Interest Rate Derivatives

Fixed Income Trading Strategies

eurex

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Brochure Structure and Objectives

In the following brochure, we will introduce you to the fixed income derivatives traded at Eurex and illustrate their most significant applications. Futures on fixed income securities ("fixed income futures") and options on fixed income futures are jointly referred to as "fixed income derivatives". The basic characteristics of fixed income securities and their key analytical figures are initially explained to provide a better understanding of these products. Basic knowledge of the securities business is a prerequisite. Explanations of fixed income securities contained in this brochure predominantly refer to those issues on which Eurex fixed income derivatives are based.

Characteristics of Fixed Income Securities

Bonds – Definition

A bond is understood as raising debt capital in the market on a large scale. In this context, the lenders' claims are certified in securities. A placement of securities in the market is referred to as an "issue", and the borrower is called the "issuer". Bonds can be systematized with respect to their maturity, issuer, terms of interest payment, credit rating and further categories. Fixed income securities feature a fixed coupon, and interest must be paid on the face value (nominal value). Depending on the terms, interest payments are usually made annually or semi-annually. The fixed income derivatives traded at Eurex are based on a basket of either German or Swiss fixed income government bonds.

In Switzerland, the Swiss National Bank (SNB) manages debt issuances for the Swiss Federal Department of Finance. So-called "money market book-entry claims", Treasury Notes and Confederation Bonds are issued to raise capital. Only Confederation Bonds – issued with a range of different maturities – can be traded without restrictions, while the other government debt securities can only be exchanged between SNB and banks, or in interbank trading.

The German Finance Agency ("Bundesrepublik Deutschland Finanzagentur GmbH") has been responsible for issuing German Federal securities, on behalf of the German government, since June 2001. The EUR-denominated bonds underlying Eurex fixed income derivatives feature the following maturities and coupon payment terms:

German Federal securities	Maturity	Coupon payment
German Federal Treasury notes (Bundesschatzanweisungen – "Schätze")	2 years	Annual
German five-year Federal notes (Bundesobligationen – "Bobls")	5 years	Annual
German Federal bonds (Bundesanleihen – "Bunds")	10 and 30 years	Annual

The terms of these issues do not provide for early redemption by calling or drawing.

The following scenario will be used as the basis of interest calculations in this chapter:

Example:

Debt security issue	**German Federal bond**
... by the issuer	Federal Republic of Germany
... with the first coupon payment date on[1]	July 04, 2005
... at the issue date	May 28, 2004
... with a lifetime of	10 years and 37 days
... a redemption date on	July 04, 2014
... a fixed interest rate of	4.25 %
... coupon payment	annual
... a nominal value of	100

Lifetime and Remaining Lifetime

It is important to differentiate between the terms lifetime and remaining lifetime for an understanding of bonds and fixed income derivatives. The lifetime refers to the period of time from the issuance of the security to the repayment of the face value. The remaining lifetime is the timeframe remaining from an observed point in time until the repayment of the issued security.

Example:

The bond has a lifetime of	**10 years and 37 days**
… on the valuation date	July 06, 2004 ("today")
… the remaining lifetime is	9 years and 363 days

Nominal and Actual Rate of Interest (Coupon and Yield)

The nominal rate of interest of a fixed income bond is understood as the coupon level in relation to the face value of the bond. The issued price and the traded price usually do not correspond to the face value of bonds as they are quoted above or below par, which means that their value is above or below the face value of 100 percent (also referred to as "par"). Both the coupon payments and the invested capital are considered

1 Interest starts to accrue on May 28, 2004. Hence, the bond has a "long" first coupon with an interest period in excess of one year.

for the calculation of the rate of return. The actual rate of return – the "yield" – deviates from the nominal rate of interest, unless the security is traded exactly at 100 percent. For a bond that is quoted above (below) its nominal value, the actual rate of return is lower (higher) than the nominal interest rate.

Example:

The bond has	
... a nominal value of	100
... but is trading at a price of	99.68
... a fixed interest rate of	4.25 %
... a coupon of	4.25 % × 100 = 4.25
... a yield of	4.29 %[2]

In this case, the bond's yield is higher than its nominal interest rate.

Accrued Interest

A bond can be sold many times in between the specified interest payment dates (coupon dates). The buyer pays the seller accrued interest for the period from the last coupon date to the value date of the transaction, as he will receive the full coupon at the next coupon date. The interest accumulated from the last coupon date to the observed point in time is referred to as "accrued interest".

Example:

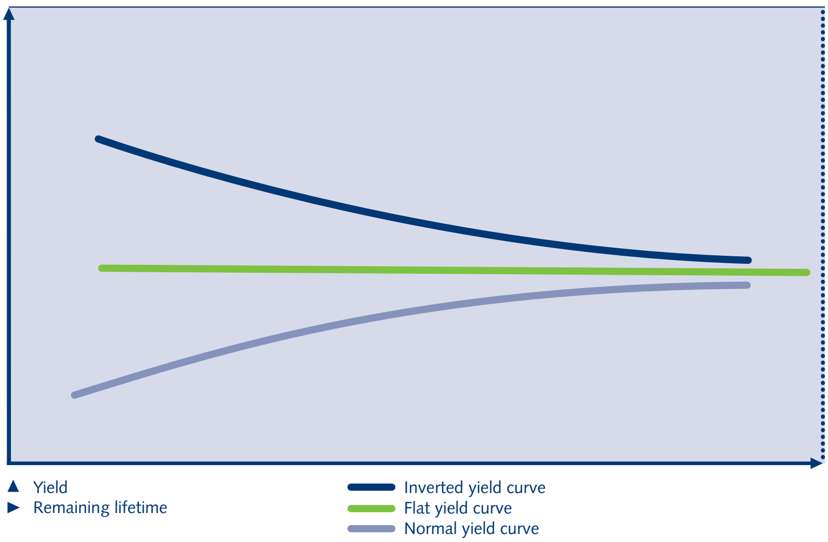
The bond is purchased on	August 12 (purchase on August 10 + 2 days' value)
… the coupon rate is	4.25%
… the time period since the last coupon payment is	39 days (July 4 to August 12 = 39 days)[3]
… this results in accrued interest of	4.25 × 39/365 = 0.4541

2 At this point, we have not yet covered exactly how yields are calculated: For this purpose, we need to take a closer look at the concepts of present value and accrued interest, which we will cover in the following sections.
3 Based on the "actual/actual" interest convention.

The Yield Curve

Bond yields primarily depend on the credit rating of the issuer and the remaining lifetime of the issue. As the underlying instruments of Eurex fixed income derivatives are highest grade government bonds, the following illustrations only consider the relationship between yield and remaining lifetime. This is often described in the form of a mathematical function, the so-called yield curve. Bonds with a long remaining lifetime usually have higher yields than bonds with a shorter remaining lifetime due to the long-term capital commitment. This case is known as a "normal" yield curve. A yield curve that offers the same yield for all remaining lifetimes is called a "flat" yield curve. An "inverse" or "inverted" yield curve is characterized by a downward slope of the function.

Yield Curves



Bond Valuation

The previous sections showed that bonds carry a certain yield for a given remaining lifetime. This is calculated using the bond's market value (price), the interest (coupon) payments and redemption payments (cash flows).

At which market value (price) is the yield (actual rate of return) of a bond equivalent to the current market yield? A common money market rate (Euribor) is applied in the following examples to keep the calculation concise, even though such a valuation does not reflect true market conditions.

To provide a stepwise explanation, the calculation of a bond with an annual interest payment that becomes due in exactly one year is demonstrated initially. The coupon and the nominal value are repaid at maturity.

Example:

Money market interest rate p.a.	2.35 %
Bond	5.00% Bobl Series 136 due on August 19, 2005
Nominal value	100
Coupon	5.00 %
Valuation date	August 19, 2004 ("today")

This results in the following present value:[4]

$$\text{Present value} = \frac{100 + 5}{1 + 0.0235} = 102.59$$

To determine the present value of a bond, future payments are divided by the yield factor (1 + money market rate). This calculation is known as discounting cash flows. The resulting price is called the "present value" as it refers to the current point in time (today).

The future cash flows of a bond with a remaining lifetime of three years are illustrated in the following example.

4 The general formula is provided in Appendix 1.

Example:

Discount rate p.a.	3.36 %
Bond	4.75 % Bund due July 4, 2008
Nominal value	100
Coupon	4.75 %
Valuation date	July 4, 2005 ("today")

The present value of a bond can be calculated with the following equation:

$$\text{Present value} = \frac{\text{Coupon (c1)}}{\text{Yield factor}} + \frac{\text{Coupon (c2)}}{(\text{Yield factor})^2} + \frac{\text{Nominal value (n)} + \text{Coupon (c3)}}{(\text{Yield factor})^3}$$

$$\text{Present value} = \frac{4.75}{1 + 0.0336} + \frac{4.75}{(1 + 0.0336)^2} + \frac{104.75}{(1 + 0.0336)^3} = 103.90$$

When calculating the value of a bond at a point in time that does not coincide with the coupon date, the first coupon must only be discounted for the remaining lifetime until the next coupon date. The exponentiation of the yield factor changes accordingly up to the bond's maturity date.

Example:

Interest rate p.a.	4.29 %
Bond	4.25 % Bund due July 4, 2014
Nominal value	100
Coupon	4.25 %
Valuation date	July 14, 2004 ("today")
Remaining term for the first coupon	355 days or 355 / 365 = 0,972603 years[5]
Accrued interest	4.25 × 47/365 = 0.5473[6]

The annualized interest rate is calculated, on a pro rata basis, using the following dicount factor for remaining lifetimes of less than one year:

$$\frac{1}{1 + (0.0429 \times 0.972603)}$$

For remaining lifetimes of more than one year (1.972603; 2.972603; ... 9.972603), the interest rate must be "compounded"; meaning that it must be raised to a higher power. The process is hence called "compounding". Therefore, the price of the bond is:

$$\text{Present value} = \frac{4.25}{1 + (0.0429 \times 0.972603)} + \frac{4.25}{(1 + 0.0429)^{1.972603}} + \ldots + \frac{104.25}{(1 + 0.0429)^{9.972603}} = 99.7950$$

5 Period from July 4, 2004 to July 4, 2005 = 365 days
6 The bond has a long first coupon. The first coupon payment date was May 28, 2004; the next is July 4, 2005.

For the purpose of simplification, the discount factor for periods of less than one year will also be raised to a given power in the following.[7]

The previous equation can also be interpreted in the sense that the present value of the bond equals the sum of the individual present values, thus all coupon payments and the repayment of the nominal value. This model can only be applied for several periods under the assumption of a constant interest rate. The flat yield curve implied thereby is, however, usually not realistic. Despite this simplification, the present value calculation with a flat yield curve is the basis of several risk indicators, which will be presented in the following chapters.

For bond prices, the present value (also known as the "dirty price") must be distinguished from the so-called "clean price" of a bond. According to prevailing convention, the clean price – as the difference between dirty price and accrued interest – is quoted as a tradable market price. For this purpose, the formula is:

Clean price = Present value – Accrued interest
Clean price = 99.7950 – 0.5473 = 99.2477

In the following, the present value (dirty price) is distinguished from the traded price of a bond (clean price).

A change in market interest rates has a direct impact on the discount factors and therefore on the present value of bonds. If interest rates rise by one percentage point from 4.29 percent to 5.29 percent, the following present value results for the value introduced above:

$$\text{Present value} = \frac{4.25}{1+(0.0529 \times 0.972603)} + \frac{4.25}{(1+0.0529)^{1.972603}} + \ldots + \frac{104.25}{(1+0.0529)^{9.972603}} = 92.2113$$

The clean price thus changes as follows:

Clean price = 92.2113 – 0.5473 = 91.6640

The present value of the bond fell by 7.60 percent from 99.7950 to 92.2113 due to the rise in interest rates. The clean price fell by 7.64 percent (from 99.2477 to 91.6640). The relationship between the present value of a bond, respectively the clean price, and the development of interest rates can be described as follows:

There is an inverse relationship between bond prices and market yields.

[7] The general formula is provided in Appendix 1.

Macaulay Duration

In the previous section we examined the impact of interest rate changes on the bond price. Another method to determine the interest rate sensitivity of bonds is based on the concepts of Macaulay Duration and modified duration.

The Macaulay Duration was developed to analyze the change in the value – the sensitivity – of bonds and bond portfolios, for the purpose of hedging against adverse interest rate developments.

As described, there is an inverse relationship between interest rates and the present value of bonds – the immediate effect of rising yields are falling prices. On the other hand, the coupon payments can be reinvested more profitably so that the future value of the portfolio is increased. The Macaulay Duration is usually expressed in years – it specifies the period of time after which both described effects offset each other. It can therefore be used to ensure that the sensitivity of a portfolio corresponds to the given investment horizon. Note that the concept is based on the assumption of a flat yield curve as well as a parallel shift of the curve – that is, an equal change of interest rates across all maturities.

Macaulay Duration summarizes interest rate sensitivity in a single figure. The relative amount of risk can be pinpointed in the change of a bond's duration, or looking at the difference in duration between various bonds.

A bond's Macaulay Duration depends on the valuation characteristics of each security. It is lower,

- the shorter the remaining lifetime;
- the higher the market interest rate; and
- the higher the coupon.

The Macaulay Duration of the bond from the previous example is calculated as follows:

Example:

Valuation date	July 14, 2004 ("today")
Bond	4.25% Bund due July 4, 2014
Interest rate p.a.	4.29 %
Remaining term for the first coupon	355 days or 355 / 365 = 0.972603 years[8]
Present value of the bond	99.7950

[8] Period from July 4, 2004 to July 4, 2005 = 365 days

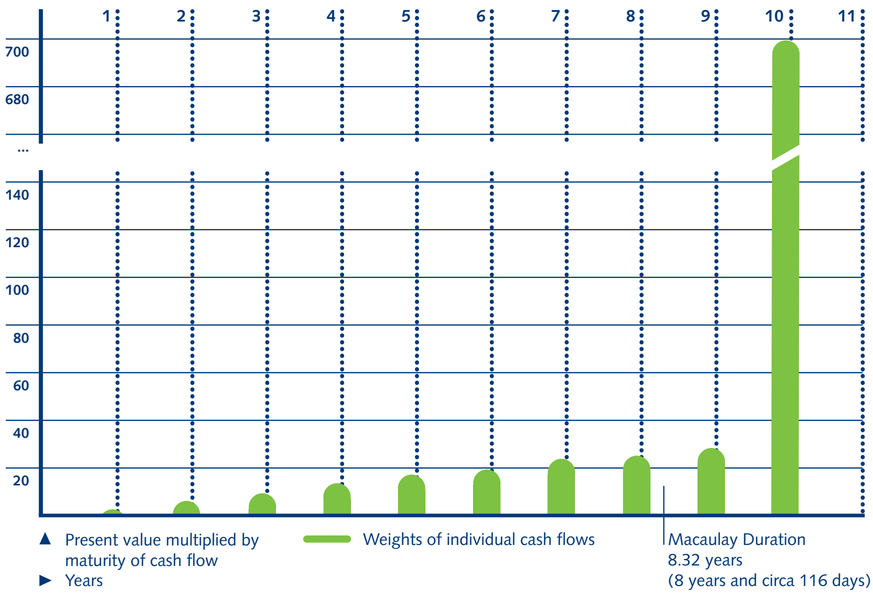
Calculation:

$$\text{Macaulay Duration} = \frac{\frac{4.25}{(1+0.0429)^{0.972603}} \times 0.972603 + \frac{4.25}{(1+0.0429)^{1.972603}} \times 1.972603 + \ldots + \frac{104.25}{(1+0.0429)^{9.972603}} \times 9.972603}{99.795}$$

$$\text{Macaulay Duration} = \frac{830.3803}{99.7950} = 8.32 \text{ years}$$

The factors used in the formula (0.972603; 1.972603; ... 9.972603) correspond to the remaining lifetimes of the coupons and the repayment of the nominal value. These remaining lifetimes are multiplied with the present value of the specific return flows. The Macaulay Duration is the sum of the remaining lifetimes of all cash flows, weighted by the proportion of each cash flow to the total present value of the bond. Therefore, a bond's Macaulay Duration is most heavily affected by the remaining lifetime of the cash flows featuring the largest present value.

Macaulay Duration (Remaining Lifetime Weighted by Present Value)



The concept of Macaulay Duration can also be applied to bond portfolios. For this purpose the duration values of the individual bonds are weighted by their share of the total present value of the portfolio and added up.

Modified Duration

Modified duration is based on the concept of Macaulay Duration. It specifies the percentage change in the present value (clean price plus accrued interest), given a one unit (one percentage point) change in the market interest rate. The modified duration is equivalent to the negative value of the Macaulay Duration, discounted over one period of time.

$$\text{Modified duration} = -\frac{\text{Duration}}{1 + \text{Yield}}$$

The modified duration of the above mentioned example is:

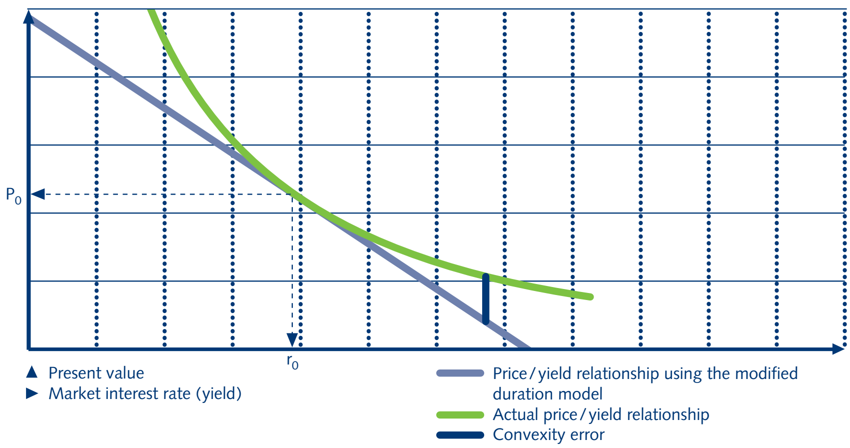
$$\text{Modified duration} = -\frac{8.32}{1 + 0.0429} = -7.98$$

If the interest rate rises by one percentage point, then the present value of the bond should fall by 7.98 percent according to the modified duration model.

Convexity – the Tracking Error of Duration

Even if the premises mentioned in the previous section are valid, using modified duration to calculate the change in value is bound to yield imprecise results, as it assumes a linear relationship between present value and the interest rate. In general, however, the price/yield relationship of bonds tends to be convex. When estimating price changes with modified duration, the change in value is thus over- or underestimated.

Relationship between Bond Prices and Capital Market Yields



It can generally be stated that estimations of price changes by means of modified duration become increasingly inaccurate for greater changes in interest rates. In our example, the reevaluation resulted in a decrease of the bond price by 7.60 percent compared to an estimated 7.98 percent based on modified duration. The inaccuracy resulting from the non-linear relationship when applying modified duration can be corrected by the so-called convexity formula.

Compared to the formula used for modified duration, the convexity factor is calculated by multiplying each summand in the numerator by $(1 + t_{c1})$, and the known denominator by $(1 + {}_tr_{c1})^2$.

The calculation is carried out again for the same example:

$$\text{Convexity} = \frac{\frac{4.25}{(1+0.0429)^{0.972603}} \times 0.972603 \times (1+0.972603) + \frac{4.25}{(1+0.0429)^{1.972603}} \times 1.972603 \times (1+1.972603) + \ldots + \frac{104.25}{(1+0.0429)^{9.972603}} \times 9.972603 \times (1+9.972603)}{99.795 \times (1+0.0429)^2} = 78.72$$

This convexity factor is entered into the following equation:

Percentage change in present value
= (Modified duration × Change in market interest rates) + (0.5 × Convexity × (Change in market interest rates)^2)

The outcome of a rise in interest rates from 4.29 percent to 5.29 percent is:

$$\text{Percentage change in present value} = (-7.98 \times 0.01) + (0.5 \times 78.72 \times (0.01)^2) = -0.0759 = -7.59\%$$

A comparison of the results for the three calculation methods shows:

Calculation method	**Result**
Recalculating the present value	–7.60 %
Projection using modified duration	–7.98 %
Projection using modified duration and convexity	–7.59 %

It is evident that, by taking convexity into account, the result is very close to the price determined in the reevaluation, whereas the estimate based on modified duration differs significantly.

Eurex Fixed Income Derivatives

Characteristics of Exchange Traded Financial Derivatives

Introduction

Derivative instruments (or simply "derivatives") are forward contracts whose prices are determined by reference to underlying cash market instruments – such as stocks or bonds – or commodities – such as crude oil – that are traded in the spot market. The instruments that serve as basis are referred to as "underlying instruments" or "underlyings". Derivatives trading is characterized by settlement taking place at fixed dates ("settlement dates") in the future. In contrast to cash market transactions – in respect of which delivery is made against payment two or three days after the trade date (settlement period) – futures contracts are settled on only four dates per year.

Derivatives are traded both at organized derivatives markets such as Eurex and off-exchange (over-the-counter, OTC). In contrast to OTC derivatives, exchange traded products generally feature standardized contract specifications as well as an ongoing valuation of positions (known as "margining") via a Clearing House. Futures and options on financial instruments are traded at Eurex.

Flexibility

At an organized derivatives market, traders are able to establish positions in line with their market assessment and appetite for risk without having to buy or sell securities. They can neutralize the position before contract maturity or expiration with an offsetting transaction (closeout). Profits or losses resulting from a position in futures and options on futures are credited or debited, in cash, on a daily basis.

Transparency and Liquidity

Trading standardized contracts results in a concentration of order flows, thus ensuring market liquidity. Liquidity means that major quantities of a product can be bought or sold at any time, without excessive impact on prices. Electronic trading at Eurex guarantees extensive transparency of prices, traded volumes and trade data.

Leverage Effect

With futures and options, it is not necessary to invest the full nominal value of the contract. Hence, in terms of the capital invested or pledged, the profit or loss potential is much greater for futures or options than for the underlying stocks or bonds.

Introduction to Fixed Income Futures

Fixed Income Futures – Definition

Fixed income futures are standardized forward transactions between two parties, based on fixed income instruments such as bonds. They comprise the obligation:

... to purchase	**Buyer**	**Long future**	**Long future**
... or to deliver	**Seller**	**Short future**	**Short future**
... a given financial instrument	Underlying instrument	German Federal bonds	Swiss Confederation bonds
... with a given remaining lifetime		8.5–10.5 years	8–13 years
... in a set amount	Contract size	EUR 100,000 nominal	CHF 100,000 nominal
... at a set point in time	Maturity	March 10, 2005	March 10, 2005
... at a determined price	Futures price	112.00	124.50

Eurex fixed income futures are based on the delivery of a bond with a remaining lifetime that lies within a fixed range. The list of deliverable bonds in a respective contract comprises a range of issues with different coupons, prices and maturities. The concept of a notional bond is used to standardize these different issues. This will be described in more detail in the following sections on contract specifications and conversion factors.

Futures Positions – Obligations

A futures position can either be "long" or "short":

Long position Buying a futures contract	**Short position** Selling a futures contract
The buyer's obligations: At maturity, a long position automatically results in the obligation to buy deliverable bonds: The obligation to buy the interest rate instrument relevant to the contract on the delivery date at the pre-determined price.	**The seller's obligations:** At maturity, a short position automatically results in the obligation to deliver such bonds: The obligation to deliver the interest rate instrument relevant to the contract on the delivery date at the pre-determined price.

Settlement or Closeout

Futures are generally settled by means of cash settlement, or by physical delivery of the underlying instrument. Eurex fixed income futures provide for the physical delivery of securities. Depending on the contract traded, the holder of a short position is obliged to deliver specific long-term Swiss Confederation bonds; or short-term, medium-term or long term German government bonds. The holder of a corresponding long position must take delivery against payment of the delivery price.

Securities from the respective issuer are deliverable, provided that their remaining lifetime (at the delivery date) lies within the fixed range defined for each contract – the so-called delivery window. The choice of bonds to be delivered must be disclosed by the holder of a short position; this is called "notification". The selection and valuation of a bond for the purposes of contract settlement is described in the section on "Bond Valuation".

However, entering a futures position usually does not serve the purpose of actually delivering or receiving the underlying instrument at the delivery date. Futures are rather used to replicate the price development of the underlying throughout the lifetime of the contract. The buyer of a futures contract can realize his profit following a price increase of the futures by simply selling the number of contracts originally purchased. Vice versa, a short position can be closed out by buying back futures.

That is why a significant reduction of open interest (the number of contracts in the respective futures contract that have not been closed out) can be observed during the days prior to maturity of a fixed income futures contract. Open interest can even exceed the total volume of deliverable bonds during a contract's lifetime. However, this figure falls significantly as soon as the shift ("rollover") from the front contract month to the next contract maturity sets in when approaching maturity.

Contract Specifications

Detailed specifications of Eurex fixed income futures are listed in the "Eurex Products" brochure, or on the Eurex website **www.eurexchange.com > Trading > Products**. The most important specifications of Eurex fixed income futures are described in the following example based on a Euro-Bund and a CONF Futures contract.

A trader buys

… 2	Contracts	The futures transaction is based on a nominal value of 2 × EUR 100,000 of deliverable bonds for the Euro-Bund Futures, or 2 × CHF 100,000 of deliverable bonds for the CONF Futures.
... June	Maturity month	The next three quarterly months within the March, June, September, December cycle are available for trading. Thus, the Euro-Bund and CONF Futures have a maximum remaining lifetime of nine months. The Last Trading Day is two exchange trading days before the 10th calendar day (delivery day) of the maturity month.
Euro-Bund Futures or CONF Futures	Underlying instrument	The underlying instrument for Euro-Bund Futures is a 6% notional long-term German Federal bond. For CONF Futures it is a 6% notional Swiss Confederation bond.
... at 112.00 or 124.50, respectively	Futures price	The futures price is quoted in percent, to two decimal points, of the nominal value of the underlying bond. The minimum price change (tick) is EUR 10.00 or CHF 10.00 (0.01 %).

In this example, the buyer is obliged to buy German Federal bonds (or Swiss confederation bonds) eligible for delivery, with a nominal value of EUR (CHF) 200,000 (2 × 100,000). However, the buyer can closeout the position (and thus relieve himself of the obligation) with the corresponding offsetting transaction (sale of two futures).

Eurex Fixed Income Futures – Overview

The specifications of the individual fixed income futures mainly differ in terms of the delivery window, that is the basket of deliverable bonds defined by the remaining lifetime. Furthermore, the Euro-Schatz Futures and the Euro-Bobl Futures feature a different minimum price change ("tick size"). In addition, the Euro-Buxl® Futures have a nominal coupon of four percent whereas the Euro-Bund, Euro-Bobl and Euro-Schatz Futures have a nominal coupon of six percent. The remaining lifetimes of eligible bonds for each product are listed in the following table:

Underlying instrument: German Federal securities	Nominal contract value	Minimum price change (points)	Remaining lifetime of deliverable bonds	Eurex product code
Euro-Schatz Futures	EUR 100,000	0.005	1 3/4 to 2 1/4 years	FGBS
Euro-Bobl Futures	EUR 100,000	0.005	4 1/2 to 5 1/2 years	FGBM
Euro-Bund Futures	EUR 100,000	0.01	8 1/2 to 10 1/2 years	FGBL
Euro-Buxl® Futures	EUR 100,000	0.02	24 to 35 years	FGBX

Underlying instrument: Swiss Confederation bonds	Nominal contract value	Minimum price change (points)	Remaining lifetime of deliverable bonds	Eurex product code
CONF Futures	CHF 100,000	0.01	8 to 13 years	CONF

Futures Spread Margin and Additional Margin

Cash or securities must be deposited at Eurex Clearing AG – the Eurex Clearing House – when entering a futures position. Eurex Clearing AG guarantees all clearing members the fulfillment of contracts in the case a potential member default. The pledged Additional Margin (provided as collateral) protects the Clearing House from the economic effects of adverse price movements of the futures contract. As the direct counterparty of all trades concluded at Eurex, the Clearing House must ensure market integrity even in the case of clearing member default.

Offsetting long and short positions in different contract months of the same futures contract are referred to as time spread positions. Due to the high correlation of these positions, the Futures Spread Margin rates are lower than those for Additional Margin, which is charged for all outright positions (open non-spread long or short positions).

The calculation of margin requirements by the Eurex clearing house is described in detail in the "Risk-based Margining" brochure (**www.eurexchange.com > Documents > Publications**).

Variation Margin

A common misconception regarding fixed income futures is the assumption that physical delivery of bonds is based on the price at which the futures position was established. In fact, the delivery of bonds is settled based upon the Final Settlement Price of the respective futures contract (see the following details regarding conversion factors and delivery prices). This is due to the daily revaluation of futures positions throughout the contract lifetime – referred to as "marking-to-market". The Clearing House uses Variation Margin to effect this revaluation, settling pending profits or losses on open positions on a daily basis. The calculation of Variation Margin is illustrated in the following example; profits are shown with a positive and losses with a negative sign.

Calculating the Variation Margin for a new futures position:
Daily futures settlement price
– Futures purchase or selling price
= Variation Margin

At the close of trading, the settlement price of the CONF Futures is 124.65. The position's entry price was 124.50.

Example – CONF Variation Margin:
CHF 124,650 (124.65 % of CHF 100,000)
– CHF 124,500 (124.50 % of CHF 100,000)
= CHF 150

The buyer of the CONF Futures makes a profit of CHF 150 per contract on the first day (0.15 percent of CHF 100,000, respectively 0.15 percent of the nominal value). This is credited via Variation Margin. Alternatively, the calculation can be described as the difference between 124.65 and 124.50 = 15 ticks. The futures contract is based on a nominal value of CHF 100,000. The minimum price movement of 0.01 thus corresponds to CHF 10 (1,000 × 0.01) – this is also called the "tick value". The profit of the trade with one futures contract is therefore 15 × CHF 10 × 1 = CHF 150.

The calculation for Euro-Bund Futures is carried out along the same line. The Euro-Bund Futures contract purchased at EUR 112.00 has a settlement price of EUR 111.70. The Variation Margin is calculated as follows:

Example – Long Euro-Bund Futures Variation Margin:
EUR 111,700 (111.70 % of EUR 100,000)
EUR –112,000 (112.00 % of EUR 100,000)
= EUR –300

The buyer of the Euro-Bund Futures takes a loss of EUR 300 per contract (0.3 percent of the nominal value of EUR 100,000). He is debited the Variation Margin. In other words: 111.70 –112.00 = Loss of 30 ticks; multiplied with the Euro-Bund Futures' tick value of EUR 10 results in EUR –300.

Calculating the Variation Margin during the contract's lifetime:
Futures Daily Settlement Price on the current exchange trading day
– Futures Daily Settlement Price on the previous exchange trading day
= Variation Margin

Calculating the Variation Margin when the contract is closed out:
Futures price of the closing transaction
– Futures Daily Settlement Price on the previous exchange trading day
= Variation Margin

The Futures Price – Fair Value

The chapter "Valuation of a Bond" focused on how changes in interest rates impact the present value of a bond. The following section describes the futures price's dependency on the value of the deliverable bonds.

To purchase a bond at a future date, a trader can alternatively buy a futures contract today (pledging margin) or buy the bond in the cash market and hold it until the target date. While the purchase of the bond in the cash market causes actual costs, which are financed by the received coupon inflows (accrued interest), a futures position neither involves financing costs nor proceeds from accrued interest.

9 Note that costs which might be incurred as a result of providing collateral (Additional Margin, Futures Spread Margin) have not been taken into account here.

Assuming market equilibrium, the futures price must be determined in such a way that both the cash and futures purchase yield identical results. Theoretically, it must not be possible to realize risk-free profits (arbitrage) with offsetting transactions in the cash and derivatives market.

Both investment strategies are compared with each other in the following table:

Time	Period	Futures purchase Investment/valuation	Cash bond purchase Investment/valuation
Today		Entering into a futures position (no cash outflow)	Bond purchase (market price plus accrued interest)
	Futures lifetime	Investing the equivalent of financing costs saved on the money market	Coupon income (if any) invested on the money market
Futures delivery		**Portfolio value** Bond (purchased at the futures price) plus income on the money-market investment of the financing costs saved	**Portfolio value** Value of the bond (including accrued interest) plus any coupon interest (including associated reinvestment income)

Taking the factors referred to above into account, the futures price is determined based on the relationship outlined below:[10]

Futures price = Cash price + Financing costs – Income on the cash position

This can be expressed mathematically as follows:[11]

$$\text{Futures price} = C_t + (C_t + c\frac{t-t_0}{\text{actual}}) \times {}_t r_c \times \frac{T-t}{360} - c \times \frac{T-t}{\text{actual}}$$

Whereby:

C_t: Current clean price of the underlying (at the current point in time t)

c: Bond coupon (percent; actual/actual for EUR-denominated bonds)

t_0: Coupon date

t: Value date

${}_t r_c$: Short-term refinancing rate (percent; actual/360)

T: Value date

T-t: Remaining lifetime of the futures contract (days)

actual: Actual number of days of the observation period's year

[10] Readers should note that the formula shown here has been simplified for the sake of transparency; specifically, it does not take into account the conversion factor, interest on the coupon income, borrowing cost/lending income or any diverging value date conventions in the professional cash market.

[11] Number of days in the year, as defined according to the convention used in the respective markets. Financing costs are usually calculated based on the money market convention (actual/360), whereas the accrued interest and income on the cash positions are calculated on an actual/actual basis, which is the market convention for all EUR-denominated government bonds.

Cost of Carry and Basis

The difference between the proceeds (coupon returns) and the financing costs incurred on a cash position is referred to as the "cost of carry". The futures price can therefore also be described as follows:[12]

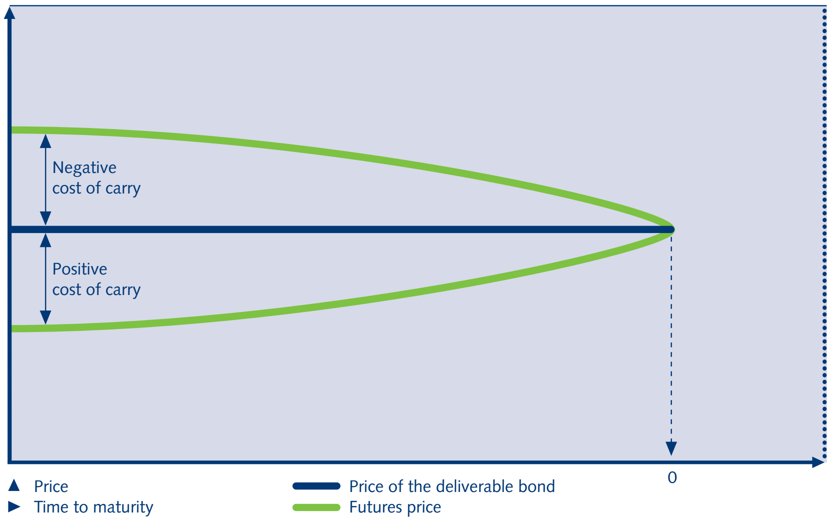
Price of the deliverable bond = Futures price + Cost of carry

The basis is the difference between the bond price in the cash market (expressed by the prices of deliverable bonds) and the futures price. It therefore corresponds to:

Price of the deliverable bond = Futures price + Basis

Depending on whether the cost of carry is positive or negative, the futures price can be lower or higher than the price of the underlying instrument. The basis diminishes with approaching maturity. This effect of "basis convergence" can be explained by the fact that both the financing costs and the bond returns decline as the remaining lifetime declines. The basis equals zero at maturity – at which point the futures price is equal to the price of the underlying.

Basis Convergence (Schematic)



The following relationships apply:

Financing costs > Income on the cash position: **– >** **Negative** cost of carry
Financing costs < Income on the cash position: **– >** **Positive** cost of carry

[12] Cost of carry and basis are also shown in literature using a reverse sign.

Conversion Factor (Price Factor) and Cheapest-to-Deliver (CTD) Bond

The deliverable bonds are not homogeneous, as they may originate from the same issuer but feature different coupons, maturities and consequently also different prices.

At delivery the conversion factor is used to help calculate a final delivery price. Essentially, the conversion factor generates a price at which a bond would trade if its yield were six or four percent respectively on delivery day. One of the assumptions made in the conversion factor formula is that the yield curve is flat on the delivery date, and, in addition, exactly represents the notional coupon of the futures contract. Based on this assumption, practically all bonds in the delivery basket would be equally attractive for delivery. Of course this is not the case in reality – the effects of this calculation method are described below.

Delivery price = Final Settlement Price of the futures × Conversion factor of the bond + Accrued interest of the bond

A bond's delivery price is calculated as follows:
Given the different conventions in respect to the number of interest days for CHF-denominated and EUR-denominated bonds (CHF: 30/360; euro: actual/actual) two different formulae are used for the conversion factor; these are cited in the appendices. The conversion factor values for all deliverable bonds are published on the Eurex website: **www.eurexchange.com > Market Data > Clearing Data > Deliverable Bonds and Conversion Factors**.

The conversion factor (CF) of a delivered bond is integrated into the futures price formula as follows (see page 25 for an explanation of the variables used):

$$\text{Theoretical futures price} = \frac{1}{CF}\left[C_t + (C_t + c\,\frac{t - t_0}{\text{actual}}) \times {}_t r_c \times \frac{T - t}{360} - c \times \frac{T - t}{\text{actual}}\right]$$

The calculation of the theoretical price of the Euro-Bund Futures September 2004 is demonstrated in the following example.

Example:

Value date	August 25, 2004
Bond	3.75% Federal Republic of Germany, due July 4, 2013
Price of the CTD	96.30
Futures delivery date	September 10, 2004
Accrued interest	3.75 × (52/365) = 0.53
Conversion factor of the CTD	0.849220
Money market interest rate p.a.	2.10%

$$\text{Theoretical futures price} = \frac{1}{0.849220}\left[96.30 + \left[(96.30 + 0.53) \times 0.021 \times \frac{16}{360}\right] - 3.75 \times \frac{16}{365}\right]$$

$$\text{Theoretical futures price} = \frac{1}{0.849220}\left[96.30 + 0.09037 - 0.16438\right] = 113.31$$

In practice, the yield curve is only seldom at the level of the notional coupon; the conversion factor formula's assumption of a flat yield curve is usally incorrect as well. For this reason, implied discounting at the notional coupon rate usally does not reflect the prevailing yield curve structure.

The conversion factor thus inadvertently creates a bias which promotes certain bonds for delivery above all others. The futures price follows the price of the deliverable bond, which offers the greatest advantage for a short position at maturity. This bond is referred to as the **C**heapest-**t**o-**D**eliver ("CTD") bond. If the delivery price of a bond is higher than its corresponding market price, then holders of a short position can take advantage of this by buying the bond in the cash market and selling at the higher delivery price. The bond with the greatest price advantage is usually selected for this purpose. Conversely, the bond offering the smallest price disadvantage will be chosen if delivery results in a loss for all deliverable bonds.

Identifying the CTD Bond

At the delivery date of a futures contract, purchasing a bond in the cash market and immediate delivery of the bond into a futures contract should not yield a profit – otherwise, cash-and-carry arbitrage would take place. This concept is illustrated in the following formula and examples.

Basis = Cash bond price – (Futures price × Conversion factor)

The basis equals zero at maturity. At this point in time, we can change the formula as follows:

$$\frac{\text{Cash bond price}}{\text{Conversion factor}} = \text{Futures price}$$

This futures price is called the "zero basis futures price". The following table shows an example for a number of deliverable bonds (note that we have used hypothetical bonds for the purposes of illustrating this effect). The cash market price at delivery as well as the zero basis futures price (which is the cash market price divided by the conversion factor) is shown for a yield of 4.25 percent.

Zero Basis Futures Price for a Yield of 4.25%

Coupon	Maturity	Conversion factor	Price at a 4.25% yield	Price divided by conversion factor
3.75 %	04.07.2013	0.849220	96.37	**113.48**
4.25 %	04.01.2014	0.877404	99.98	113.95
4.25 %	04.07.2014	0.872591	99.99	114.59

The table shows that each of the deliverable bonds features a different zero basis futures price; the January 2013 bond has the lowest value of 113.48. If for example, the futures price was 113.50 at delivery, an arbitrageur could buy the bond at 96.37 and sell it directly into the futures contract at 113.50 × 0.849220 = 96.3865, realizing an arbitrage profit of 1.65 ticks. Neither of the other two bonds would offer an arbitrage profit with a futures price of 113.50. Accrued interest is ignored as the bond is purchased and sold via the futures contract on the same day.

This shows that the bond with the lowest zero basis futures price is most likely to be considered for delivery – the cheapest cash bond to purchase in the cash market in order to settle a short delivery into the futures contract: the CTD bond.

Based on this example, we now examine the change of the zero basis futures price for different market yields, and the determination of the CTD bond.

Zero Basis Futures Price at 4.25%, 5.00%, 6.00%, 7.00% Yield

Coupon	Maturity	Conversion factor	Price at 4.25%	Price/ CF	Price at 5.00 %	Price/ CF	Price at 6.00 %	Price/ CF	Price at 7.00 %	Price/ CF
3.75	04.07.2013	0.849220	96.37	**113.48**	91.24	**107.44**	84.92	100.00	79.12	93.17
4.25	04.01.2014	0.877404	99.98	113.95	94.49	107.69	87.74	**100.00**	81.59	92.99
4.25	04.07.2014	0.872591	99.99	114.59	94.27	108.03	87.26	100.00	80.91	**92.72**

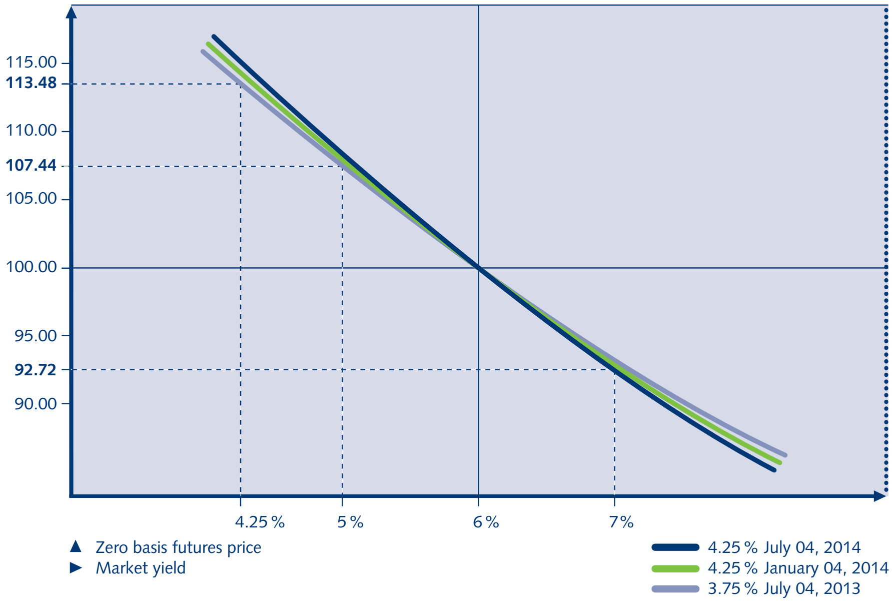
The following rules can be deducted from the table above:

- If the market yield is above the notional coupon level, bonds with a longer duration (lower coupon given similar maturities/longer maturity given similar coupons) will be preferred for delivery.
- If the market yield is below the notional coupon level, bonds with a shorter duration (higher coupon given similar maturities/shorter maturity given similar coupons) will be preferred for delivery.
- When yields are at the notional coupon level (six or four percent) the bonds are almost all equally eligible for delivery.

As already stated, the reason for a preference of certain bonds lies in the "incorrect" discount rate of six or four percent that is implied by the calculation of the conversion factor. For example, when market yields are below the level of the notional coupon, the calculation of the delivery price undervalues all deliverable bonds. As bonds with a low duration are less sensitive to discount rate fluctuations, the undervaluation is least pronounced for these bonds. Bonds with a low duration are **c**heapest-**t**o-**d**eliver (CTD) with market yields below the implied discount rate (the notional coupon rate); the opposite effect applies for market yields above the notional coupon.

Based on the three deliverable bonds in our example, the following chart illustrates how the CTD changes as the yield curve shifts.

Identifying the CTD Bond in Different Market Scenarios



Applications of Fixed Income Futures

There are three reasons for using derivatives: Trading, hedging and arbitrage.

Trading means entering into risk positions on the derivatives market for the purpose of making a profit, assuming that market developments are forecast correctly. Hedging is the protection of a current or a planned portfolio against adverse price movements. Taking advantage of price imbalances to realize risk-free profits is called arbitrage.

It is important for the equilibrium of derivative markets that both traders and hedgers are active. Trades can also occur between hedgers, if one counterparty wants to hedge the value of an existing portfolio against falling prices and the other counterparty wants to hedge the purchase price of a planned portfolio against expected price increases. The transfer of risks between these market participants is the main function of a derivatives market. Arbitrage ensures that the market prices of derivative contracts diverge only marginally (and for a short period of time) from their theoretical values.

Trading Strategies

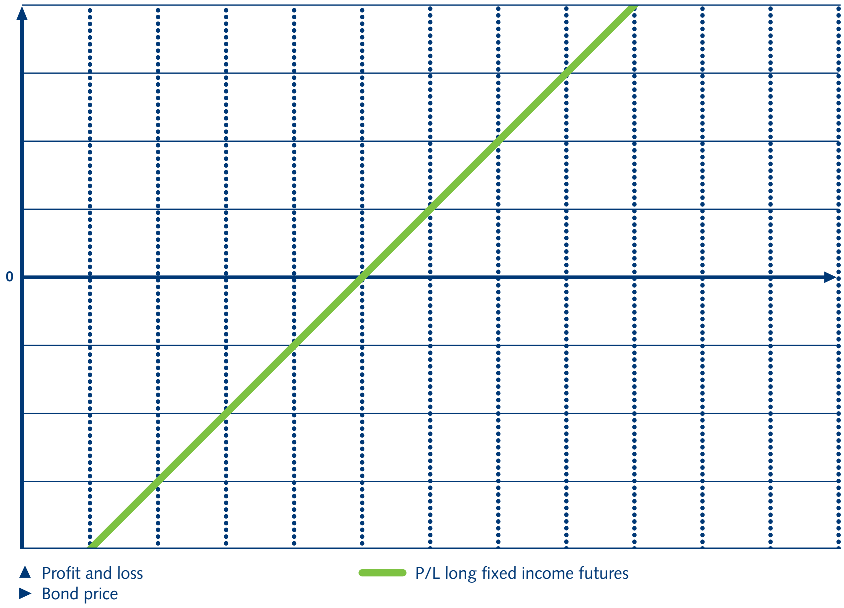
Basic Futures Strategies

Straight exposure in fixed income futures offers traders the advantage that they can profit from expected interest rate moves without having to tie up capital by buying bonds. In contrast to a cash market investment, only Additional Margin must be pledged for a non-spread futures position (see chapter "Futures Spread Margin and Additional Margin"). Traders incurring losses on their futures position – for example due to an incorrect forecast – are obliged to immediately and fully settle such losses (via Variation Margin payments). Total Variation Margin flows during the lifetime of the futures contract can amount to a multiple of the amount pledged originally. The change in value relative to the capital investment is therefore by far greater than for a comparable exposure in the cash market. This effect is referred to as the "leverage effect". In other words: On the one hand, exposure in fixed income futures offers a great potential for gains. On the other hand, it also holds correspondingly high risks.

Long Positions ("Bullish" Strategies)

Traders expecting falling market yields for a certain remaining lifetime will decide to buy futures contracts covering the corresponding section of the yield curve. If the prediction turns out to be correct, a profit is made on the futures position. Such a long position comprises, as is characteristical for futures, a risk of loss proportional to the potential for gains. In principle, the price/yield relationship of a fixed income future is equivalent to that of a portfolio of deliverable bonds.

Profit and Loss Profile on the Last Trading Day – Long Fixed Income Futures



Motivation

The trader wants to profit from an expected trend without tying up capital in the cash market.

Initial Situation

The trader expects a decline in yields for German five-year Federal notes (Bundesobligationen).

Strategy

The trader buys ten June Euro-Bobl Futures at 110.100, which he intends to closeout during the lifetime of the contract. If the price of the Euro-Bobl Futures rises, the trader makes a profit that is equivalent to the difference between the purchase price and the higher selling price. The determination of the right time to sell requires continuous analysis of the market.

The calculation of Additional Margin and Variation Margin is outlined for a hypothetical market development in the following table. The amount of Additional Margin results from the multiplication of the margin parameter specified by Eurex (here: EUR 1,200 per contract) by the number of contracts.[13]

Date	**Transaction**	**Purchase/ selling price**	**Daily Settlement Price**	**Variation Margin[14] profit in EUR**	**Variation Margin loss in EUR**	**Additional Margin[15] in EUR**
Mar 11	Buy 10 June Euro-Bobl Futures	110.100	109.910		1,900	−12,000
Mar 12			109.970	600		
Mar 13			109.805		1,650	
Mar 14			109.690		1,150	
Mar 15			109.830	1,400		
Mar 18			110.140	3,100		
Mar 19			110.025		1,150	
Mar 20	Sell 10 June Euro-Bobl Futures	110.370		3,450		
Mar 21						+12,000
Result		0.270		8,550	5,850	0

Changed Market Situation

The trader closes out the futures position on March 20, at a price of 110.370. The pledged Additional Margin is released on the following day.

Result

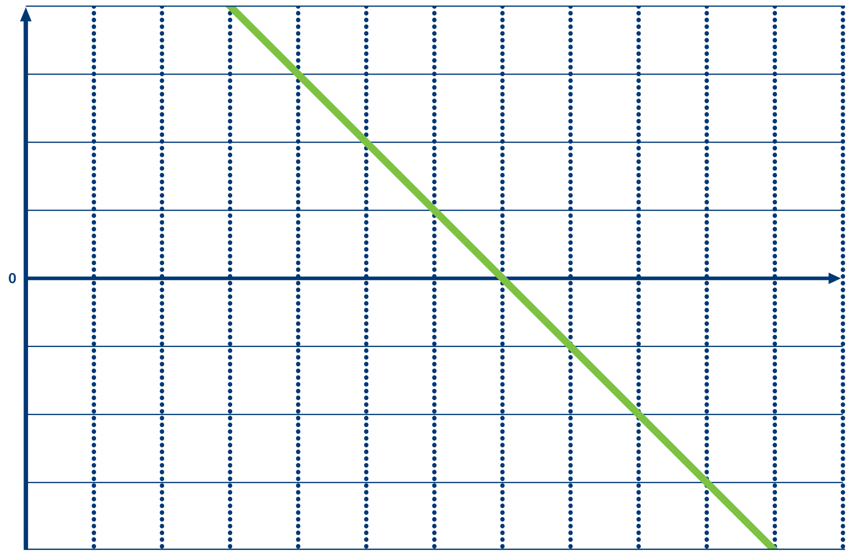
The proceeds of EUR 2,700 from the difference between the purchase price and the selling price is equal to the balance of the Variation Margin flows settled daily (EUR 8,550 – EUR 5,850). Alternatively, the net profit can also be described as the accumulated futures price movements, multiplied by ten contracts and the value of one point (EUR 1,000): (110.370 – 110.100) × 10 × EUR 1,000 = EUR 2,700.

13 Current margin parameters are available on the Eurex website: **www.eurexchange.com > Clearing > Risk & Margining > Risk Parameters**.
14 See chapter "Variation Margin".
15 See chapter "Futures Spread Margin and Additional Margin".

Short Positions ("Bearish" Strategies)

If, on the contrary, an investor assumes a rising market yield, he sells futures contracts. The graph for the short position in fixed income futures illustrates potential gains and risk exposure, depending on the development of the futures price.

Profit and Loss Profile on the Last Trading Day – Short Fixed Income Futures



▲ Profit and loss
► Bond price

P/L short fixed income futures

Motivation

The investor wants to profit from rising yields. However, he does not have the possibility to go "short" in fixed income securities, that means to sell them without owning them.

Initial Situation

The investor expects a rise in yield for German Federal Treasury notes (Bundesschatzanweisungen).

Strategy

The investor decides to enter into a short position of 20 contracts in June Euro-Schatz Futures at a price of 104.985. This position is closed by buying back the contracts after a certain period of time. Again, the amount of Additional Margin results from the multiplication of the margin parameter specified by Eurex (here: EUR 500 per contract) by the number of contracts.

Date	Transaction	Purchase/ selling price	Daily Settlement Price	Variation Margin profit in EUR	Variation Margin loss in EUR	Additional Margin in EUR
Mar 11	Sell 20 June Euro-Schatz Futures	104.985	105.000		300	–10,000
Mar 12			104.600	8,000		
Mar 13			104.485	2,300		
Mar 14			104.520		700	
Mar 15			105.200		13,600	
Mar 18			105.450		5,000	
Mar 19			105.720		5,400	
Mar 20	Buy 20 June Euro-Schatz Futures	105.605		2,300		
Mar 21						+10,000
Result		–0.620		12,600	25,000	0

Changed Market Situation

The investor closes out the futures position on March 20, at a price of 105.605. The pledged Additional Margin is released on the following day.

Result

The loss of EUR 12,400 equals the accumulated daily Variation Margin flow (EUR 12,600 – EUR 25,000). Alternatively, the net result can be described as the accumulated futures price movements, multiplied by 20 contracts and the value of one point (EUR 1,000): (104.985 – 105.605) × 20 × EUR 1,000 = EUR –12,400.

Spread Strategies

A spread is the simultaneous purchase and sale of futures. The purpose of entering into a spread position is to generate a profit from expected changes in the price difference between the long and the short position.

Spreads appear in different forms. Time spreads and Inter-product Spreads are outlined in the following section.

Time Spread

In a time spread, the trader enters a long and a short position in futures with the same underlying instrument, but with different contract maturities. This strategy can be based on two different motivations: On the one hand, the forecast of a changed price difference between both contracts can be based on an expected change of the financing costs for the different maturities. On the other hand, the spread position can be used to take advantage of an assumed mispricing of both or one of the contracts, in conjunction with the assumption that this mispricing will be leveled out by the market. Simultaneously entering into long and short positions reduces the total market risk in comparison to an outright long or short position. Even if the investor's expectations are not met, the loss of one futures position will be largely offset by the counter position. Hence, Eurex applies reduced margin rates for time spread positions (Futures Spread Margin instead of Additional Margin).

Time Spread	
Purchase Simultaneous purchase of a fixed income futures contract with a shorter lifetime and the sale of the same futures contract with a longer lifetime	**Sale** Simultaneous sale of a fixed income futures contract with a shorter lifetime and the purchase of the same futures contract with a longer lifetime
... where a positive (negative) spread induced by the difference in financing costs between the shorter and the longer maturity is expected to widen (narrow); or	... where a positive (negative) spread induced by the difference in financing costs between the shorter and the longer maturity is expected to narrow (widen); or
… where the contract with the longer lifetime is overvalued in relative terms.	… where the contract with the shorter lifetime is overvalued in relative terms.

Motivation

In April, a trader analyses the value of the September Euro-Bobl Futures and realizes that the contract is overvalued. He expects a widening of the spread between the June and September maturities.

Initial Situation

June Euro-Bobl Futures	109.810
September Euro-Bobl Futures	109.755

Strategy

Purchase of five Euro-Bobl Futures June/September time spreads.

Buy June Euro-Bobl Futures at a price of	−109.810
Sell September Euro-Bobl Futures at a price of	+109.755
Price of June/September spread bought	−0.055

Changed Market Situation

In May, the trader's expectations set in. A decision is taken to close the spread position and to thereby realize the profit.

Sell June Euro-Bobl Futures at a price of	+110.340
Buy September Euro-Bobl Futures at a price of	−109.990
Price of June/September spread sold	+0.350

Result

June/September spread entry level	−0.055
June/September spread closeout level	+0.350
Result per contract	+0.295

The total profit for the five contracts is: 5 × 0.295 × EUR 1,000 = EUR 1,475.00.

Inter-product Spread

In an Inter-product Spread, the trader enters into long and short positions in futures with different underlying instruments. The purpose of this strategy is to exploit diverging yield development in the respective maturity segments. If – assuming a "normal" yield curve – yields for the ten-year segment rise stronger than in the five-year and two-year segments, this is referred to as a "steepening" yield curve, whereas a "flattening" curve is characterized by declining yield differentials between the short-term, medium-term and long-term segments.

The Inter-product Spread also features reduced risk in comparison to an outright futures position. When calculating Additional Margin, the correlation of the price development is accounted for, as the Euro-Bund and Euro-Bobl Futures are combined in one Margin Group.[16]

The legs, as the individual long and short positions, must be weighted using the contracts' modified duration, as the interest rate sensitivity differs for bonds (and hence for the corresponding futures contracts) with different remaining lifetimes. Otherwise, parallel shifts of the yield curve would also result in a change in the value of the spread.

16 See the "Risk-based Margining" brochure.

Inter-product Spread	
Purchase Simultaneous purchase of a fixed income future on a shorter-term underlying instrument and sale of a fixed income future on a longer-term underlying instrument, with identical or similar contract maturities	**Sale** Simultaneous sale of a fixed income future on a shorter-term underlying instrument and purchase of a fixed income future on a longer-term underlying instrument, with identical or similar contract maturities
… where the yield curve is expected to steepen.	… where the yield curve is expected to flatten.

Motivation

In the middle of May, a trader assumes that the yield curve – starting from a normal structure – will become "steeper" between the ten-year and 30-year segments; that means that the yields in the very long-term segment will increase more (or decrease less) than in the long-term segment.

Initial Situation

June Euro-Bund Futures	121.04
June Euro-Buxl® Futures	103.20
Euro-Bund/Euro-Buxl® ratio	2.31:1

Strategy

The trader wants to profit from the expected development with the simultaneous purchase of 23 Euro-Bund Futures and sale of ten Euro-Buxl® Futures. The long-term and very long-term positions are weighted unequally to take into account the different interest rate sensitivities of the two legs. The success of this strategy mainly depends on the yield differential – not on the absolute level of market yields.

Changed Market Situation

At the beginning of June, the yield in the 30-year segment has risen by 20 basis points, compared to just ten basis points in the ten-year segment. The market prices of the Euro-Buxl® and Euro-Bund Futures have developed as follows:

June Euro-Bund Futures	120.20
June Euro-Buxl® Futures	99.31

The trader decides to closeout his position, and makes a profit of EUR 19,580:

Result from the Euro-Bund position		EUR
June Euro-Bund Futures bought at a price of June Euro-Bund Futures sold at a price of	–121.04 +120.20	–121,040 +120,200
Loss per contract Loss incurred on the Euro-Bund position (23 contracts)		– 840 – 19,320

Result from the Euro-Buxl® position		EUR
June Euro-Buxl® Futures sold at a price of June Euro-Buxl® Futures bought at a price of	103.20 –99.31	103,200 –99,310
Profit per contract Profit made on the Euro-Buxl® position (10 contracts)		3,890 38,900

Total result in EUR	–19,320 + 38,900 = 19,580

Hedging Strategies

Traders who want to hedge a long or short position in the cash market against adverse short-term market developments will – depending upon the position to be hedged – buy or sell futures contracts. In effect, this allows them to lock in their cash market position at a specific futures price level.

Hedging interest rate positions largely comprises selecting the appropriate futures contract; determining the number of contracts required to hedge the cash market position ("hedge ratio"); and deciding on a potential adjustment of this hedge ratio throughout the observed timeframe.

Selecting the Futures Contract

In an ideal case, a future is used to hedge securities that are eligible for the basket of deliverable bonds for that contract. For example, when hedging an existing portfolio, a trader is free to closeout the futures on the Last Trading Day and to therefore close the hedge position, or to deliver the securities at maturity.

Where futures are used to acquire a portfolio, the holder of a long position can decide to either take delivery of the securities when the contract is settled or, alternatively, to closeout the futures position and buy them on the cash market. If there are no futures contracts with the same lifetime as the bonds to be hedged, or if hedging individual securities in the portfolio is too complex, then contracts that feature a high correlation to the portfolio are used for hedging.

"Perfect Hedge" versus "Cross Hedge"

In a "perfect" hedge, losses from the change in value of the cash market position are almost exactly compensated for by changes in value of the future. In practice, a perfect hedge of a portfolio is usually not possible. This is due to the fact that futures cannot be traded in fractions of contracts, and also to mismatches between cash securities and futures contracts. In addition, the remaining lifetime of the future often does not match the horizon of the hedge. If for these reasons the hedge position does not precisely offset the performance of the portfolio, the hedge is called a cross hedge.

Hedging Considerations

Basis Risk – the Cost of Hedging

The final result of each hedge depends on the correlation of the price development of the hedged asset to the futures or option contract used for hedging.

For futures on government bonds we can assume that the futures prices is closely oriented to the price of the CTD bond. When hedging with exchange traded futures, the absolute price risk is thus converted into "basis risk". The basis risk depends on the relationship between the hedging instrument and the position to be hedged. It materializes where the performance of the position to be hedged is not completely compensated for – or overcompensated – by the hedge.

Extent of the Basis Risk

Hedgers are often prepared to tolerate a certain degree of basis risk in order to manage larger-sized market exposure. In the light of extremely liquid and transparent exchange traded futures on government bonds, these contracts are regularly used to hedge bonds that are not the CTD, and even for corporate bonds. Of course, the reliability of the hedge decreases with a falling correlation between the bond to be hedged and the CTD bond, potentially resulting in a significant degree of basis risk.

Hedging the CTD Bond and Other Bonds

The application of the conversion factor in the hedge ratio calculation was already outlined in the chapter "Conversion Factor (Price Factor) and Cheapest-to-Deliver (CTD) Bond". The conversion factor assures the quality of the hedge in hedging a CTD bond, as long as no substantial changes of the yield curve take place as time progresses. The hedge can be compromised by a change of the CTD bond caused by a shift of the yield curve during the duration of the hedge. Hedgers should closely monitor the situation and adjust the hedge to the changed conditions if necessary.

Determining the Hedge Ratio

The ratio of the futures position to the portfolio, respectively the number of futures contracts required for the hedge, is referred to as the hedge ratio. Due to the contract specifications, only integer numbers of futures contracts (round lots) can be traded. Several methods with different levels of accuracy exist for the determination of the hedge ratio. The following section outlines the most common procedures.

Nominal Value Method

With this method the number of futures contracts is determined from the ratio of the portfolio's nominal value to that of the futures contract used for hedging. The nominal value method is indeed the simplest but also mathematically the most imprecise calculation method outlined here. The hedge ratio is calculated with the aid of the nominal value method as follows:

$$\text{Hedge ratio} = \frac{\text{Nominal value of the bond portfolio}}{\text{Nominal value of fixed income futures}}$$

Nominal value of the bond portfolio = Sum of the bonds' nominal values

Nominal value of fixed income futures = Nominal contract size of a fixed income future (CHF 100,000 or EUR 100,000)

Potential differences in the interest rate sensitivity of the futures contracts and the bonds are not considered here.

Modified Duration Method

The **m**odified **d**uration (MD) can be used to calculate the sensitivity of the cash market and futures positions, and to determine the hedge ratio on that basis.

The following parameters are used for the calculation of the hedge ratio using modified duration:

The **c**heapest-**t**o-**d**eliver (CTD) bond	as the underlying instrument of the futures contract[17];
the modified duration	of the individual positions and thus of the total portfolio, as a measure of their interest rate sensitivity. The modified duration of the portfolio is equivalent to the aggregate modified duration of its component securities, weighted by their present value;[18]
the conversion factor,	which standardizes the different coupons to 6% or 4%.

[17] See chapters "Conversion Factor (Price Factor)" and "Cheapest-to-Deliver (CTD) Bond".
[18] See chapters "Macaulay Duration" and "Modified Duration".

The modified duration of a futures position is expressed as the modified duration (MD) of the CTD bond, divided by the conversion factor (based on the assumption that futures price = CTD/conversion factor). The hedge ratio is calculated as follows using modified duration:

$$\text{Hedge ratio} = \frac{\text{Market value of the bond portfolio}}{\text{Price (CTD)} \times 1{,}000} \times \frac{\text{Modified duration of the bond portfolio}}{\text{Modified duration (CTD)}} \times \text{Conversion factor}$$

The MD of a portfolio is derived from the weighted sum of the MDs of the portfolio's individual bonds. This method's restrictions result from the limitations of the duration model outlined in the sections „Macaulay Duration“ and „Modified Duration“.

Motivation
A pension fund manager expects a CHF 10,000,000 cash inflow from a fixed-term deposit in the middle of September, which is to be invested in Swiss Confederation bonds. As he anticipates a decline in interest rates across all segments of the curve, the current price level (March) in the Swiss bond market needs to be locked in.

Initial Situation

Market value of the bond portfolio	CHF 10,000,000
Price of the CTD bond	106.49
September CONF Futures	124.05
Modified duration of the portfolio	– 8.00 %
Modified duration of the CTD	– 8.95 %
Conversion factor	0.82524

Strategy
The strategy involves the purchase of CONF Futures September at 124.05 in March and the subsequent closeout of the futures position at a higher price. This is designed to return a profit on the futures position, which should largely compensate for the expected price increase of the bonds to be purchased.

Hedge ratio based on modified duration:

$$\text{Hedge ratio} = \frac{10{,}000{,}000}{106{,}490} \times \frac{-8.00}{-8.95} \times 0.82524 = 69.27$$

The hedge is arranged in March with the purchase of 69 CONF Futures at 124.05.

Changed Market Situation

In September, the market yields declined as anticipated. The fund manager closes out the futures position.

Market value of the bond portfolio	CHF 10,210,000
Price of the CTD bond	109.59
September CONF Futures	127.15

Result

Date	Bond portfolio	CHF	CONF Futures	CHF
March	Market value	10,000,000	69 contracts bought at 124.05	– 8,559,450
September	Market value	10,210,000	69 contracts sold at 127.15	+ 8,773,350
	Loss	= – 210,000	Profit	= 213,900

The overall result of the total position is shown below:

Profit (long CONF position)	CHF 213,900
Loss (higher bond purchase price)	CHF – 210,000
Total	CHF 3,900

The CHF 210,000 increase in the investment volume was more than compensated for by the offsetting position.

For a duration hedge it must be noted that, due to convexity, the hedge result can become inaccurate for major price changes. Therefore, convexity must be taken into consideration for long-term hedges.[19]

Sensitivity Method

The sensitivity (basis point value) method is also based on the concept of duration – the premises of that model apply accordingly. However, here the interest rate sensitivity is expressed as the instrument's change in value for an interest rate change by one basis point (0.01 percentage points).

The hedge ratio is calculated as follows using the sensitivity method:[20]

$$\text{Hedge ratio} = \frac{\text{Basis point value of the cash position}}{\text{Basis point value of the CTD bond}} \times \text{Conversion factor}$$

[19] To maximize the convexity of the overall position, sell the futures with the lowest convexity (given a duration in line with the portfolio). To minimize the convexity of the overall position, the convexity of the short hedge (in absolute terms) needs to be brought in line with the bond portfolio. See the chapter "Convexity – The Tracking Error of Duration" for the impact of convexity on the value of a bond.

[20] The basis point value is equivalent to the modified duration, divided by 10,000, as it is defined as absolute (rather than percent) present value change per 0.01 percent (rather than 1 percent) change in market yields.

$$\text{Basis point value (sensitivity) of the cash position} = \text{Market value of the bond portfolio} \times \frac{MD_{\text{bond portfolio}}}{10{,}000}$$

$$\text{Basis point value (sensitivity) of the CTD bond} = \text{Market value of the CTD bond} \times \frac{MD_{\text{CTD}}}{10{,}000}$$

Motivation

An institutional investor would like to liquidate his bond portfolio with a market value of EUR 40,000,000 in the course of the next two months. He fears that interest rates could rise – and that prices could fall – by the time of the planned sale.

Initial Situation

Market value of the bond portfolio	EUR 40,000,000
Euro-Bund Futures	112.59
Price of the CTD bond	95.98
Modified duration of the portfolio	– 8.20 %
Basis point value of the portfolio	EUR – 32,800.00
Modified duration of the CTD	– 7.18%
Conversion factor of the CTD	0.849220
Basis point value of the CTD	(100,000 × 0.9598 / 10,000) × – 7.18 = EUR – 68.91

Strategy

The strategy comprises the sale of Euro-Bund Futures at 112.59 and the subsequent closeout of the futures position at a cheaper price. This is designed to make a profit on the futures position which should compensate for the expected loss on the bonds.

Hedge ratio according to the basis point value method:

$$\text{Hedge ratio} = \frac{\text{Basis point value of the cash position}}{\text{Basis point value of the CTD bond}} \times \text{Conversion factor}$$

$$\text{Hedge ratio} = \frac{-32{,}800.00}{-68.91} \times 0.849220 = 404.21 \text{ contracts}$$

The hedge is created with the sale of 404 Euro-Bund Futures September at 112.59.

Changed Market Situation

Market yields have risen by approximately 0.30 percentage points (30 basis points) until September. The investor closes out the short futures position, buying back the Euro-Bund Futures.

Market value of the bond portfolio	EUR 38,987,750
Euro-Bund Futures	110.09

Result

Date	Bond portfolio	EUR	Euro-Bund Futures	EUR
March	Market value	40,000,000	404 contracts sold at 112.59	45,486,360
September	Market value	38,987,750	404 contracts bought at 110.09	– 44,476,360
	Loss	= – 1,012,250	Profit	= 1,010,000

The overall result of the total position is shown below:

Profit (short Euro-Bund position)	EUR	1,010,000
Loss (loss in value of the portfolio)	EUR	– 1,012,250
Total	EUR=	– 2,250

The profit from the Euro-Bund Futures position almost fully compensated for the loss on the bond portfolio.

Static and Dynamic Hedging

Simplifying the interest rate structure upon which the hedging models are based can, over time, lead to inaccuracies in the hedge ratio. Hence, it is necessary to adjust the futures position to ensure the desired total or partial hedge effect. Such a continuous adjustment is referred to as a dynamic hedge (or "tailing"). In contrast, the initial hedge ratio is not changed in a static hedge. Traders must consider costs and benefits of an adjustment.

Cash-and-Carry Arbitrage

In general, arbitrage is defined as entering into risk-free positions exploiting price differences (or mispricing) of derivatives or securities. In the so-called cash-and-carry arbitrage, bonds are purchased in the cash market and a short position in the respective futures contract is entered into. The sale of bonds and the simultaneous purchase of a future is referred to as reverse cash-and-carry arbitrage. In each case, the trader enters into a long position in the market perceived as undervalued – this may be the cash or derivatives market. Even though such arbitrage strategies are often referred to as "risk-free", their actual result depends on a number of factors, which can imply several risks. For example, this includes the exact price development and the resulting Variation Margin cash flows as well as changes of the CTD bond during the duration of the hedge. A detailed examination of all fators influencing (reverse) cash-and-carry arbitrage positions is not possible within the scope of this brochure. The theoretically correct basis can be determined by discounting the delivery price. The opportunity to enter cash-and-carry positions usually only exists for a very short period of time; the potential for profit rarely exceeds the transaction costs.

Initial Situation

Valuation date	August 25, 2004
CTD bond	3.75% Bund due July 4, 2013
Price of the CTD bond	96.30
Money market interest rate	2.10%
Theoretical futures price[21]	113.31
Euro-Bund Futures	113.61
Futures delivery date	September 10, 2004

If the futures contract is quoted above its theoretically correct price, an arbitrageur buys the deliverable bonds and enters a short position in the respective future. Based on one single future, the arbitrageur executes the following transactions:

Transaction	EUR	Remarks
CTD bought	96,830.00	Clean price 96,300 + 530 accrued interest
Financing costs until futures maturity	90.37	96,830 × 0.0210 × (16/360) years[22]
Total amount invested in the bonds	96,920.37	96,830 + 90.37

The delivery price at maturity of the future, plus the profit and loss settlements throughout the lifetime, must be compared with the overall investment. The delivery price results from the Final Settlement Price, multiplied with the conversion factor, plus accrued interest.

Transaction	EUR	Remarks
Short futures position	113,610.00	
Final Settlement Price	113,400.00	
Profit from Variation Margin	210.00	
Delivery price	97,000.18	113,400.00 × 0.849220 + 698.63 accrued interest

If the profit from the short position is added as a return to the delivery price, the profit of the arbitrage transaction results as the difference to the invested capital.

Total profit:	**97,000.18 + 210.00 – 96,920.37 = 289.81**

The arbitrageur made a profit of EUR 289.81 due to the imbalance of prices.

21 See chapter "Conversion Factor and Cheapest-to-Deliver (CTD) Bond".
22 Money market day-count convention "actual/360".

Introduction to Options on Fixed Income Futures

Options on Fixed Income Futures – Definition

An option is a contract entered into between two parties. By paying the option price (the premium) the buyer of an option acquires the right, for example,

... to buy	Call option	Calls
... or to sell	Put option	Puts
... a given fixed income futures contract	Underlying instrument	Euro-Bund Futures
... in a set amount	Contract size	One contract
... until a set point in time	Last Trading Day	September 23, 2005
... at a determined price	Exercise price	112.50

The seller (sometimes also called the "writer") is obliged to sell (in the case of a call option) or to buy (in the case of a put option) the underlying futures contract at a fixed exercise price, if the buyer claims his right to exercise the option. The option buyer pays the option price, or premium, in exchange for this right. This premium is settled using the "futures-style" premium posting method. This means that the premium is not fully paid until the option expires or is exercised. Consequently, and in line with futures, daily settlement of profits and losses is effected by means of Variation Margin (see chapter "Variation Margin").

Options on Fixed Income Futures – Rights and Obligations

A trader enters into a position on the option market by buying and selling options.

Long position	**Short position**
The buyer of the options enters into a long position – depending on the contract traded, this may be a long call or a long put.	The seller of the options enters into a short position – depending on the contract traded, this may be a short call or a short put.

Buyers and sellers of options on fixed income futures have the following rights and obligations:

Call		**Put**	
Call buyer **Long call** The buyer of a call has the right, but not the obligation, to buy the futures contract at an exercise price specified in advance.	Call seller **Short call** In the event of exercise, the seller of a call is obliged to sell the futures contract at an exercise price specified in advance.	Put buyer **Long put** The buyer of a put has the right, but not the obligation, to sell the futures contract at an exercise price specified in advance.	Put seller **Short put** In the event of exercise, the seller of a put is obliged to buy the futures contract at an exercise price specified in advance.

An option position on fixed income futures can be closed out by entering into an offsetting trade ("closeout" – see below); the buyer of the option can also close it by exercising the option.

Closeout

A closeout means neutralization through an offsetting transaction. For instance, a short position of 2,000 call options September 112.50 on Euro-Bund Futures can be closed out with the purchase of 2,000 call options of the same series. In this way, the obligations arising from the original short position are fully offset. Likewise, a long position of 2,000 put options September 112.50 on Euro-Bund Futures can be closed out with the sale of 2,000 put options of this series.

Exercising Options on Fixed Income Futures

In case of an exercise of an option on fixed income futures by the holder of the long position, the Clearing House assigns this exercise to an open short position. This is carried out in a random process and is referred to as "assignment". Here, the affected option positions are liquidated and the respective futures positions are booked to the buyer and the seller of the option. For this purpose, the exercise price of the option is applied as the purchase and respective selling price of the future. The futures positions which are opened – depending on the underlying option position – are outlined in the following table:

Exercising a ...		Assignment of a ...	
Long call	**Long put**	**Short call**	**Short put**
results in the opening of a ...			
Long future	**Short future**	**Short future**	**Long future**

Options on fixed income futures can be exercised on any exchange trading day before expiration (American-style option). The option's expiration date lies before the future's Last Trading Day. If the holder of an option decides to exercise, he must inform the Clearing House, which assigns a short position in a neutral random process.

Contract Specifications – Options on Fixed Income Futures

Eurex options are exchange traded contracts with standardized characteristics. The specifications for Eurex products can be found on the Eurex website **www.eurexchange.com** and in the "Eurex Products" brochure.

The most important terms are described in the following example.

A trader buys:

… 20	Contracts	One contract comprises the right to buy or sell one fixed income futures contract.
… September 2005	Expiration month	Every option has a limited lifetime and a set expiration date. The expiration months available for trading are the three nearest calendar months, as well as the following month within the March, June, September and December cycle; i.e. lifetimes of one, two and three months, as well as a maximum of six months are available. Hence, for the months March, June, September and December, the expiration months for the option and the maturity months for the underlying futures are identical (although the Last Trading Days differ for options and futures). In the case of the other contract months, the maturity month of the underlying instrument is the quarterly month following the expiration date of the option. Hence, the option always expires before the maturity of the underlying futures contract.
… 115.00	Exercise price (also called "strike price")	This is the price at which the buyer can enter into the corresponding futures position. At least nine exercise prices are always available for each contract month. The price intervals for this contract are set at 0.50 points.
… Call	Call option	The buyer can convert this position into a long futures position. Upon exercise, the seller enters into a short futures position.
… Options on the Euro-Bund Futures	Underlying instrument	The Euro-Bund Futures is the underlying instrument for the option contract.
… at 0.15	Option price (premium)	Buyers of options on fixed income futures pay the option price to the seller upon exercise, in exchange for the right. The option premium is EUR 10.00 per 0.01 points. Therefore a premium of 0.15 is really worth EUR 150. The premium for 20 contracts is 20 × EUR 150 = EUR 3,000.

In our example, the buyer purchases the right to enter into a long position in 20 Euro-Bund Futures at an exercise price of 115.00, and pays EUR 3,000 to the seller, in exchange for this right. The seller on the other hand is obliged to sell 20 Euro-Bund Futures at a price of 115.00, if the buyer makes use of his right to exercise and the exercise is assigned to him. This obligation stands until the Last Trading Day of the option.

Premium Payment and Risk-based Margining

Buyers of options on fixed income futures do not pay the premium on the day following the purchase of the contract, as is the case for equity or equity index options. Here, the premium is paid upon exercise or expiration of the option. Contract price changes during the lifetime are accounted for with Variation Margin. When the option is exercised, the buyer pays the premium equivalent to the Daily Settlement Price on this day. Based on the daily settlement of profits and losses, this method is referred to as "futures-style" premium posting, for which – as for the underlying futures contract – Additional Margin must be pledged to cover market risk.

Motivation

The trader expects a decline in prices for the Euro-Bund Futures September. To limit his risk in case of an opposite development, he decides on a put option position.

Strategy

On July 6, Euro-Bund Futures September are traded at 113.78. The trader buys ten put options on this contract with an exercise price of 114.00, at a price of 0.55, which corresponds to a premium of EUR 550 per option contract.

Date	Transaction	Purchase / selling price in EUR	Option Daily Settlement Price in EUR	Variation Margin[23] credit in EUR	Variation Margin debit in EUR	Additional Margin[24, 25] in EUR
Jul 06	10 put options bought	0.55	0.91	3,600		16,000
Jul 07			0.81		–1,000	

Changed Market Situation

Meanwhile, Euro-Bund Futures are quoted at 113.50. The trader decides to exercise the option, which is traded at 0.70.

Jul 08	Exercise	0.70			–3,100	
Jul 09	Opening of a short position in September Euro-Bund Futures					+/–0 In this case the Additional Margin rates for futures and options are identical.
	Total up to entry into futures position			3,600	– 4,100	

23 See chapter "Variation Margin".
24 See chapter "Futures Spread Margin and Additional Margin".
25 Current margin parameters are available on the Eurex website: **www.eurexchange.com > Clearing > Risk & Margining > Risk Parameters**.

The Variation Margin on the day of exercise (July 8) is calculated as follows:

Profit made on the exercise	EUR 5,000	Difference between the exercise price (114.00) and the Daily Settlement Price (113.50), multiplied by the contract value and the number of contracts.
Change in option value compared to the previous day	EUR –1,100	EUR 7,000 – EUR 8,100
Option premium to be paid	EUR –7,000	0.70 × 10 × 1,000
Variation Margin on July 8	EUR –3,100	

Result of Exercise

Overall, the trader incurs a loss of EUR 500 with these transactions. The loss can be expressed either as the difference between the option price of EUR 5,500 fixed at conclusion of the contract (but not paid in full until exercise), and the EUR 5,000 gain from the exercise; or as the net balance of the Variation Margin payments (EUR 3,600 – EUR 4,100). When exercising an option, the change in value of the option between the purchase and the opening of the futures position does not have an immediate impact on the trader's net result. The Additional Margin Parameter for Options on Euro-Bund Futures is identical to that of the underlying futures contract.

However, exercise of the option is not sensible in this case. This is because the trader can make a profit by closing out the position by selling the put option at a higher price than the original purchase price.

Result of Closeout

Given the previous day's settlement price of 0.81, a sale on July 8 at a price of 0.70 would only result in a Variation Margin debit of EUR 1,100 (0.11 × 10 × EUR 1,000). The profit and loss calculation for selling the option is shown below:

Date	Transaction	Purchase/ selling price in EUR	Option daily settlement price in EUR	Variation Margin-credit in EUR	Variation Margin-debit in EUR	Additional Margin in EUR
[…]	[…]	[…]	[…]	[…]	[…]	
Jul 08	Sale	0.70			– 1,100	
Jul 09						–16,000
Total			3,600		–2,100	

The trader make a total profit of EUR 1,500 when selling the options, equivalent to the difference between the selling and purchase price (0.70 – 0.55), multiplied by the contract value and the number of futures contracts. The trader is refunded the Additional Margin.

Options on Fixed Income Futures – Overview

The following three options on fixed income futures are currently traded at Eurex:

Product	Product code
Options on Euro-Schatz Futures	OGBS
Options on Euro-Bobl Futures	OGBM
Options on Euro-Bund Futures	OGBL

Option Price

Components

The option price is comprised of two components – intrinsic value and time value.

Option value = Intrinsic value + Time value

Intrinsic Value

An option that allows the purchase or sale of the underlying instrument at more attractive terms than at the market price is said to have an "intrinsic value". The intrinsic value can be positive or zero, but never negative.

For calls: Intrinsic value = Futures price – Exercise price of the option, if this is > 0; otherwise it is zero.
For puts: Intrinsic value = Exercise price – Futures price, if this is > 0; otherwise it is zero.

An option is "in-the-money", "at-the-money" or "out-of-the-money" depending upon whether the price of the underlying is above, at, or below the exercise price:

	Calls	Puts
Exercise price < Futures price	in-the-money (intrinsic value > 0)	out-of-the-money (intrinsic value = 0)
Exercise price = Futures price	at-the-money (intrinsic value = 0)	at-the-money (intrinsic value = 0)
Exercise price > Futures price	out-of-the-money (intrinsic value = 0)	in-the-money (intrinsic value > 0)

Time Value

The time value reflects the buyer's potential chances of his forecasts on the development of the underlying instrument being met during the remaining lifetime. The buyer is prepared to pay a certain sum – the time value – for this opportunity. The closer an option moves towards expiration, the lower the time value becomes until it eventually reaches zero on that date. The time value decay accelerates as the expiration date approaches.

Time value = Option price – Intrinsic value

Determining Factors

The theoretical price of options on fixed income futures can be calculated independently of the current supply and demand situation, on the basis of various parameters. An important component of the option price is the intrinsic value as introduced earlier (see section on "Intrinsic Value"). The lower (calls) or higher (puts) the exercise price compared to the current market price of the underlying instrument, the higher the intrinsic value and hence the higher the option price. The option premium is equivalent to the time value if the option is at-the-money or out-of-the-money. The following section illustrates the determining factors of time value.

Volatility of the Underlying Instrument

Volatility measures the extent and intensity of fluctuations in the price of the underlying instrument. The greater the volatility, the higher the option price. An underlying instrument whose price fluctuates strongly provides option buyers with a greater opportunity of meeting their price forecast during the lifetime of the option. That is why they are prepared to pay a higher price for the option. Sellers, in turn, demand a higher price to cover their increasing risks.

There are two concepts of volatility:

Historical volatility	Implied volatility
This is based on historical data and represents the annualized standard deviation of the returns on the underlying instrument.	This corresponds to the volatility reflected in a current market option price. In a liquid market it is the indicator for the changes in returns anticipated by market participants.

Remaining Lifetime of the Option

The longer the remaining lifetime, the greater the chance that the expectations of option buyers on the price of the underlying instrument will be fulfilled during the remaining period of time. Conversely, the longer lifetime increases risks from a seller's point of view, which is why a higher option price is required. The closer the option moves towards expiration, the lower the time value and hence the lower the option price. As the time value equals zero on the expiration date, time acts against the option buyer and in favor of the option seller.

The time value is relinquished when the option is exercised – the net result achieved by way of exercise is generally less than optimal (see chapter "Premium Payment and Risk-based Margining").

Influencing Factors

The premium of a call is higher,	The premium of a call is lower,
the higher the price of the underlying instrument;	the lower the price of the underlying instrument;
the lower the exercise price;	the higher the exercise price;
the longer the remaining lifetime;	the shorter the remaining lifetime;
the higher the volatility.	the lower the volatility.

The premium of a put is higher,	The premium of a put is lower,
the lower the price of the underlying instrument;	the higher the price of the underlying instrument;
the higher the exercise price;	the lower the exercise price;
the longer the remaining lifetime;	the shorter the remaining lifetime;
the higher the volatility.	the lower the volatility.

Important Risk Parameters – Greeks

The price of an option is affected by a number of parameters, predominantly changes in the underlying price, time and volatility. A series of sensitivity factors – known as the "Greeks" – are used to estimate the impact of these parameters on the option price.

The price calculations in this chapter are based on the assumption that any change occurring refers to the parameter discussed in each case, with all other influencing factors remaining constant.

Delta

The delta of an option indicates the change in the option price for a one unit change in the price of the underlying futures contract. Delta itself changes in the event of fluctuations in the underlying instrument. For calls, the delta value is between zero and one. It lies between minus one and zero for puts.

Call option deltas	$0 \leq \text{delta} \leq 1$
Put option deltas	$-1 \leq \text{delta} \leq 0$

The value of delta depends on whether an option is in-, at- or out-of-the-money:

		Out-of-the-money	**At-the-money**	**In-the-money**
Long	**Call**	$0 < \text{delta} < 0.50$	0.50	$0.50 < \text{delta} < 1$
	Put	$-0.50 < \text{delta} < 0$	– 0.50	$-1 < \text{delta} < -0.50$
Short	**Call**	$-0.50 < \text{delta} < 0$	– 0.50	$-1 < \text{delta} < -0.50$
	Put	$0 < \text{delta} < 0.50$	0.50	$0.50 < \text{delta} < 1$

The delta can be used to calculate option price changes. This is shown in the following example (note that theoretical prices have been rounded to two decimal places, in line with the minimum price change of the contract):

Initial Situation

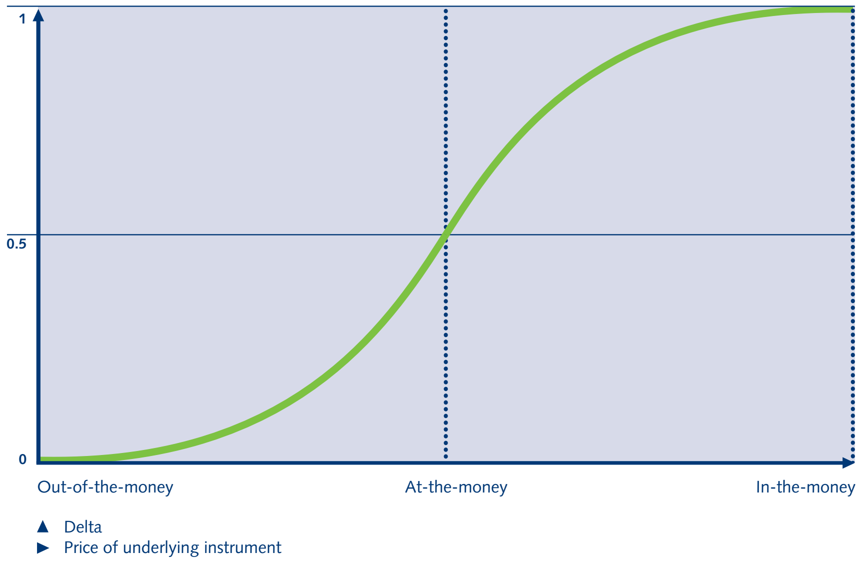
Price of the August 114.50 call option on the September Euro-Bund Futures	0.12
Call delta	0.21
June Euro-Bund Futures	113.70

Using the delta to calculate the value of the call option as a function of price changes in the underlying instrument:

Changes in the futures price			Changes in the price of the call on the futures		
Price	**Price change**	**New price**	**Price**	**Price change according to delta**	**New price**
113.70	+ 0.10	113.80	0.12	+ 0.021 (= + 0.1 × 0.21)	0.14 (rounded)
113.80	– 0.05	113.75	0.14	– 0.0105 (– 0.05 × 0.21)	0.13 (rounded)

The dependency of the option price on price changes in the underlying futures contract is displayed in the following chart:

Long Call Delta as a Function of Price Changes in the Underlying Instrument



Gamma

As the underlying futures price changes, so too does the delta of an option. Gamma can be described as the rate of change of delta: The higher the gamma, the stronger the change in delta in the event of a one unit change in the underlying instrument price. Gamma can thus be used to recalculate delta. The gamma factor for long options is always positive. Gamma is at its highest level for at-the-money options immediately before expiration.

Initial Situation

Price of the August 114.50 call option on the September Euro-Bund Futures	0.12 (= EUR 120)
Call delta	0.21
Gamma	0.2936
September Euro-Bund Futures	113.70

Changed Market Situation

Price change in the Euro-Bund Futures		
from 113.70	by 0.10	to 113.80

Using the delta factor (old) to recalculate the option price		
from 0.12	by 0.021	to 0.141 (rounded: 0.14)
or from EUR 120	by 0.021 × EUR 1,000	to EUR 140 (rounded)

Using the gamma factor to recalculate the delta factor		
from 0.21	by 0.02936	to 0.23936

If the price of the underlying instrument increases by an additional 10 ticks (0.10%), from 113.80 to 113.90, the new delta factor can be used to calculate the change in the option price.

Using the delta factor (new) to recalculate the option price		
from 0.141	by 0.023936	to 0.164936 (rounded: 0.16)
or from EUR 140	by 0.023936 × EUR 1,000	to EUR 164.94 (rounded: EUR 160)

Vega (Kappa)

Vega is a measure of the impact of volatility on the option price. Vega indicates by how many units the option price will change given a one percentage point change in the expected volatility of the underlying instrument. The longer the remaining lifetime of the option, the higher the vega. It is at its maximum with at-the-money options and shows identical behavior for both calls and puts.

The following example outlines how the option price reacts to a change in volatility.

Initial Situation

Price of the August 114.50 call option on the September Euro-Bund Futures	0.12 (= EUR 120)
Expected volatility	4.00 %
Call vega	0.075

Changed Market Situation

Change in volatility		
from 4.00 %	by one percentage point	to 5.00 %

Resulting Changes

Using the vega to recalculate the option price		
from 0.12	by 0.075	to 0.195 (rounded: 0.20)
or from EUR 120	by 0.075 × EUR 1,000	to EUR 195 (rounded: EUR 200)

Theta

Theta describes the influence of the time value decay on the option price. It indicates the unit change in the option price given a one-period reduction in the remaining lifetime. Theta is defined as the derivative of the option price for the remaining lifetime, expressed as a negative value. With long positions in options on fixed income futures, its value is always negative. This effect is called time value decay (or simply "time decay"). As options near expiration, time value decay increases in intensity. The decay is at its maximum with at-the-money options immediately before expiration.

Trading Strategies for Options on Fixed Income Futures

Options on fixed income futures can be used to implement strategies to exploit price changes in the respective fixed income futures contract, or in the underlying securities, while limiting the exposure to the option premium paid. These strategies therefore combine the motive for trading fixed income futures with the risk and reward profile of options. Options can also be used to trade "pure" volatility. As previously mentioned, the underlying instruments available for trading are the Euro-Bund, Euro-Bobl and Euro-Schatz Futures.

The four basic option positions, as well as the most commonly-used spreads and synthetic positions are outlined in this section.

Long Call

Motivation
A trader wants to benefit from an expected price rise in fixed income futures, while limiting potential losses in the event of his forecast being inaccurate.

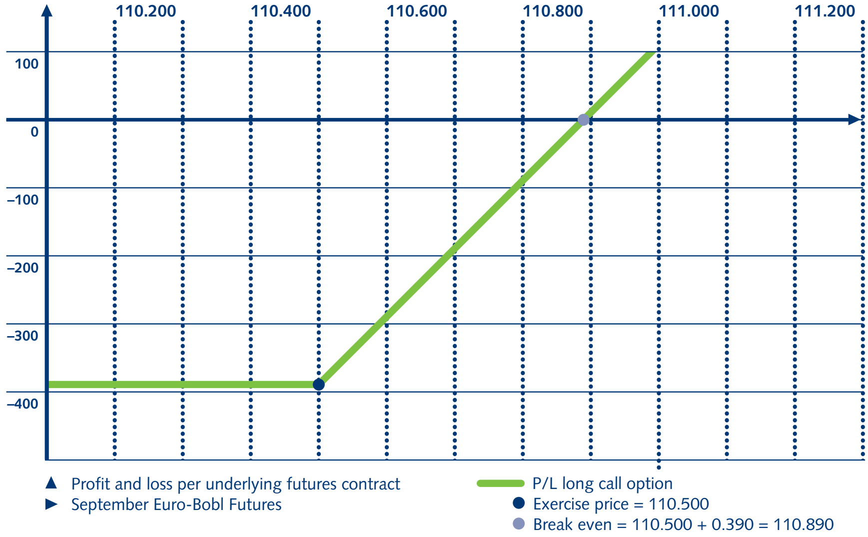
Initial Situation

September Euro-Bobl Futures	110.750
Price of the August 110.500 call option on the September Euro-Bobl Futures	0.390

The trader buys 20 contracts of the 110.500 call on the September Euro-Bobl Futures at a price of 0.390.

Changed Market Situation
A few days later, the futures price has risen to 111.000, and the option is now traded at 0.550. Although an early exercise of the option would return a profit of EUR 0.110 per contract (111.000 – 110.500 – 0.390), the option's time value would be lost in this way. In contrast, a closeout of the option position would yield a profit of EUR 0.160 (0.550 – 0.390) per contract. The overall profit for the total position would thus be EUR 3,200 (20 option contracts × 32 ticks × EUR 5 tick value). The profit and loss profile of the long call option is illustrated in the following diagram. Note that the analysis is based on expiration; time value is therefore not taken into account.

Profit and Loss Profile on the Last Trading Day, Long Call Option on the September Euro-Bobl Futures – P/L in EUR



Short Call

Motivation

A trader expects five-year yields on the German capital market to remain unchanged, or to rise slightly. Based on this forecast, he expects the price of the Euro-Bobl Futures to remain constant or fall slightly.

Initial Situation

The trader does not hold any long futures position.

September Euro-Bobl Futures	110.750
Price of the August 110.500 call option on the September Euro-Bobl Futures	0.390

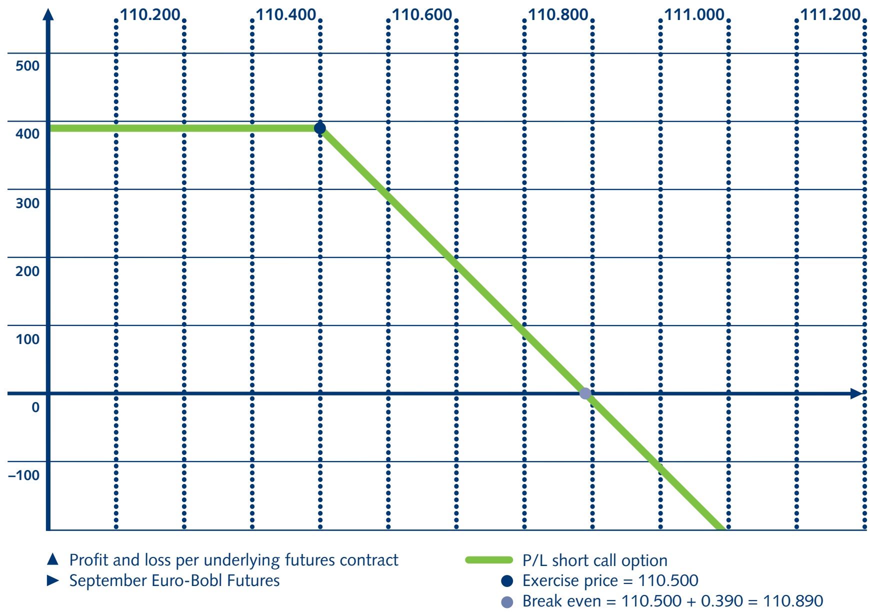
Strategy

The trader sells call options on the Euro-Bobl Futures September at a price of 0.390, equivalent to EUR 390 per contract. The premium is settled according to the “futures-style” posting method.

Changed Market Situation

If the trader's forecast on the price development turns out to be correct, the option expires worthless and he (as the seller) makes a profit equivalent to the value of the premium received. If, however, contrary to expectations, the prices rise, the trader must expect the option to be exercised. This can be avoided by buying back the option at a higher price, thus liquidating the position. The risk exposure for such a "naked" short call position is significant, as illustrated in the following chart showing the risk/reward profile of short call positions at expiration.

Profit and Loss Profile on the Last Trading Day, Short Call Option on the September Euro-Bobl Futures – P/L in EUR



Long Put

Motivation

A trader expects prices of two-year German bonds to fall. At the same time, he wants to limit the risk exposure of his position. The maximum loss of a bought option corresponds to the premium paid.

Initial Situation

September Euro-Schatz Futures	105.770
Price of the August 105.80 call option on the September Euro-Schatz Futures	0.120

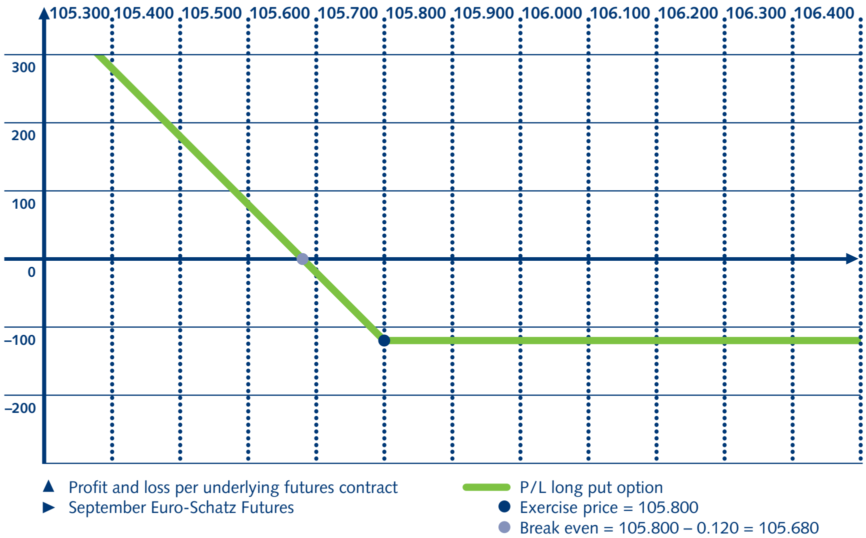
Strategy

The trader decides to buy a put option on the Euro-Schatz Futures.

Changed Market Situation

Two days later, the Euro-Schatz Futures is trading at 105.595 and the value of the put option has risen to 0.235. The option's intrinsic value is 0.205 (105.800 – 105.595). At this point in time, the trader has the choice of holding, selling or exercising the option. As with the long call, exercising the option would not make sense at this point, as this would mean giving up time value of 0.030 (0.235 – 0.205). Instead if the option is closed out, the investor can make a profit of 0.115 per contract (0.235 – 0.120). If, however, the option position is held and the futures price rises, the option will be out-of-the-money and will consequently lose value. Unless the trader expects a continued fall in futures prices, he will closeout the contracts held, in order to avoid a loss on the remaining time value until expiration.

Profit and Loss Profile on the Last Trading Day, Long Put Option on the September Euro-Schatz Futures – P/L in EUR



Short Put

Motivation

A trader expects the prices of the Euro-Bund Futures to remain unchanged, or to rise slightly, and is prepared to accept significant risk exposure in the event of the market going the other way.

Initial Situation

September Euro-Bund Futures	113.70
Price of the August 113.50 put option on the September Euro-Bund Futures	0.32

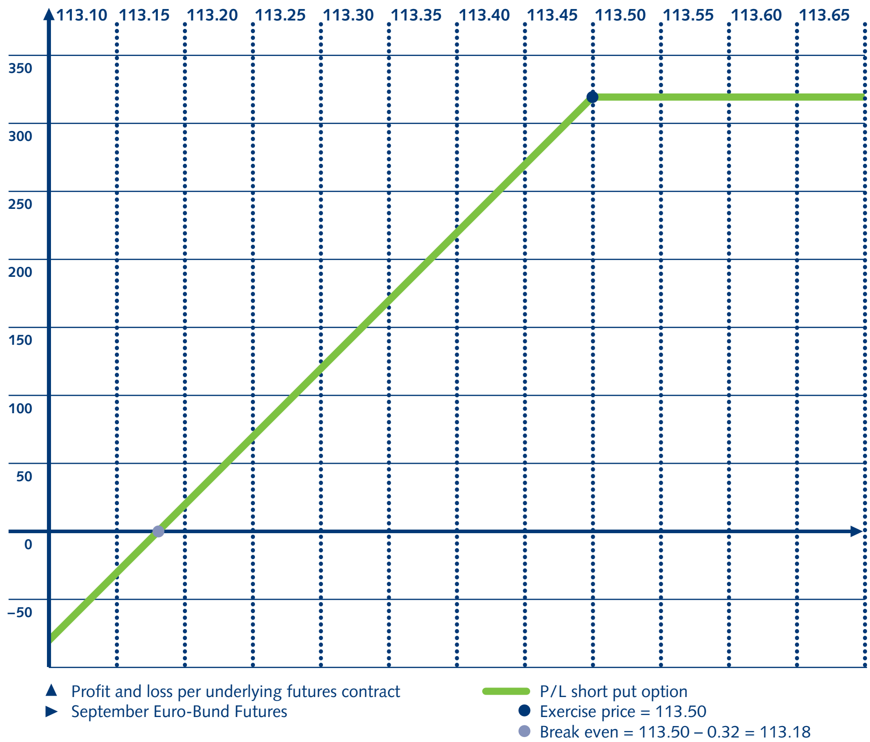
Strategy

The trader sells put options on the Euro-Bund Futures, at a price of EUR 0.32.

Changed Market Situation

Two days after selling the options, the price of the Euro-Bund Futures has fallen to 113.32. This has pushed up the put option to 0.50. Since the short put option is now making a loss and the trader wants to avoid any further losses, he decides to buy back the options at the current price, cutting the losses on the short position at 0.18, or EUR 180 per contract.

Profit and Loss Profile on the Last Trading Day, Short Put Option on the September Euro-Bund Futures – P/L in EUR



Bull Call Spread

Motivation

A trader expects a slight rise in the price of the Euro-Bund Futures. He wants to simultaneously limit the risk and reduce the costs of the position.

Initial Situation

September Euro-Bund Futures	113.70
Price of the August 113.50 call option on the September Euro-Bund Futures	0.48
Price of the August 114.00 call option on the September Euro-Bund Futures	0.25

Strategy

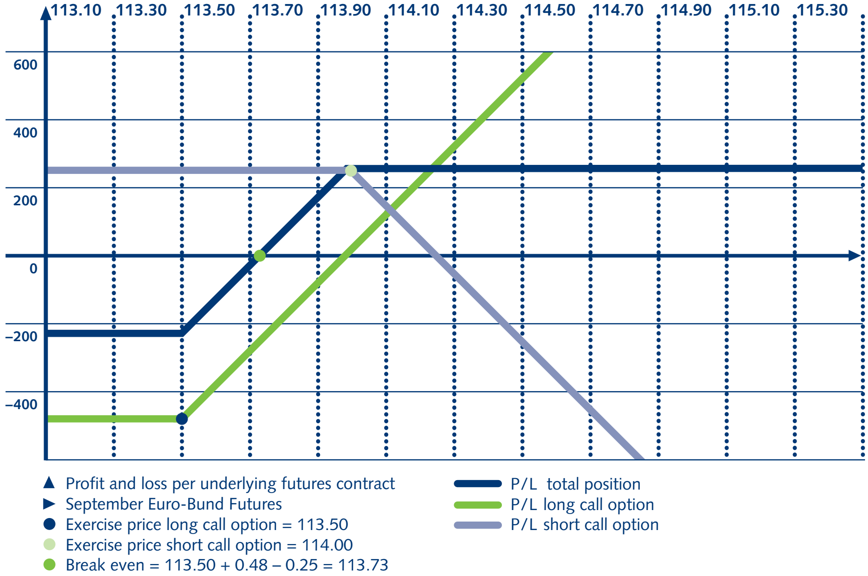
The trader decides to construct a bull call spread. This position comprises the simultaneous purchase of a call option with a lower exercise price and sale of a call option with a higher exercise price. Selling the higher exercise call puts a cap on the maximum profit, but partially covers the costs of buying the call option with a lower exercise price – thus reducing the overall costs of the strategy. A net investment of 0.23 points – or EUR 230 per contract pair – is required to buy the bull call spread.

Changed Market Situation

The price level of the Euro-Bund Futures has risen to 114.30 two weeks after opening the position. The 113.50 call is traded at 0.90, and the 114.00 call at 0.50. At this point, the trader closes out the spread and receives a net premium of 0.40 per contract. This results in a net profit of 0.17.

The following profit and loss profile is the result of holding the options until expiration.

Profit and Loss Profile on the Last Trading Day, Bull Call Spread on the September Euro-Bund Futures – P/L in EUR



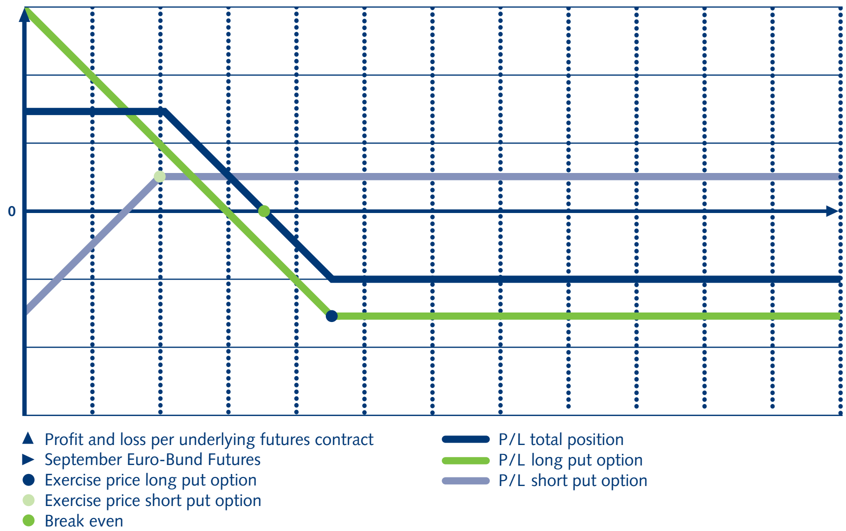
On the Last Trading Day, the maximum profit is made when the price of the underlying instrument is equal to or lies above the higher exercise price. In this case, the profit made is the difference between the exercise prices less the net premium paid. If the price of the underlying instrument is higher, any additional profit made from the more expensive option is offset by the equivalent loss incurred on the short position.

Bear Put Spread

Motivation
A trader expects a slight fall in the price of the Euro-Bund Futures. In line with the long bull call spread discussed above, he wants to benefit from the expected development, but with limited investment and limited risk.

Strategy
The trader decides to construct a bear put spread by simultaneously buying a put with a higher exercise price and selling a put with a lower exercise price. The maximum loss is limited to the net premium paid. This would be incurred if the price rose to at least the level of the higher exercise price. The maximum profit, which is equivalent to the difference of the exercise prices less the net premium paid, is made if the price of the Euro-Bund Futures on the Last Trading Day is equal to, or falls below the lower exercise price.

Profit and Loss Profile on the Last Trading Day, Bear Put Spread



Long Straddle

Motivation

Having remained stable for quite some time, prices of German five-year Federal notes (Bundesobligationen) are expected to become more volatile, although the exact market direction is uncertain.

Initial Situation

September Euro-Bobl Futures	111.100
Price of the September 111.000 call option on the September Euro-Bobl Futures	0.270
Price of the September 111.000 put option on the September Euro-Bobl Futures	0.170

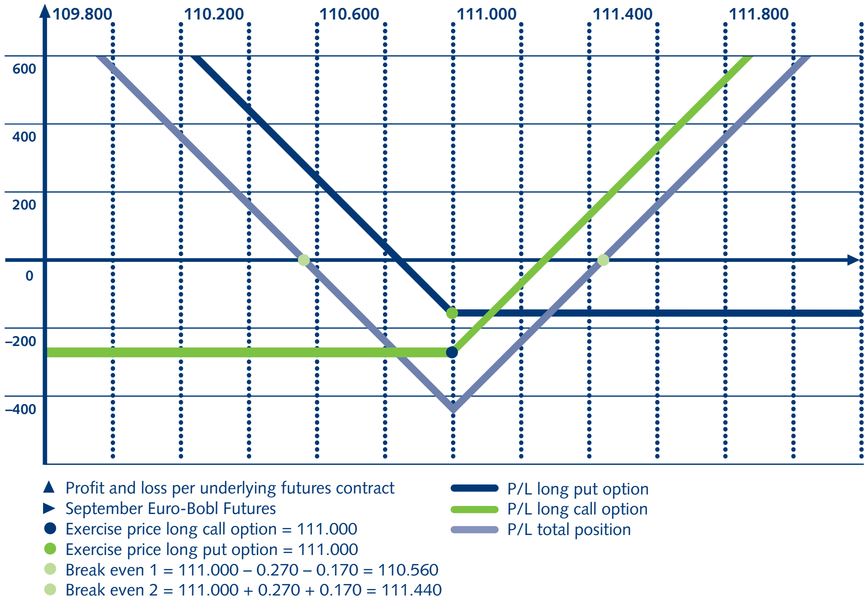
Strategy

The trader buys one at-the-money call option and one at-the-money put option, to benefit from a rise in the option prices should volatility increase. The success of the strategy does not necessarily depend on whether Euro-Bobl Futures prices are rising or falling.

Changed Market Situation

After a period of strong price fluctuation, the Euro-Bobl Futures is trading at 111.350. The call option is now valued at 0.640 points, the put at 0.120. The strategy has turned out to be successful, as the volatility has resulted in a significant increase in the time value of the call option (from 0.170 to 0.290), whereas the now out-of-the-money put option has fallen only marginally (from 0.170 to 0.120). Moreover, the intrinsic value of the call option increased (from 0.100 to 0.350) while the put option shows none. It is important to note that, in the event of a price decrease or a temporary recovery in the futures price, the aggregate value of both options would have increased provided that volatility had risen sufficiently. As a double long position, a straddle is exposed to particularly strong time decay, which can offset any positive performance. For the strategy to be profitable on the Last Trading Day, the price of the underlying instrument must differ from the exercise price by at least the aggregate option premium.

Profit and Loss Profile on the Last Trading Day, Long Straddle on the September Euro-Bobl Futures – P/L in EUR



Long Strangle

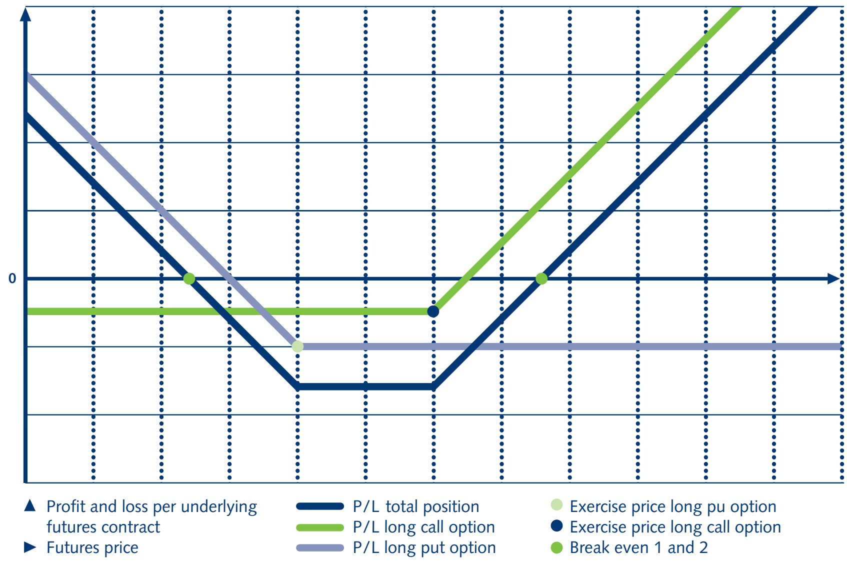
Motivation

A trader expects a significant increase in volatility in the two-year sector of the German capital market. He wants to benefit from the expected development but strictly limit his risk exposure.

Strategy

The trader decides to buy a strangle using options on the Euro-Schatz Futures. Similar to the straddle, this position is made up of a long call and a long put option. With the strangle, however, the put usually has a lower exercise price than the call. The sum of the premiums and, in this case, the maximum loss, is lower than for the straddle. However, by "separating" the exercise prices, the profit potential is also reduced.

Profit and Loss Profile on the Last Trading Day, Long Strangle

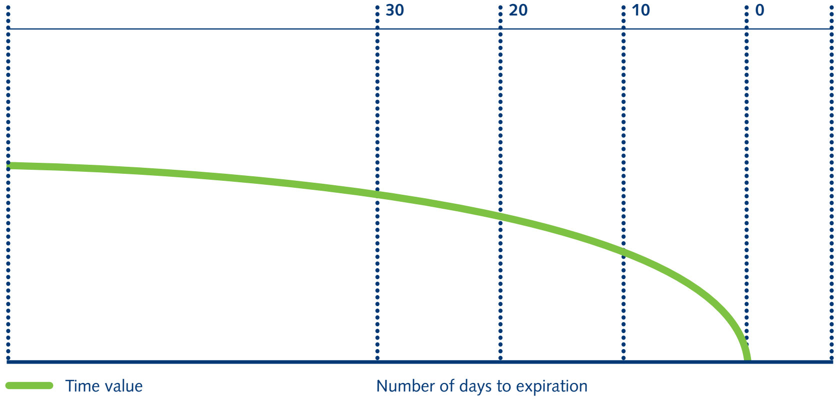


Impact of Time Value Decay

Time Value Decay

The remaining lifetime of an option contract influences the level and the further trend of time value. As explained in the section "Theta", the time value declines progressively until the Last Trading Day. The time decay per period is smaller for long-running options than for those which are about to expire. Other things being equal, an option with a longer remaining lifetime has a higher time value and is therefore more expensive.

Time Value for a Long At-the-Money Option Position



Exercise, Hold or Close

Most examples are based on the assumption that an option is held until the Last Trading Day. However, closing the position before the Last Trading Day, or even exercising it during its lifetime are valid alternatives.

It is, however, unwise to exercise an option during its lifetime as the buyer forfeits time value by doing so.

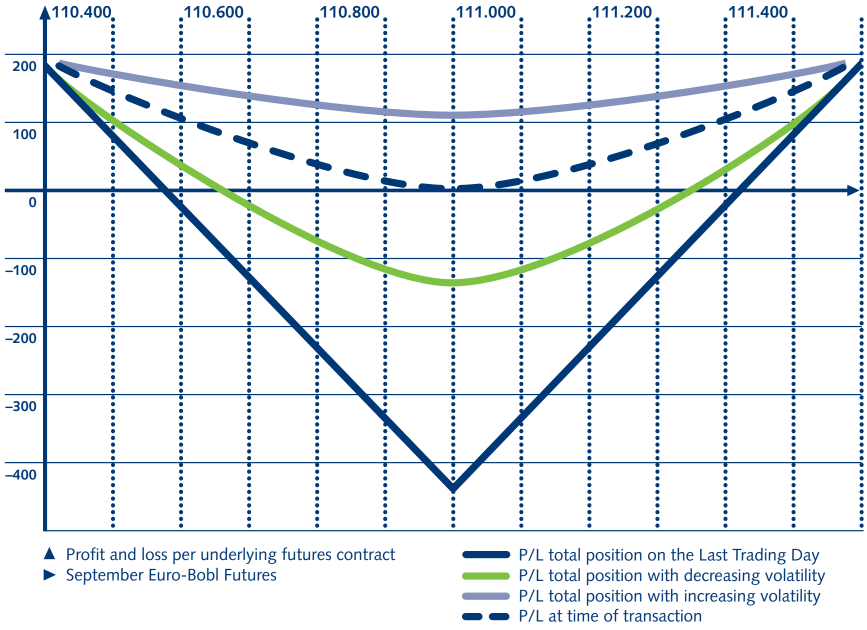
Sale of the option on the exchange (closeout)	Exercising the option
The profit or loss is equivalent to the difference between the entry price and the prevailing selling price of the option (intrinsic value plus time value).	The profit is equivalent to the difference between the intrinsic value and the premium paid for the option.

Traders must continuously check during the lifetime of an option whether, according to their assessment, the expected price trend will compensate for continued time decay. With a long call option, for example, the position should be closed as soon as no further rise in the underlying instrument price is expected. These remarks are made on the assumption that other parameters, in particular volatility, remain constant.

Impact of Market Volatility

The graph covering the purchase of a straddle was based on the assumption that the position was held until the Last Trading Day of the options. At that point in time, a profit will only be made if the price of the underlying instrument deviates from the exercise price by more than the sum of the two option premiums. In practice, however, it is rather unlikely that there will be a profit on the Last Trading Day, due to the dual loss of time value. Hence, the aim of this strategy is generally to close the position immediately after an increase in volatility has occurred. The profit and loss profile for different volatility levels is illustrated in the following chart:

Profit and Loss Profile Given Different Volatility Levels, Long Straddle on the September Euro-Bobl Futures – P/L in EUR



The dotted-line function depicts the value immediately after the position is entered into. The P/L profile on the Last Trading Day is already known. The value of the two long positions rises if volatility increases, meaning that a profit will be made (light blue line) regardless of the futures price. The position should be closed as soon as no further short-term increase in volatility is expected. If volatility declines, the profit and loss line will move closer to the profile on the last trading day, as the decrease in volatility and the lapse of time reduce the time value (green line).

Trading Volatility – Using Futures to Maintain a Delta-neutral Position

The value of an option is affected by a number of variables, notably the price of the underlying instrument, the time to expiration and volatility. Knowing this, option traders have devised a selection of different trading strategies, enabling them to trade a view not just on the expected change in the market price of the underlying instrument, but also the development of volatility over time.

If a trader believes that current implied volatility levels (as derived from market prices) are not in line with his own forecast, it is possible to construct a strategy which will allow to trade the volatility component of an option whilst remaining neutral to market direction over time.

The following example demonstrates how a trader who is bullish of volatility can profit from buying options perceived as undervalued whilst maintaining a delta-neutral position with the use of futures.

Example

September Euro-Bund Futures	113.20
Price of the 113.00 call option on the September Euro-Bund Futures	1.32
Delta	0.54
Implied volatility	8%

Using an option pricing model, the trader is able to work out that the current "implied" volatility of the 113.00 call option on the Euro-Bund Futures is eight percent. The trader's own "forecast" volatility between now and expiration of the option is deemed to be higher. The trader decides to buy the "undervalued" options on the basis that if volatility does increase as expected between now and expiration of the option a profit will ensue.

However, being long of a call means that although the trader is now bullish of volatility, he is also exposed to a fall in the futures price. To eliminate this exposure, the trader needs to create a delta-neutral position by which his exposure is purely to volatility. The easiest way for achieving a delta-neutral position is to sell an appropriate number of futures contracts (note that long futures have a delta of +1 and short futures have a delta of –1). In line with the option delta of 0.54, the trader needs to sell 54 September futures (100 × 0.54 = 54) to turn the long position of 100 call options into a delta-neutral position.

Option position	Option position delta	Futures position	Futures position delta	Net delta
Buy 100 call options on the September Euro-Bund Futures 113.00	100 × 0.54 = 54	Sell 54 September Euro-Bund Futures	= 54 × (–1) = – 54	0

As time goes by the underlying futures price will rise and fall which means that the delta of the long call will change. Therefore, in order to remain delta-neutral the trader has to regularly rebalance the hedge position. Theoretically the strategy requires continuous adjustment – practically speaking, this would not be feasible due to the trading costs involved. Instead the trader decides to adjust the position depending upon certain tolerance levels (for example once a day, or if the position becomes too delta positive or negative, for instance). In the following example we will look at the position over ten trading days, with adjustments taking place once a day.

Volatility trade

Day	Futures price	Delta 113 call net delta	Total position delta	Futures adjustment	Futures profit profit/loss (ticks – versus closeout)[26]
1	113.20	54	0	Sell 54	–2,322
2	112.68	46	– 8	Buy 8	760
3	113.31	55	+ 9	Sell 9	–288
4	114.00	66	+11	Sell 11	407
5	113.43	56	–10	Buy 10	200
6	112.62	44	–12	Buy 12	1,212
7	112.93	49	+ 5	Sell 5	–350
8	112.31	39	–10	Buy 10	1,320
9	113.00	50	+11	Sell 11	–693
10	113.63	61	+11	Sell 11	–

End of trading period – day ten	
Futures price	113.63
113 call premium	1.50

When initiating the strategy, the trader buys 100 contracts of the 113.00 call option on the Euro-Bund Futures, for a premium of 1.32, with a delta equivalent to 54 futures contracts. To create a delta-neutral position at the end of day one, the trader has to sell 54 futures. On day two the futures price falls to 112.68, resulting in a new call delta of 0.46. This means that the net delta position at that point is eight contracts short (= 46 – 54). In order to maintain a delta-neutral position, the trader has to buy eight futures contracts at a price of 112.68. This process of rebalancing is repeated each day for a period of ten days. At the end of this period, the original 100 contracts of the 113 call option on the Euro-Bund Futures are closed out at premium of 1.50. The futures price on day ten is 113.63. The net result of the overall strategy is summarized below, broken down into three categories.

[26] See following page.

Total profit from futures rebalancing (ticks) = 2,568
The profit/loss on the rebalancing is calculated in ticks. For example, at the end of day two the trader has to buy eight futures contracts at 112.68. The final futures price on day ten is 113.63; therefore, the trader has made 760 ticks profit from rebalancing on day two: (113.63 – 112.68) × 8 contracts = 760 ticks.

Loss incurred on the original futures position (ticks) = –2,322
At the outset, the trader sells 54 futures at 113.20 to create the delta-neutral position. At the end of day ten the futures position is closed out at 113.63, generating a loss of (113.20 – 113.63) × 54 = –2,322 ticks.

Profit on the option position (ticks) = 1,800
At the outset, the trader buys 100 contracts of the 113.00 call option on the Euro-Bund Futures, at a premium of 1.32. Closing out the option position at the end of day ten, at 1.50, yields a profit of (1.50 – 1.32) × 100 = 1,800 ticks.

Total profit on the strategy (ticks) = 2,046 (= 2,568 – 2,322 + 1,800)
The total profit on the strategy amounts to 2,046 ticks (EUR 10 × 2,046 = EUR 20,460). This includes a gain on the original options trade, plus the net effect of futures rebalancing, whilst the original futures trade generated a loss.

We can see from the table above that the volatility expressed in the daily futures price over the ten day period was significant and, as a result, a profit ensued. It is worth noting that at the outset of a volatility trade such as this, the trader does not actually *know* precisely where his profit (if any) will come from: the original futures hedge, the option position or rebalancing. The main point is that if volatility does increase over the duration of the trade period, a profit will ensue.

The outlook for a delta-neutral position incorporating a short option position is exactly the opposite: a profit will be made if the actual volatility over the period of the trade is lower than the implied volatility upon the option premium was based. Note that there is no difference regarding the use of calls or puts for this kind of strategy – in practice, a delta-neutral position is often initiated by buying or selling at-the-money straddles.

Hedging Strategies

Options can be used to hedge an exposure right up until the Last Trading Day. Alternatively they can be used on a dynamic basis to hedge an exposure for a shorter duration if required. In addition, options may be used to provide either full or partial protection of a portfolio. The following examples show the flexibility of options hedging.

Hedging Strategies for a Fixed Time Horizon

Motivation
A fund manager has a portfolio of German Federal bonds (Bundesanleihen) worth EUR 40,000,000 under management. Although after a strong price rally, he does not rule out further price rises, the fund manager is looking to hedge his profits. Using the sensitivity method, he determines a hedge ratio of 404 contracts (see the chapter on the "Sensitivity Method"). This means that a short position of 404 Euro-Bund Futures is required to hedge the position. While this hedge transaction eliminates the risk exposure, it will also neutralize any profit potential should prices rise further.

Since the fund manager does not wish to completely neutralize the portfolio, he decides to buy put options on the Euro-Bund Futures. In this way a minimum price is secured for the contingent short futures position whose price development most closely matches that of the portfolio to be hedged. At the same time, the profit potential of the securities portfolio is maintained, albeit reduced by the option premium paid, without any obligation to actually sell the securities.

If the portfolio value is to be hedged until the option's Last Trading Day, the fund manager will apply the hedge ratio of 404 contracts calculated for the futures hedge, as the ratio between the option and futures is 1:1. This approach ignores changes in the option's value during its lifetime.

Initial Situation

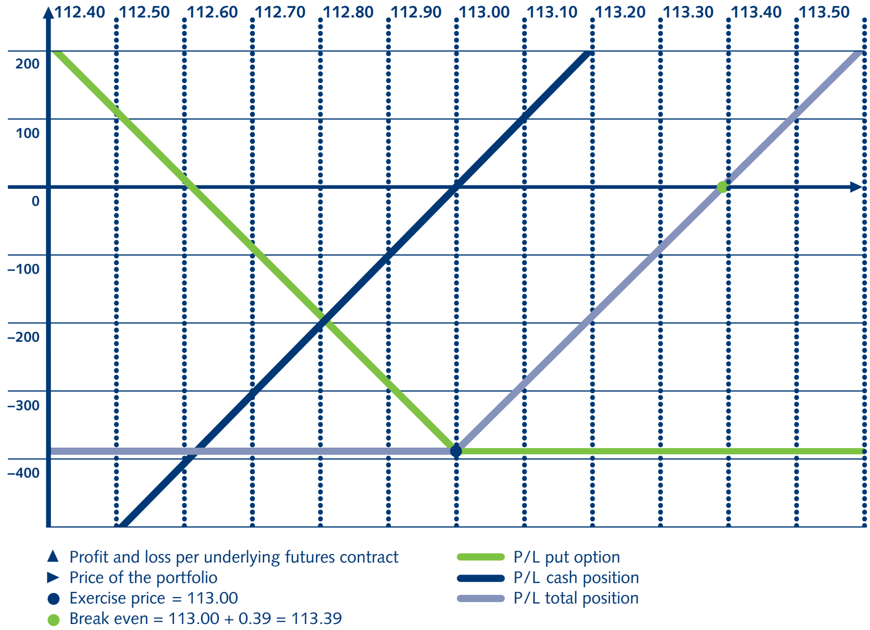
September Euro-Bund Futures	113.00
Price of the August 113.00 put option on the September Euro-Bund Futures	0.39

Strategy

The fund manager buys put options on the September Euro-Bund Futures with an exercise price of 113.00. If the futures price remains unchanged or rises, the performance of the overall position is reduced by the put premium paid of 0.39. However, if the futures price falls below the put's exercise price, the loss on the hedged portfolio is limited to this level. Assuming that the cash position tracks the performance of the futures contract, the profit and loss profile for the total position – as set out below – is identical to that of a long call on the Euro-Bund Futures. This is why this combination is also referred to as a "synthetic long call".

Example: September Euro-Bund Futures			
Futures price at maturity	**Profit/loss on the cash position equivalent to the future**	**Profit/loss on the 113.00 put option**	**Profit/loss on the total position**
112.20	−0.80	0.41	−0.39
112.30	−0.70	0.31	−0.39
112.40	−0.60	0.21	−0.39
112.50	−0.50	0.11	−0.39
112.60	−0.40	0.01	−0.39
112.70	−0.30	−0.09	−0.39
112.80	−0.20	−0.19	−0.39
112.90	−0.10	−0.29	−0.39
113.00	0	−0.39	−0.39
113.10	0.10	−0.39	−0.29
113.20	0.20	−0.39	−0.19
113.30	0.30	−0.39	−0.09
113.40	0.40	−0.39	0.01
113.50	0.50	−0.39	0.11
113.60	0.60	−0.39	0.21

Profit and Loss Profile on the Last Trading Day, Using a Long Put Option on the Euro-Bund Futures to Hedge a Cash Position – P/L in EUR



Delta Hedging

If the portfolio value is to be hedged for a certain period of the option's overall lifetime, changes in value in the cash and option positions must be continuously matched during that period. The delta factor – in other words, the impact of price changes in the underlying instrument on the option price – is particularly important in this context. The delta for an option that is exactly at-the-money is 0.5 (refer to chapter "Delta"). This means that a one unit price change in the underlying instrument leads to a change of 0.5 units in the option price.

On the assumption that, for the sake of simplicity, the cash position behaves in line with a notional hedge position of 404 Euro-Bund Futures for a fully hedged cash position, a delta of 0.5 would necessitate the purchase of 2 × 404 options instead of just 404 contracts.

As was illustrated in the chapter on "Gamma", the delta value changes with each change in the underlying price. Hence, the number of options bought has to be adjusted continuously. If, for example, the options move out-of-the-money due to a price rise and the delta falls to 0.25, the option position would have to be increased to 4 × 404 contracts. This dynamic hedging strategy is referred to as "delta hedging".

Gamma Hedging

The frequent switching involved in delta hedging results in high transaction costs. The so-called gamma hedge offers the possibility to provide a constant hedge ratio strategy throughout the options' entire lifetime. The purpose of this hedging method is to establish a gamma value of zero for the option portfolio, resulting in a constant delta even in the event of price changes in the underlying instrument. The simplest way to achieve this is to hedge a cash position by entering into a long put and a short call position on the corresponding futures contract, with the same exercise price. It is useful to remember that the delta values of both positions always add up to one, which corresponds to an overall gamma of zero. It is also worth noting that the combination of the long put and the short call is equal to a short futures position. On the basis of the delta hedge example, a call option with an exercise price of 113.00 would be sold additionally, at a price of 0.39. This strategy provides for an offset between the cash position on the one hand and the option position on the other hand. While in the event of falling prices, the cash position suffers a loss that is set off against profits on the options strategy, the opposite is true when prices rise.

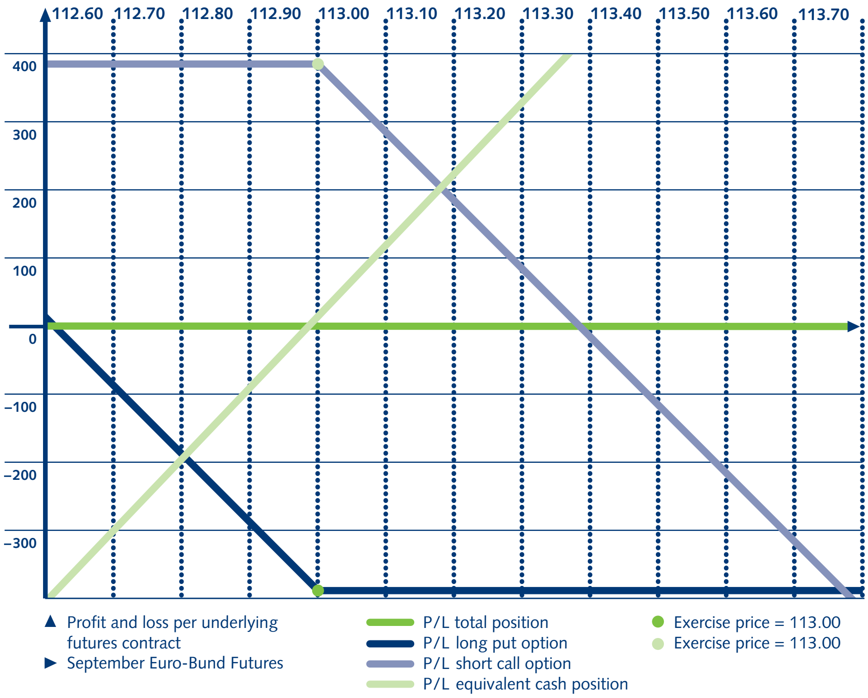
Assuming the position is held until the Last Trading Day, this would result in the following profit and loss pattern:

Example: September Euro-Bund Futures

Futures price at maturity	Profit/loss on the cash position equivalent to the future	Profit/loss on the long 113.00 put option	Profit/loss on the short 113.00 call option	Profit/loss on the total position
112.20	−0.80	0.41	0.39	0
112.30	−0.70	0.31	0.39	0
112.40	−0.60	0.21	0.39	0
112.50	−0.50	0.11	0.39	0
112.60	−0.40	0.01	0.39	0
112.70	−0.30	−0.09	0.39	0
112.80	−0.20	−0.19	0.39	0
112.90	−0.10	−0.29	0.39	0
113.00	0	−0.39	0.39	0
113.10	0.10	−0.39	0.29	0
113.20	0.20	−0.39	0.19	0
113.30	0.30	−0.39	0.09	0
113.40	0.40	−0.39	−0.01	0
113.50	0.50	−0.39	−0.11	0
113.60	0.60	−0.39	−0.21	0

The fund manager makes neither a profit nor loss on this position, irrespective of market development. Because this strategy creates a synthetic short futures contract, the profit/loss profile is equivalent to selling 404 Euro-Bund Futures at 113.00.
A practical example for this type of position would be a situation where the hedger started out with a Long Put and subsequently wishes to change the characteristics of his position.

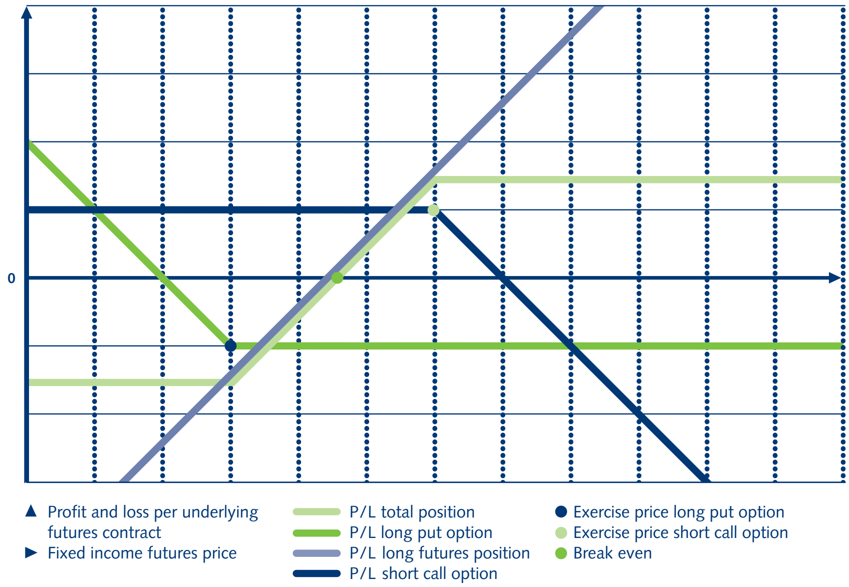
Profit and Loss Profile on the Last Trading Day, Gamma Hedging Using Options on the September Euro-Bund Futures – P/L in EUR



Zero Cost Collar

Both the delta and gamma hedge strategies provide a full neutralization of the cash position against interest rate or price changes. As an alternative, the portfolio manager can allow his position to fluctuate within a tolerance zone, thus only hedging against greater deviations. He buys a put with an exercise price below the current market price and sells a call with a higher exercise price for this purpose. A zero cost collar is where the premiums for both options are equal. Options on fixed income futures allow an almost symmetrical interval around the current price in the form of a zero cost collar to be created (not taking transaction costs into consideration).

Profit and Loss Profile on the Last Trading Day, Zero Cost Collar



The profit and loss profile for a long cash position with a collar on expiration is equivalent to a bull spread position.

Relationships between Futures and Options, Arbitrage Strategies

Synthetic Option and Futures Positions

Options on fixed income futures give the buyer the right to enter into exactly one contract of the respective underlying instrument. A call option can be replicated by a put option combined with a future, a put option by a future and a call. A long call and a short put result in a profit and loss profile identical to a long future. Because of the restriction of the option expiration date being prior to the maturity date of the futures contract, such "synthetic" positions can only be held during part of the futures' lifetime.

Creating synthetic positions is attractive if mispricing makes them cheaper than the "original" contract. Price imbalances exceeding transaction costs, thus providing arbitrage opportunities, arise for very short periods of time only and are therefore generally available to professional arbitrageurs only. The synthetic positions described in this section mainly serve to illustrate the relationships between options and futures.

Synthetic Long Call

A synthetic long call is created by combining a long futures position with a long put option. Similar to the "real" call, this position is characterized by limited risk exposure and theoretically unlimited profit potential.

Motivation
A trader expects a short-term reduction in five-year yields. He wants to benefit from the expected price increases, at the same time entering into a position with limited risk exposure. This is why he decides on a long call position.

Initial Situation

September Euro-Bobl Futures	111.100
Price of the 111.00 call option on the September Euro-Bobl Futures	0.290
Price of the 111.00 put option on the September Euro-Bobl Futures	0.160

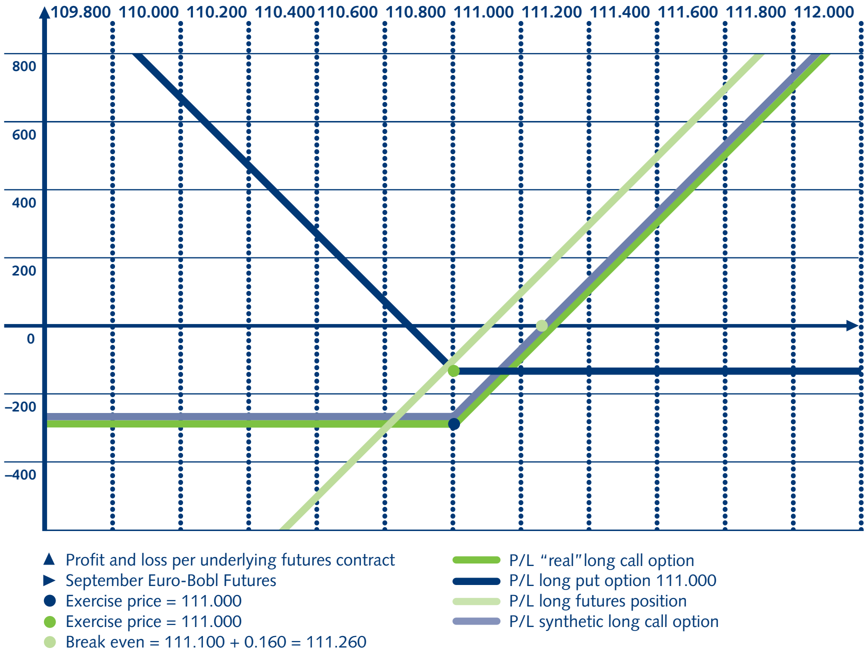
Strategy
On the basis of prevailing market prices, the trader determines whether a direct call purchase or the synthetic position is more favorable (projecting the results on the Last Trading Day of the option). The two alternatives are compared in the following table:

Example: September Euro-Bobl Futures					
Futures price at maturity	**Profit/loss on the long futures position**	**Value of the 111.000 put option**	**Profit/loss on the 111.000 put option call position**	**Profit/loss on the synthetic long 111.000 call position**	**Profit/loss on the"real" long 111.000**
110.500	−0.600	0.500	0.340	−0.260	−0.290
110.600	−0.500	0.400	0.240	−0.260	−0.290
110.700	−0.400	0.300	0.140	−0.260	−0.290
110.800	−0.300	0.200	0.040	−0.260	−0.290
110.900	−0.200	0.100	−0.060	−0.260	−0.290
111.000	−0.100	0	−0.160	−0.260	−0.290
111.100	0	0	−0.160	−0.160	−0.190
111.200	0.100	0	−0.160	−0.060	−0.090
111.300	0.200	0	−0.160	0.040	0.010
111.400	0.300	0	−0.160	0.140	0.110
111.500	0.400	0	−0.160	0.240	0.210

Result

The synthetic long call option has an advantage of 0.030, or EUR 30, over the "real" long call on the Last Trading Day.

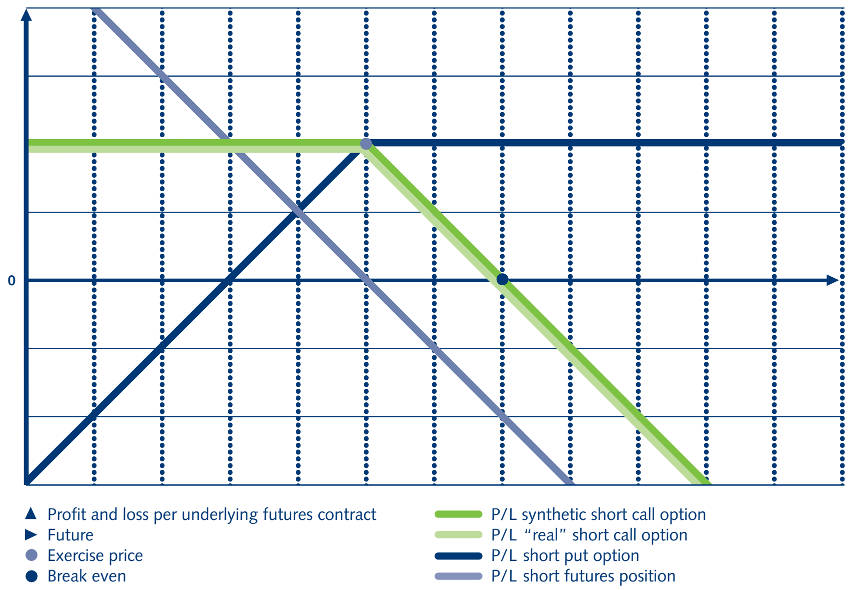
Profit and Loss Profile on the Last Trading Day, Synthetic Long Call, Option on the September Euro-Bobl Futures – P/L in EUR



Synthetic Short Call

A synthetic short call is created by combining a short futures position with a short put option. Similar to the "real" short call, the profit potential is limited to the premium received, while the loss potential upon rising prices is unlimited. If a trader expects prices to stagnate or to fall, he decides on a short call position, taking the high risk exposure of this position into account. If a synthetic position can be established at more favorable terms than trading the call directly, it will be favored by the trader.

Profit and Loss Profile on the Last Trading Day, Synthetic Short Call



Synthetic Long Put

A synthetic long put is created by combining a short futures position with a long call. Similar to all long option positions, the maximum loss is limited to the premium paid. The maximum profit is equivalent to the exercise price less the option premium paid.

Motivation

A trader expects two-year German capital market yields to rise on a short-term horizon. He wants to benefit from the expected price slump while taking a limited exposure.

Initial Situation

September Euro-Schatz Futures	105.775
Price of the 105.700 call option on the September Euro-Schatz Futures	0.145
Price of the 105.700 put option on the September Euro-Schatz Futures	0.100

Strategy

The trader decides to buy a put option on the Euro-Schatz Futures, comparing the "real" position with the synthetic put:

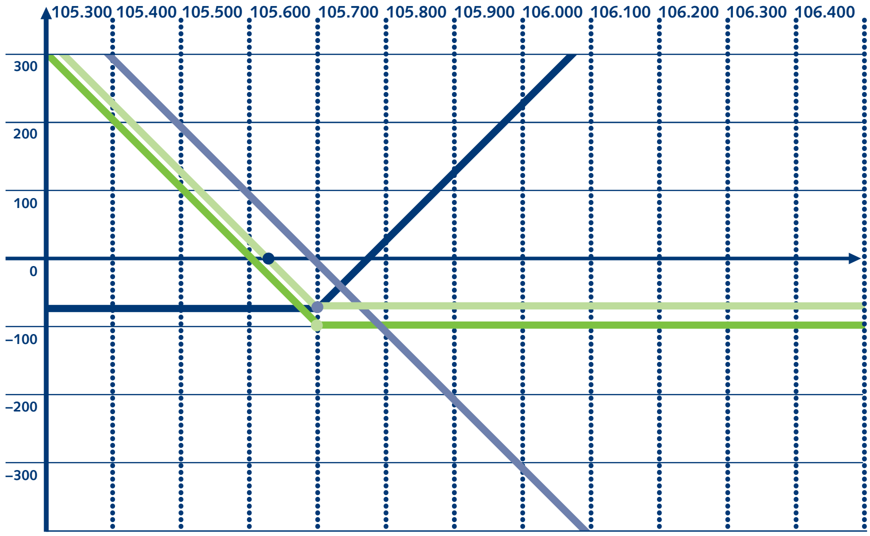
Example: September Euro-Schatz Futures

Futures price at maturity	Profit/loss on the short futures position	Value of the 105.700 call option	Profit/loss on the 105.700 call option	Profit/loss on the synthetic 105.700 long put position	Profit/loss on the "real" 105.700 long put position
105.300	0.475	0.000	–0.145	0.330	0.300
105.400	0.375	0.000	–0.145	0.230	0.200
105.500	0.275	0.000	–0.145	0.130	0.100
105.600	0.175	0.000	–0.145	0.030	0.000
105.700	0.075	0.000	–0.145	–0.070	–0.100
105.800	–0.025	0.100	–0.045	–0.070	–0.100
105.900	–0.125	0.200	0.055	–0.070	–0.100
106.000	–0.225	0.300	0.155	–0.070	–0.100
106.100	–0.325	0.400	0.255	–0.070	–0.100

Result

The synthetic put has an advantage of 0.03, or EUR 30 per contract, over the "real" put. For this reason, the trader decides on the synthetic long put position.

Profit and Loss Profile on the Last Trading Day, Synthetic Long Put, Option on the September Euro-Schatz Futures – P/L in EUR



▲ Profit and loss per underlying futures contract
► September Euro-Schatz Futures
● Exercise price = 105.700
● Exercise price = 105.700
● Break even = 105.775 – 0.145 = 105.630

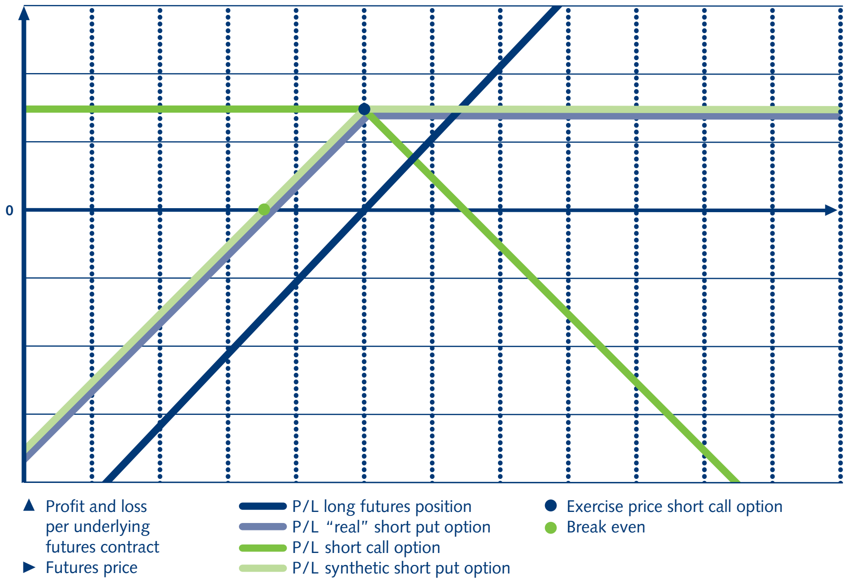
P/L "real" long put option
P/L synthetic long put option
P/L long call option
P/L short futures position

Synthetic Short Put

A synthetic short put is a combination of a long futures position and a short call option. The maximum loss incurred on the Last Trading Day of the option is equal to the exercise price less the premium received. The profit potential is limited to the premium received.

Comparing the real and synthetic positions is in line with the examples illustrated above.

Profit and Loss Profile on the Last Trading Day, Synthetic Short Put



Synthetic Long Future/Reversal

Synthetic futures positions are created by combining a long and a short option position. As a rule, the bid/offer spread for options is wider than for futures contracts. This is why synthetic futures positions are hardly used as trading strategies, but almost exclusively for arbitrage purposes to exploit any mispricing of options.

A long futures position can be reproduced by combining option positions which match the characteristics of the long futures position – a long call option provides profit participation on the upside, while a short put position comprises risk exposure in the event of falling prices.

Motivation

Having analyzed the price structure for Options on Euro-Bund Futures, an arbitrageur identifies the September 113.50 put option as overpriced in relation to the corresponding call. As a result, the synthetic futures contract is cheaper than the actual Euro-Bund Futures.

Initial Situation

September Euro-Bund Futures	113.29
Price of the 113.50 call option on the September Euro-Bund Futures	0.26
Price of the 113.50 put option on the September Euro-Bund Futures	0.52

Strategy

The arbitrageur buys the synthetic futures contract and simultaneously sells the "real" futures contract. This arbitrage strategy is called a "reversal".

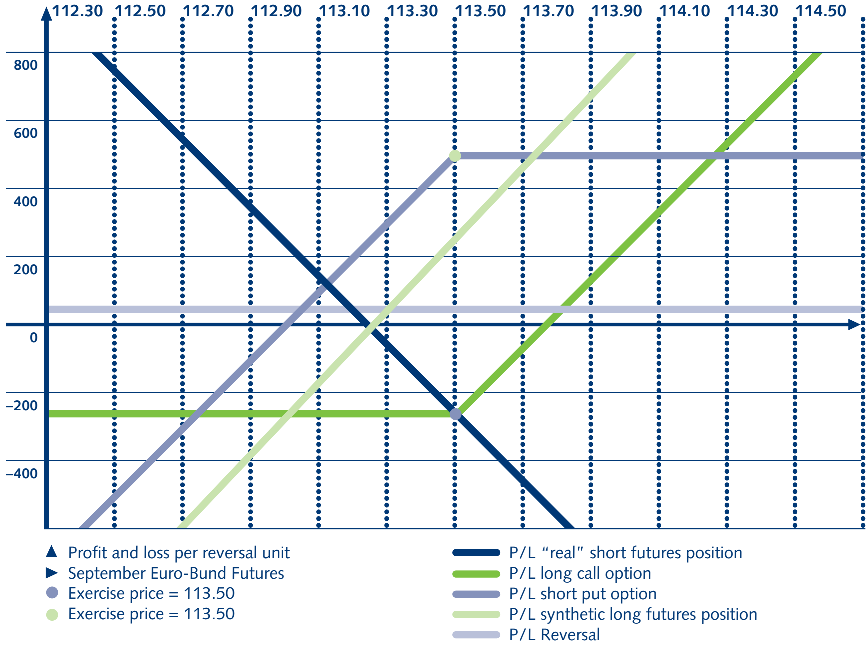
Example: September Euro-Bund Futures

Futures price at maturity	Profit/loss on the "real" short futures position	Profit/loss on the long 113.50 call option	Profit/losst on the short 113.50 put option	Profit/loss on the synthetic long futures position	Profit/loss on the reversal
112.60	0.69	−0.26	−0.38	−0.64	0.05
112.70	0.59	−0.26	−0.28	−0.54	0.05
112.80	0.49	−0.26	−0.18	−0.44	0.05
112.90	0.39	−0.26	−0.08	−0.34	0.05
113.00	0.29	−0.26	0.02	−0.24	0.05
113.10	0.19	−0.26	0.12	−0.14	0.05
113.20	0.09	−0.26	0.22	−0.04	0.05
113.30	−0.01	−0.26	0.32	0.06	0.05
113.40	−0.11	−0.26	0.42	0.16	0.05
113.50	−0.21	−0.26	0.52	0.26	0.05
113.60	−0.31	−0.16	0.52	0.36	0.05
113.70	−0.41	−0.06	0.52	0.46	0.05
113.80	−0.51	0.04	0.52	0.56	0.05
113.90	−0.61	0.14	0.52	0.66	0.05

Result

Regardless of the price development of the Euro-Bund Futures, a profit of 0.05 (or EUR 50) is made on each arbitrage unit (consisting of one contract each of long call, short put and short futures).

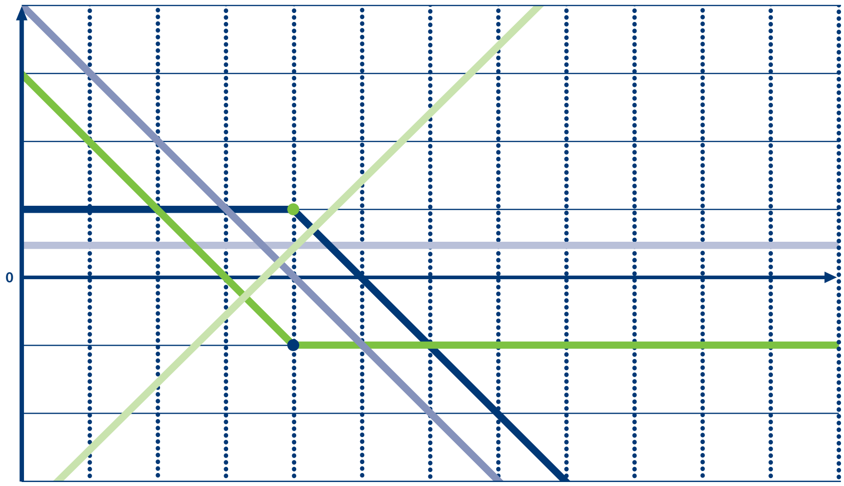
Profit and Loss Profile on the Last Trading Day, Reversal, Option on the September Euro-Bund Futures – P/L in EUR



Synthetic Short Future/Conversion

A synthetic short futures position is created by combining a short call with a long put option. Where a call option is expensive or a put option is cheap (both in relative terms), a profit can be achieved by creating a synthetic short futures position and combining it with a "real" long futures contract. This strategy, which is called a "conversion", is the opposite of a "reversal" strategy.

Profit and Loss Profile on the Last Trading Day, Conversion



Synthetic Option and Futures Positions – Overview

The components of the above-mentioned synthetic positions are summarized in the following table:

	... is created by		
Synthetic ...	**Call**	**Put**	**Future**
Long call	–	Long	Long
Short call	–	Short	Short
Long put	Long	–	Short
Short put	Short	–	Long
Long future	Long	Short	–
Short future	Short	Long	–

The table clearly illustrates that "mirror" positions, for example long call and short call, are created by opposing component positions.

Appendix

Glossary

Accrued interest

The interest accrued from the last interest payment date to the valuation date.

Additional Margin

Additional Margin is designed to cover the additional potential closeout costs which might be incurred. Such potential closeout costs would arise if, based on the current market value of the portfolio, the expected least favorable price development (worst case loss) were to materialize within 24 hours. Additional Margin is applicable for options on futures (options settled using "futures-style" premium posting) and non-spread futures positions.

American-style option

An option which can be exercised on any exchange trading day during its lifetime.

At-the-money

An option whose exercise price is identical to the price of the underlying instrument.

Basis

The difference between the price of the underlying instrument and the corresponding futures price. In the case of fixed income futures, the futures price must be multiplied by the conversion factor.

Bond

Borrowing on the capital market which is certificated in the form of securities vesting creditors' claims.

Call option

In the case of options on fixed income futures, this is a contract that gives the buyer the right to enter into a long position in the underlying futures contract at a set price on, or up to a given date.

Cash-and-carry arbitrage

Creating a risk-free or neutral position by exploiting mispricing on the cash or derivatives market, by simultaneously buying bonds and selling the corresponding futures contract.

Cash settlement

Settling a contract whereby a cash sum is paid or received instead of physically delivering the underlying instrument. In the case of financial futures (for example, EURIBOR Futures), cash settlement is determined on the basis of the Final Settlement Price.

Cheapest-to-deliver (CTD)

The bond which, assuming its delivery upon futures maturity, offers the seller the greatest valuation advantage (or smallest valuation disadvantage), compared to its market value.

Clean price

Present value of a bond, less accrued interest.

Closeout

Liquidating (closing) a short or long option or futures position by entering into an equal and opposite position.

Conversion factor (price factor)

The factor used to equalize the different issue terms of the various bonds eligible for delivery into a futures contract, as well as to standardize these bonds to the notional bond underlying the contract (also referred to as the "price factor"). When multiplied with a bond futures price, the conversion factor translates the futures price to an actual delivery price for a given deliverable bond, as at the delivery date of the corresponding contract. An alternative way of explaining the conversion factor is to see it as the price of a deliverable bond, on the delivery date, given a market yield of six or four percent respectively.

Convexity

Parameter used to take the non-linear price-yield correlation into account when calculating the interest rate sensitivity of fixed income securities.

Cost of carry

The difference between the income received on the cash position and the financing costs (negative amount of net financing costs).

Coupon

(i) Nominal interest rate of a bond. (ii) Part of the bond certificate vesting the right to receive interest.

Cross hedge

Strategy where the hedge position does not precisely offset the performance of the hedged portfolio due to the stipulation of integer numbers of contracts or the incongruity of cash securities and futures and/or options.

Daily Settlement Price

The daily valuation price of futures and options, determined by Eurex, on which the daily margin requirements as well as daily profit and loss calculations are based.

Delta

The change in the option price in the event of a one point change in the underlying instrument.

Derivative

Financial instrument whose value is based on an underlying instrument from which it is derived.

Discounting

Calculating the present value of the future cash flows of a financial instrument.

European-style option

An option which can only be exercised on the Last Trading Day.

Exercise

The option holder's declaration to either buy or sell the underlying instruments at the conditions set in the option contract.

Exercise price (strike price)

The price at which the underlying instrument is received or delivered when an option is exercised.

Expiration date

The date on which the rights vested in an option contract expire.

Final Settlement Price

The price on the Last Trading Day, which is determined by Eurex according to product-specific rules.

(Financial) Futures

A standardized contract for the delivery or receipt of a specific amount of a financial instrument at a set price on a certain date in the future.

Futures Spread Margin

This margin must be pledged to cover the maximum expected loss within 24 hours, which could be incurred on a futures time spread position.

Futures-style premium posting

The (remaining) option premium is not paid until exercise or expiration. This method is used by Eurex Clearing AG for options on futures.

Greeks

Option risk parameters (sensitivity measures) expressed by Greek letters.

Hedge ratio

The number of futures contracts required to hedge a cash position.

Hedging

Using a strategy to protect an existing portfolio or planned investments against unfavorable price changes.

Historical volatility

Annualized standard deviation of returns of an underlying instrument (based on empirical data).

Implied volatility

The extent of the forecast price changes of an underlying instrument which is implied by (and can be calculated on the basis of) current option prices.

Inter-product Spread

See Spread positions.

In-the-money

An option whose intrinsic value is greater than zero.

Intrinsic value

The intrinsic value of an option is equal to the difference between the current price of the underlying instrument and the option's exercise price, provided that this represents a price advantage for the option buyer. The intrinsic value is always greater than or equal to zero.

Leverage effect

The leverage effect allows participants on derivatives markets to enter into a much larger underlying instrument position using a comparably small investment. Given the impact of the leverage effect, the percentage change in the profits and losses on options and futures may be greater than the corresponding change in the underlying instrument.

Lifetime

The period of time from the bond issue until the redemption of the nominal value.

Long position

An open buyer's position in a forward contract.

Macaulay Duration

An indicator used to calculate the interest rate sensitivity of fixed income securities, assuming a flat yield curve and a linear price/yield correlation.

Margin

Collateral, which must be pledged as cover for contract fulfillment (Additional Margin, Futures Spread Margin), or daily settlement of profits and losses (Variation Margin).

Mark-to-market

The daily revaluation of futures and options on futures positions after the close of trading to calculate the daily profits and losses on those positions.

Maturity date

The date on which a contract is settled (that is, on which the exchange of underlying instrument and cash takes place).

Maturity range

Classification of deliverable bonds according to their remaining lifetime.

Modified duration

A measure of the interest rate sensitivity of a bond, quoted in percent. It records the percent change in the bond price on the basis of changes in market yields by one percentage point.

Option

The right to buy (call) or to sell (put) a specific number of units of a specific underlying instrument at a fixed price on, or up to a specified date.

Option price

The price (premium) paid for the right to buy or sell.

Out-of-the-money

A call option where the price of the underlying instrument is lower than the exercise price. In the case of a put option, the price of the underlying instrument is higher than the exercise price.

Premium

See option price.

Present value

The value of a security, as determined by its aggregate discounted repayments.

Put option

An option contract, giving the holder the right to sell a fixed number of units of the underlying instrument at a set price on or up to a set date (physical delivery).

Remaining lifetime

The remaining period of time until redemption of bonds which have already been issued.

Reverse cash-and-carry arbitrage

Creating a neutral position by exploiting mispricing on the cash or derivatives market, by simultaneously selling bonds and buying the corresponding futures contract (opposite of => Cash-and-carry arbitrage).

Risk-based Margining

Calculation method to determine collateral to cover the risks taken.

Short position

An open seller's position in a forward contract.

Spread positions

In the case of options, the simultaneous purchase and sale of option contracts with different exercise prices and/or different expirations.

In the case of a financial futures contract, the simultaneous purchase and sale of futures with the same underlying instrument but with different maturity dates (time spread) or of different futures (Inter-product Spread).

Straddle

The purchase or sale of an equal number of calls and puts on the same underlying instrument with the same exercise price and expiration.

Strangle

The purchase or sale of an equal number of calls and puts on the same underlying instrument with the same expiration, but with different exercise prices.

Synthetic position

Using other derivative contracts to reproduce an option or futures position.

Time spread

See Spread positions.

Time value

The component of the option price arising from the possibility that the trader's expectations will be fulfilled during the remaining lifetime. The longer the remaining lifetime, the higher the option price. This is due to the remaining time during which the value of the underlying instrument can rise or fall. A possible exception exists for options on futures and deep-in-the-money European-style puts.

Underlying instrument

The financial instrument on which an option or futures contract is based.

Variation Margin

The profit or loss arising from the daily revaluation of futures or options on futures (mark-to-market).

Volatility

The extent of the actual or forecast price fluctuation of a financial instrument (underlying instrument). From a mathematical perspective, volatility is equivalent to the annualized standard deviation of returns on the underlying instrument.

Worst-case loss

The expected maximum closeout loss that might be incurred until the next exchange trading day (covered by Additional Margin).

Yield curve

The graphic description of the relationship between the remaining lifetime and yields of bonds.

Valuation Formulae and Indicators

Single-Period Remaining Lifetime

$$P_t = \frac{N + c_1}{(1 + {}_t r_{c1})}$$

P_t	Present value of the bond
N	Nominal value
c_1	Coupon
${}_t r_{c1}$	Yield for the time period t_0 until t_1

Multi-Period Remaining Lifetime

$$P_t = \frac{c_1}{(1 + {}_t r_{c1})^{t1}} + \frac{c_2}{(1 + {}_t r_{c2})^{t2}} + \ldots + \frac{N + c_n}{(1 + {}_t r_{cn})^{tn}}$$

P_t	Present value of the bond
N	Nominal value
c_n	Coupon at time n
${}_t r_{cn}$	Average yield for the time period t_0 until t_n

Macaulay Duration

$$\text{Macaulay Duration} = \frac{\frac{c_1}{(1 + {}_t r_c)^{t_{c1}}} \times t_{c1} + \frac{c_2}{(1 + {}_t r_c)^{t_{c2}}} \times t_{c2} + \ldots + \frac{c_n + N}{(1 + {}_t r_c)^{t_{cn}}} \times t_{cn}}{P_t}$$

P_t	Present value of the bond
N	Nominal value
c_n	Coupon at time n
${}_t r_c$	Discount rate
t_{cn}	Remaining lifetime of coupon c_n

Convexity

$$\text{Convexity} = \frac{\frac{c_1}{(1 + {}_t r_c)^{t_{c1}}} \times t_{c1} \times (t_{c1} + 1) + \frac{c_2}{(1 + {}_t r_c)^{t_{c2}}} \times t_{c2} \times (t_{c2} + 1) + \ldots + \frac{c_n + N}{(1 + {}_t r_c)^{t_{cn}}} \times t_{cn} \times (t_{cn} + 1)}{P_t (1 + {}_t r_c)^2}$$

P_t	Present value of the bond
N	Nominal value
c_n	Coupon at time n
${}_t r_c$	Discount rate
t_{cn}	Payment date of coupon c_n

Conversion Factors

EUR-Denominated Bonds

$$\text{Conversion factor} = \frac{1}{(1.06)^f} \times \left[\frac{c}{100} \times \frac{\delta_i}{act_2} + \frac{c}{6} \times \left(1{,}06 - \frac{1}{(1.06)^n} \right) + \frac{1}{(1.06)^n} \right] - \frac{c}{100} \times \left(\frac{\delta_i}{act_2} - \frac{\delta_e}{act_1} \right)$$

Definition:

δ_e	NCD1y – DD
act_1	NCD – NCD1y, where $\delta_e < 0$
	NCD1y – NCD2y, where $\delta_e \geq 0$
δ_i	NCD1y – LCD
act_2	NCD – NCD1y, where $\delta_i < 0$
	NCD1y – NCD2y, where $\delta_i \geq 0$
f	$1 + \delta_e / act_1$
c	Coupon
n	Integer years from the NCD until the maturity date of the bond
DD	Delivery date
NCD	Next coupon date
NCD1y	1 year before the NCD
NCD2y	2 years before the NCD
LCD	Last coupon date before the delivery date

CHF-Denominated Bonds

$$\text{Conversion factor} = \frac{1}{(1.06)^f} \times \left[\frac{c}{6} \times \left(1{,}06 - \frac{1}{(1.06)^n} \right) + \frac{1}{(1.06)^n} \right] + \frac{c\,(1-f)}{100}$$

Definition:

n	Number of integer years until maturity of the bond
f	Number of full months until the next coupon date, divided by 12 (except for f = 0, where f = 1 and n = n – 1)
c	Coupon

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