	-
Sale Cap	-	+
Purchae Floor	-	+
Sale Floor	+	-
Purchase Receiver Swaption	-	+
Sale Reciever Swaption	+	-
Purchase Payer Swaption	+	-
Sale Payer Swaption	-	+

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Structured Capital Market Products

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- **Asset Swaps:**
  Change of a
  - Bond with fixed coupon into a Bond with variable coupon
  - Loan with fixed interest rate into a Loan with variable interest rate
  - Currency bond with repayment and payment of interest in different currency
- **No secondary market available, Valuation by buyer**
- **The more complex the construction, the bigger the difference (spread) between cash rate and forward rate**
- **Components (Stripping) of the Financial Instrument:**

  Purchase of a Financial Paper (Bond, Loan etc) by Investor
  Purchase of a Payer- interest/currency Swap

Asset Swap Contract

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Structured Capital Market Products

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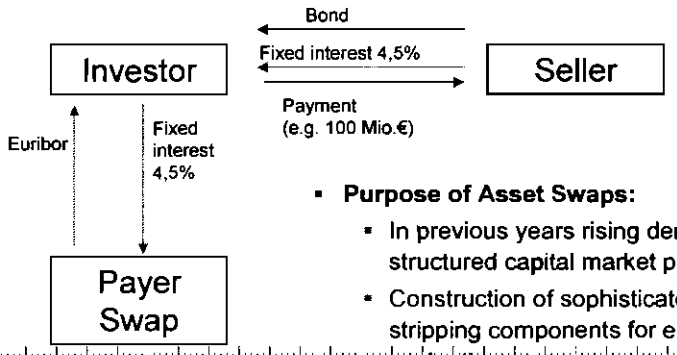
- **Asset Swaps:**
  Construction:



- **Purpose of Asset Swaps:**
  - In previous years rising demand in structured capital market products
  - Construction of sophisticated only by stripping components for easier evaluation

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Structured Capital Market Products

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- **Asset Swaps - price:**
  Determinants of influence
  - Cash-Forward-Spread: If asset swap consists of different components, (e.g. different fixed interest rates for different years, step-up or step-down loan) the spread between flexible rate (.e. Euribor) and fixed-rate widens
  - Size: Bigger Loans/Bonds are less expensive, small bond has nominal value less 10 Mio. €
  - Maturity: If duration longer than 5 years, calculation of Agio on Financial Instrument due to
    - Investment behaviour, short term investment preferred
    - Default risk, long term time horizon foreseeable only with uncertainty
  - Creditworthiness: Consideration of current and expected creditworthiness of debtor

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Structured Capital Market Products

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- **Capped Floating Rate Note**
- **Bond/Note with flexible interest rate (Floater) with maximum interest rate possibly to be paid (Cap)**
- **Cap constructed /priced as a Agio on Euribor to cover risk of loosing gains on interest rate developments**
- **Components:**
  (1) Sales of a 5 year Floater based on Euribor + 20 base points as discount
  (2) Purchase of a 5 year Cap

➔ 5 year Capped Floating Rate Note

Libor	+ Floater long (+ 20 BP)	- Cap Short (5%)	Capped Floater
5,5	5,7	0,7	5,0
5,2	5,4	0,4	5,0
5,0	5,2	0,2	5,0
4,8	5,0	XX	5,0
4,5	4,7	XX	4,7

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Structured Capital Market Products

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- **Collared Floating Rate Note**
  Bond/Note with flexible interest rate (Floater) with <u>maximum</u> interest rate possibly to be paid (Cap) <u>and</u> <u>minimum</u> interest rate possibly to receive (Floor)
- **Components:**
  (1) Sales of a 5 year Floater based on Euribor (+ e.g. 30 base points)
  (2) Purchase of a 5 year Cap (Strike e.g. 5,7%)
  (3) Sales of a 5 year Floor (Strike e.g. 1,7%)

➔ 5 year Collared Floater

Libor	+ Floater long (+30 BP)	- Cap Short (5,7%)	+ Floor (1,7%)	Capped Floater
6,0	6,3	0,6	XX	5,7
⋮	⋮	⋮	⋮	⋮
2,5	2,8	XX	XX	2,8
2,3	2,6	XX	XX	2,6
2,0	2,3	XX	XX	2,3
1,7	2,0	XX	XX	2,0
1,5	1,8	XX	0,2	2,0

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Structured Capital Market Products

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- **Step-up collared floater**
  Bond/Note with flexible interest rate (Floater) to be paid to investor, however with securitisation for issuer by <u>maximum</u> interest rate possibly to be paid (Cap) <u>and</u> <u>minimum</u> interest rate possibly to receive (Floor) during reinvestment of Bond
- **Components:**
  (1) Sales of a 5 year Floater based on Euribor (+ e.g. 20 base points)
  (2) Sales of a 5 year floor (Strike e.g. 2,8%)
  (3) Purchase of a Forward cap 1*2 (Strike e.g. 4,05%)
  (4) Purchase of a Forward cap 2*3 (Strike e.g. 4,55%)
  (5) Purchase of a Forward cap 3*4 (Strike e.g. 5,05%)
  (6) Purchase of a Forward cap 4*5 (Strike e.g. 5,80%)

➔ 5 year Step-up Collared Floater

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Structured Capital Market Products

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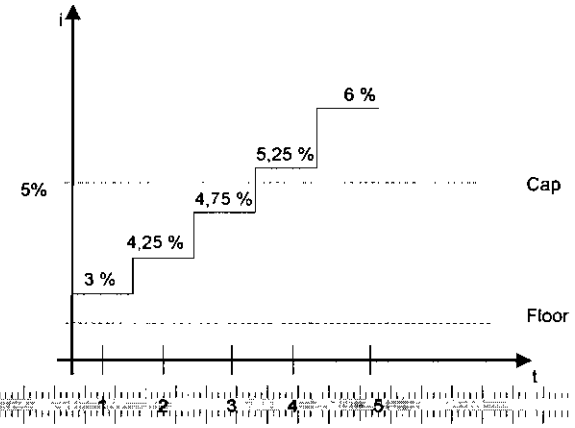
- **Step-up collared floater**



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Structured Capital Market Products

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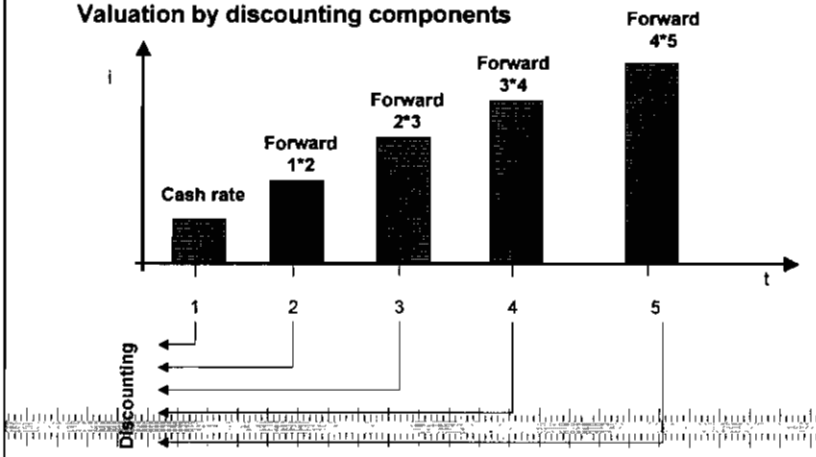
- **Step-up collared floater**
  Valuation by discounting components



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Structured Capital Market Products

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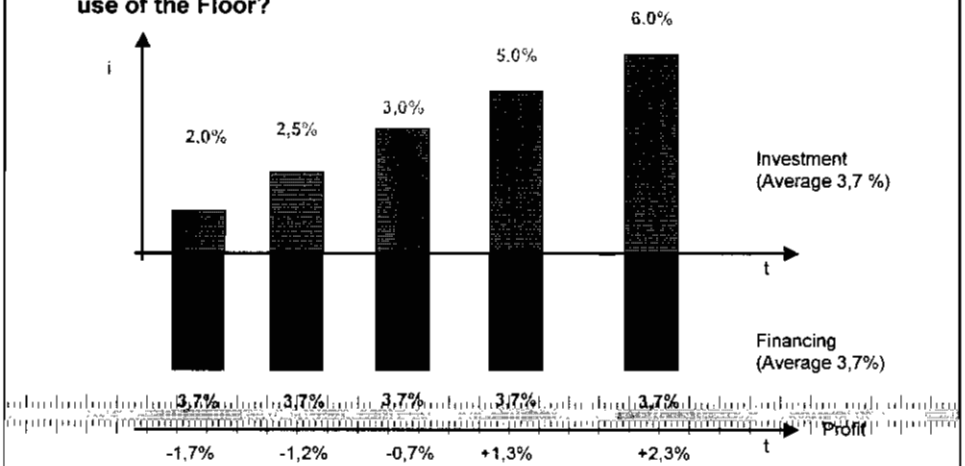
- **Step-up collared floater/Step-up Bond**
  use of the Floor?



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Structured Capital Market Products

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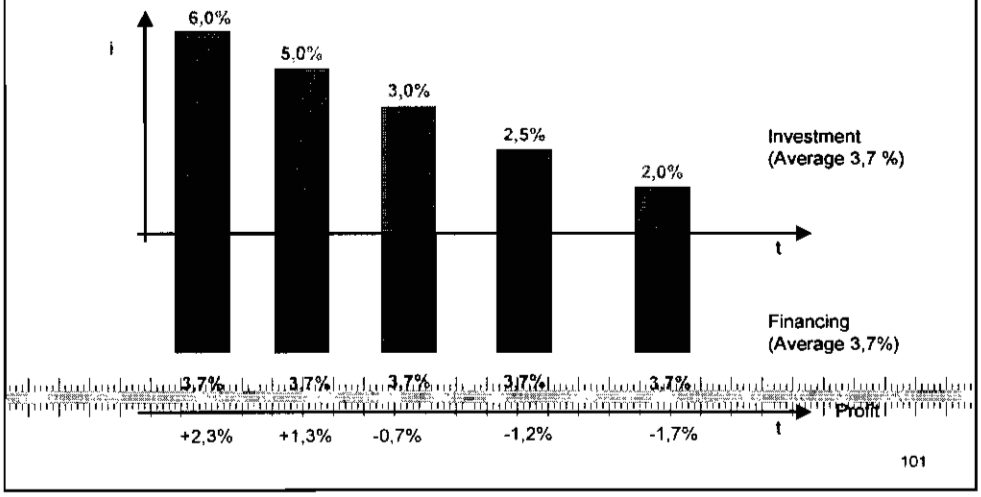
- **Step-down collared floater/Step-down Bond use of the Floor?**



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Structured Capital Market Products

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- **Purpose of**
  - Step-up collared Floater
  - Step up Bond

  } Creation of Profits at a later moment

  - Step-down collared Floater
  - Step-down Bond

  } Creation of Profits at an earlier moment

➔Design of income structure due to cash-flow situation of investor

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Structured Capital Market Products

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- **Reverse floater**
  Distraction of Cash-rate/money-market rate from a fixed interest rate, decreasing Euribor leads to increasing interest income, increasing Euribor leads to decreasing interest income
- **Example: Reverse Floater, 10 years, issued at 100%, 8,66% coupon ./. Euribor**
- **Components:**
  (1) Sales of a 10 year bond (Interest Rate e.g. 4,33%)
  (2) Sales of 10 year bond (Interest Rate e.g. 4,33%)
  (3) Purchase of 10 year bond (Interest Rate Euribor)
  (4) Purchase of a Forward Floor 1*10 (Strike e.g. 4,33%)

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10 Year Reverse floater with 8,66% interest rate minus Euribor

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Structured Capital Market Products

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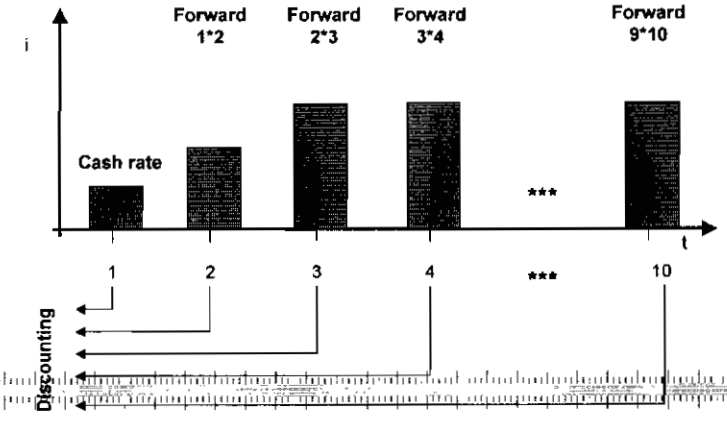
- **Reverse floater**
  Valuation by discounting components



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Structured Capital Market Products

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- **Turbo Reverse floater**
  Same as reverse Floater, but interest rates doubled in comparison to Reverse floater
  Consequence: Doubling of components, doubling of vulnerability to volatility of interest rates
- **Components:**
  (1) Sales of a 10 year bond (Interest Rate e.g. 4,33%) 2X
  (2) Sales of 10 year bond (Interest Rate e.g. 4,33%) 2X
  (3) Purchase of 10 year bond (Interest Rate Euribor) 2X
  (4) Purchase of a Forward Floor 1*10 (Strike e.g. 4,33%) 2X

10 Year Reverse floater with 17,32% interest rate minus Euribor

→ Remember: In average no higher yield possible than 10 years federal funds, Difference always with respect to immanent risks

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Structured Capital Market Products

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- **Exotic Options**
- Lookback options
  - Strike prices determined not only at the exercise date. One looks back at the path of prices over the contract period.
    - Lookback Minimum: Strike determined by the lowest price of underlying asset, observed in lifetime of option, Holder of Call can buy for that price
    - Lookback Maximum:Strike determined by the highest price of underlying asset, observed in lifetime of option, Holder of Put can sell for that price
    - Lookback Average: Applicable both for Call and Put, calculation of the median (Average) of the price of underlying asset during lifetime of option
- Call lookbacks on the min and puts on the max almost always expire in the money.
- Min and max lookbacks are reatively expensive.

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Structured Capital Market Products

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- **Exotic Options**
  - Used to create Hedging structures for capital market products (i.e. for Range Note with binary structure)
  - Offering high lever for considerably low price (good risk-/profit-relation)
  - Used by portfolio-managers to expand potential yield of their investments
  - Used by financial institutions to deal with their asset and liability mismatches

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Structured Capital Market Products

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- Asian Options
  - Similar to Lookback Option, Payouts depends on the average price of underlying asset within pre-defined time-frame (e.g. Strike: Max daily average over last three month)
    - Geometric Average Options: $(X_1 \ldots X_2)^{1/n}$
    - Arithmetic Average Options: (X1…X2)/n
- Volatility Options
  - Contract that pays out if the volatility exceeds a threshold over the period.
- Barrier Option
  - Payoff depends on whether or not the underlying asset reached a predetermined barrier price during the life of the option.
  - Immediate rebate or up-and-out pay as soon as the barrier is reached.

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- Barrier-Options:
  - Knockout options are made worthless if the barrier is reached. Down-and-out call options expire worthless, if the stock price falls below a critical level.
  - Knock-in-option has value if and only if the barrier price is attained. A down-and-in-call-option comes into existence only when the barrier is reached. Similarly for and-up-and-in put.
  - A baseball option is a call which is Knocked-Out if the closing price is below the barrier on three separate occasions.

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- Forward Start Options
  - Counting to maturity starts, when being first time in or out of the money (or proportionally in or out of the money) after a known, predefined time
  - Strike equal to positive constant α-times of the initial price (S) for underlying asset, α considering degree of being out of /in the money at moment when option starts to count
    If at start of counting "in the money": - Call: 1-α, Put α-1,
    If at start of counting "out of the money": - Call: α-1, Put 1-α
    If start counting "at the money": Call/Put α
  - Value of α, degree of being out or in the money subject to individual negotiation

Structured Capital Market Products

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- Cross option:
  - Option on underlying in one currency but strike denominated in another currency (Example: Call option on IBM Shares, denominated in USD, Strike denominated in Euro)
- Quanto Option: Cross option with exchange rate fixed at outset of trade
- Binary option: Payment of fixed amount or nothing at all, if price of underlying asset is not within frame of pre-defined values at exercise date

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Thank you for your attention

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