

Number of Equity Futures Contracts Needed for a Target
Portfolio Beta

Basic Form for Synthetic Equity or Synthetic Cash

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Number of Equity Futures Contracts Needed for Synthetic
Cash Position

Number of Futures Contracts Needed to Achieve a Target
Portfolio Duration

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Synthetic cash or synthetic equity is modeled using long or short offsetting positions in equity futures.

- A synthetic risk-free asset is formed with a long stock position and a short stock index futures position.
- A synthetic equity position is formed with a long risk-free asset and a long stock index futures position.

$$\text{number of contracts} = (\text{yield beta}) \left(\frac{\text{MD}_T - \text{MD}_P}{\text{MD}_F} \right) \left(\frac{V_P}{P_f \times \text{multiplier}} \right)$$

where:

V_P = current value of the portfolio

P_f = futures price

MD_T = target modified duration

MD_P = modified duration of the portfolio

MD_F = modified duration of the futures contract

The formula for beta of a particular asset is a is

$$\beta_a = \frac{\text{cov}(a, M)}{\sigma_M^2}$$

where:

$\text{cov}(a, M)$ = covariance of returns on asset a with the market

σ_M^2 = variance of the market returns

The number of contracts needed to achieve target portfolio beta, β_T , is

$$\text{number of contracts} = \left(\frac{\beta_T - \beta_P}{\beta_f} \right) \left(\frac{V_P}{P_f \times \text{multiplier}} \right)$$

where:

β_T = desired portfolio beta

β_P = portfolio beta

β_f = equity futures contract beta

V_P = current value of the portfolio

P_f = futures price

An equity position can be converted to a synthetic cash position for T years by using

$$\text{number of equity contracts} = - \frac{V_P(1 + R_F)^T}{P_f}$$

where:

V_P = value of the equity position

P_f = total futures price (quoted price times multiplier)

R_F = risk-free rate

T = designated period of time

Steps to Synthetically Change Equity and Bond Allocations

Preinvesting

Three Types of Foreign Exchange Risk

Hedging Foreign Market and Foreign Currency Risks

Preinvesting is taking a long futures position to create an exposure converting a future cash inflow into a synthetic equity or bond position.

- Hedging foreign market risk
 - Can sell short (sell forward) the foreign market index.
 - The effectiveness depends on correlation of the portfolio and the market index. Perfect correlation will return the foreign risk-free rate.
 - Applying a currency hedge on top of this will return the domestic risk-free rate.
- Hedging foreign currency risk
 - Problem is uncertainty of future value. Strategies to deal with this are
 - ◇ Hedge a minimum future value.
 - ◇ Hedge the estimated future value.
 - ◇ Hedge the initial value of the portfolio.

- To reallocate from equity to bonds
 - 1. Remove all systematic risk (target a beta of zero) by shorting equity futures.
 - 2. Add duration to the position (target a modified duration of more than zero) by going long bond futures.
- To reallocate from bonds to equity
 - 1. Remove all duration (target a modified duration of zero) by shorting bond futures.
 - 2. Add systematic risk to the position (target a beta of more than zero) by going long equity futures.

1. **Transaction exposure** is present when a cash flow in a foreign currency occurs at a future date. Can be hedged by selling forward in the case of a receipt or buying forward in the case of a payment.
2. **Economic exposure** refers to situations when changes in currency value affect competitiveness. Some examples are companies that
 - Export and sell products in foreign markets. Domestic currency appreciation means less competitive products internationally.
 - Purchase and import from foreign markets. Domestic currency depreciation means costs in the domestic currency increase.
 - Operate domestically, but have competitors or suppliers who are affected by changes in currency value.

This can be desirable to hedge, but difficult to quantify.

3. **Translation exposure** is the risk of converting foreign financial statements into domestic currency units. Generally not hedged as it's not seen as a real cash flow risk.

Hedging with Forwards Versus Futures

Covered Call

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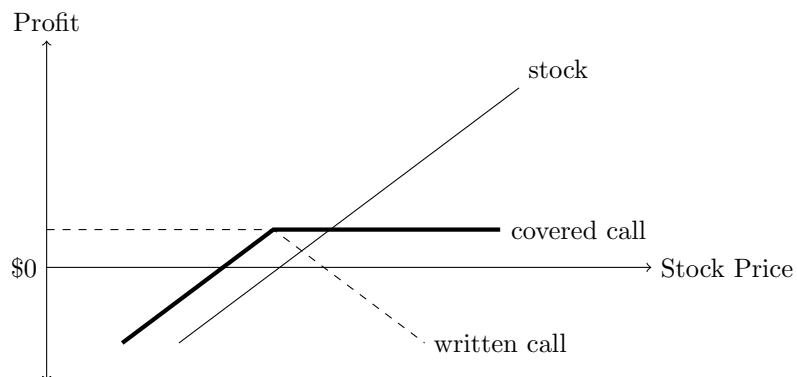
Protective Put

Bull Spread

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Buy the underlying and sell a call option. Used to generate income when the underlying price is expected to remain unchanged.



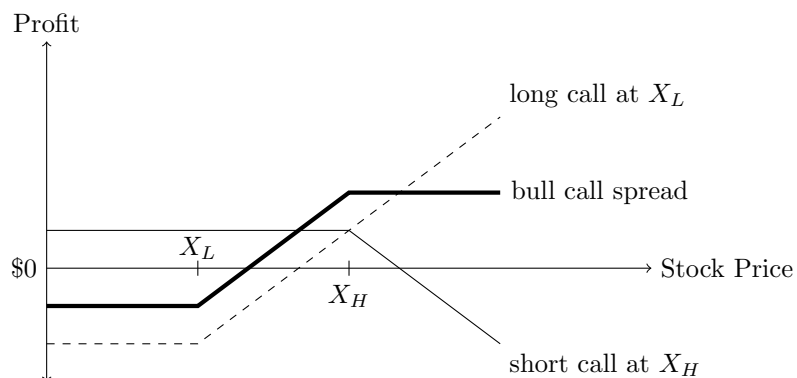
$$\text{profit} = -\max(0, S_T - X) + S_T - S_0 + C_0$$

$$\text{maximum profit} = X + C_0 - S_0$$

$$\text{maximum loss} = S_0 - C_0$$

$$\text{breakeven price} = S_0 - C_0$$

Purchase a call option with a low exercise price, X_L and sell a call with a higher exercise price, X_H . At inception, $X_L < X_H$ and $C_{L,0} > C_{H,0}$. The investor expects the stock price to end up between X_L and X_H . This provides limited upside if the stock rises, with a limited downside.



$$\text{profit} = \max(0, S_T - X_L) - \max(0, S_T - X_H) - C_{L,0} + C_{H,0}$$

$$\text{maximum profit} = X_H - X_L - C_{L,0} + C_{H,0}$$

$$\text{maximum loss} = C_{L,0} - C_{H,0}$$

$$\text{breakeven price} = X_L + C_{L,0} - C_{H,0}$$

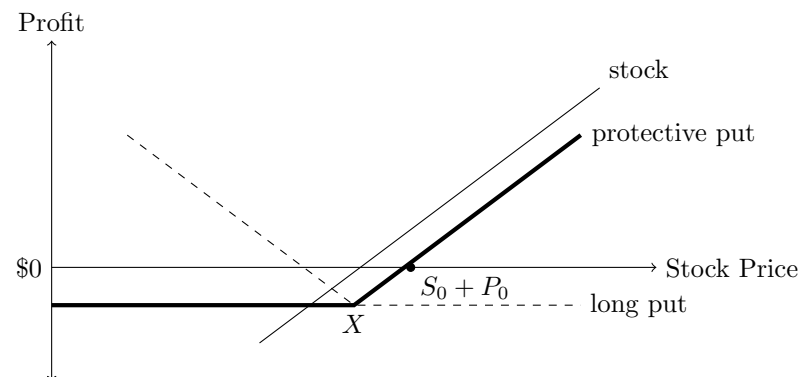
- Practical differences

- Futures are standardized while forwards are customized.
- Forwards have counterparty risk while futures use clearinghouses.
- Futures are more regulated and transparent.
- Futures require margin.

- Empirical differences

- Most bond and equity hedging is done with futures, but this creates cross-hedge and basis risk.
- Interest payment and currency hedges usually use forwards so exact amounts and dates can be hedged.
- Eurodollar futures are a large market that is mostly used by dealers and market makers to hedge their own business needs.

Buy the underlying and buy a put option. Limits downside risk at the cost of the put premium, P_0 .



$$\text{profit} = \max(0, X - S_T) + S_T - S_0 - P_0$$

$$\text{maximum profit} = S_T - S_0 - P_0$$

$$\text{maximum loss} = S_0 - X + P_0$$

$$\text{breakeven price} = S_0 + P_0$$

Bear Spread

Butterfly Spread with Calls

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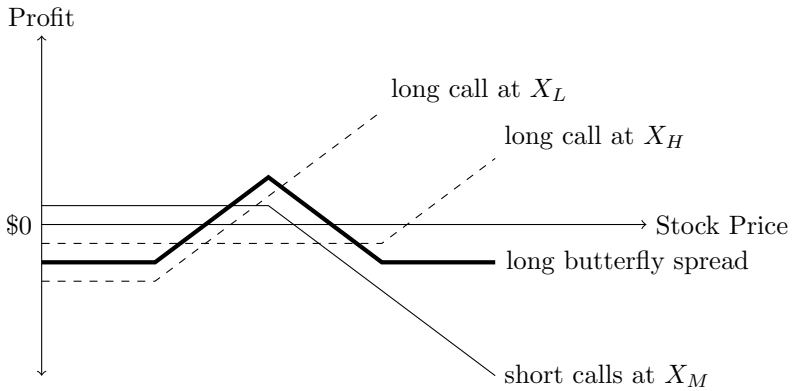
Straddle

Collar

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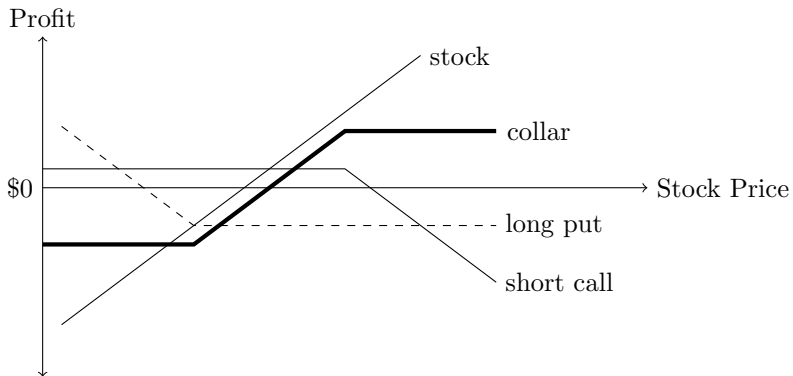
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Buy two calls at strike prices X_L and X_H and write two calls at strike price X_M with $X_L < X_M < X_H$. The investor expects the stock price to stay near X_M , but the downside loss is limited by the purchased calls.



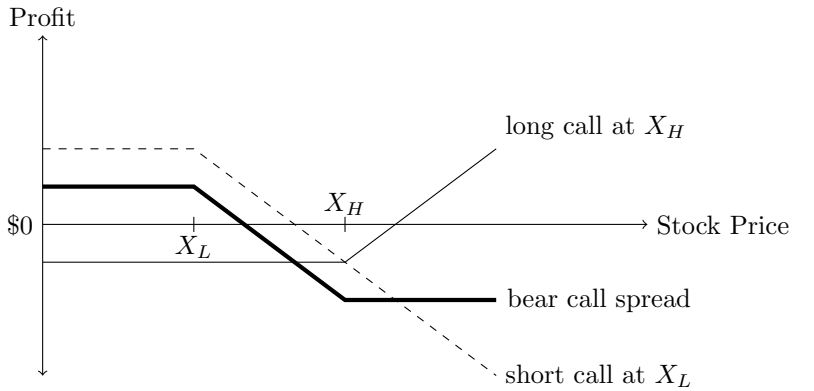
$$\begin{aligned} \text{profit} &= \max(0, S_T - X_L) - 2\max(0, S_T - X_M) \\ &\quad + \max(0, S_T - X_H) - C_{L,0} + 2C_{M,0} - C_{H,0} \\ \text{maximum profit} &= X_M - X_L - C_{L,0} + 2C_{M,0} - C_{H,0} \\ \text{maximum loss} &= C_{L,0} - 2C_{M,0} + C_{H,0} \\ \text{breakeven price} &= X_L + C_{L,0} - 2C_{M,0} + C_{H,0} \text{ and } 2X_M - X_L - C_{L,0} + 2C_{M,0} - C_{H,0} \end{aligned}$$

Combination of a protective put and a covered call. Can be zero-cost if call and put premia are equal. Usually put has lower strike X_L and call has higher strike X_H . Both the upside and downside are limited by the call and the put respectively.



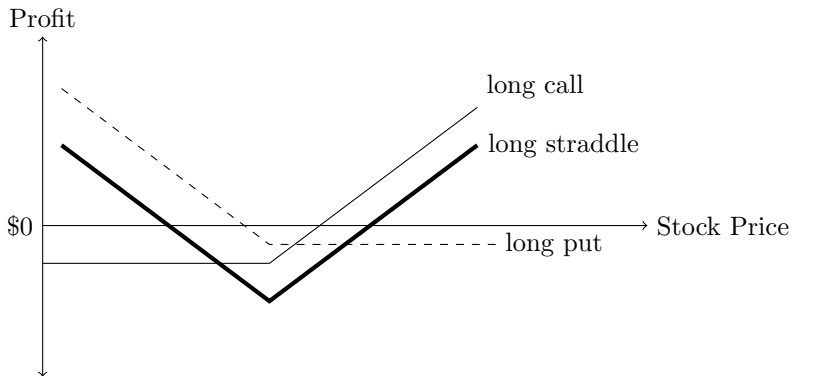
$$\begin{aligned} \text{profit} &= \max(0, X_L - S_T) - \max(0, S_T - X_H) + S_T - S_0 \\ \text{maximum profit} &= X_H - S_0 \\ \text{maximum loss} &= S_0 - X_L \\ \text{breakeven price} &= S_0 \end{aligned}$$

Sell a call with a low exercise price, X_L and buy a call with a higher exercise price, X_H . This provides limited upside if the stock falls, with a limited downside. As prices fall, the investor keeps the premium of the written call, net of the long call premium.



$$\begin{aligned} \text{profit} &= \max(0, S_T - X_H) - \max(0, S_T - X_L) + C_{L,0} - C_{H,0} \\ \text{maximum profit} &= X_H - X_L + C_{L,0} - C_{H,0} \\ \text{maximum loss} &= C_{L,0} - C_{H,0} \\ \text{breakeven price} &= X_L + C_{L,0} - C_{H,0} \end{aligned}$$

Buy both a put and a call with the same strike price and expiration on the same asset. The investor expects a large price move in some direction, and will incur a loss if the price remains static.



$$\begin{aligned} \text{profit} &= \max(0, S_T - X) + \max(0, X - S_T) - C_0 - P_0 \\ \text{maximum profit} &= S_T - X - C_0 - P_0 \\ \text{maximum loss} &= C_0 + P_0 \\ \text{breakeven price} &= X - C_0 - P_0 \text{ and } X + C_0 + P_0 \end{aligned}$$

Box Spread

Payoff of Interest Rate Calls and Puts

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Interest Rate Caps and Floors

Considerations for Delta Hedging

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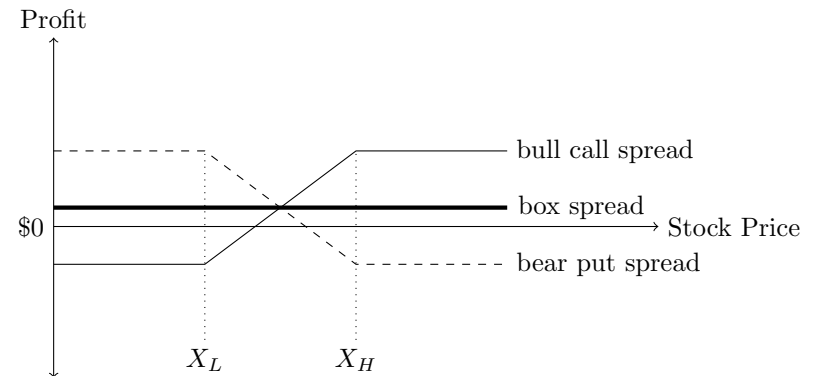
The payoff for an interest rate call is

$$\text{payoff} = NP \times \max(0, \text{LIBOR} - \text{strike rate}) \times (D/360)$$

where NP is the notional principal and D is the days in the theoretical underlying. The payoff for an interest rate put is

$$\text{payoff} = NP \times \max(0, \text{strike rate} - \text{LIBOR}) \times (D/360)$$

Combination of a bull call spread and a bear put spread. That is, a long call and short put at X_L and a long put and a short call at X_H . The payoff is always the same, regardless of the underlying price, which means assuming the prices are correct, the payoff is the risk-free rate.



- Delta is only an approximation and is less accurate for larger changes in the stock price.
- Delta changes as market conditions change, including changes in ΔS .
- Delta changes over time independent of other changes.
- In the Black-Scholes equation, $N(d_1)$ approximates delta.

Interest rate caps and floors are series of interest rate call and put options. Each cap and floor is called a caplet and floorlet.

Caps and floors are OTC contracts so they're tailored. The terms generally specify

- Reference rate—typically LIBOR.
- Cap or floor strike rate.
- Length of the agreement.
- Reset frequency, which determines days in each settlement period, D_t .
- Notional principal (NP).

Effects of Gamma on Delta Hedging

Duration of Interest Rate Swaps

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Effect of Interest Rate Swaps on Cash Flow Risk

Swap Notional Principal Needed for a Target Portfolio
Duration

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- For fixed-rate instruments, duration will be highest as interest rate changes will change the PV of cash flows.
- Floating-rate instruments have duration close to zero as future cash flows vary with interest rates.
- Floating-rate instruments can have non-zero duration if the next payment is set, e.g. with swaps. The convention is to treat the duration of the floating-rate side of a swap as half of the reset period.
- For a pay-floating swap, the duration is

$$D_{\text{pay floating}} = D_{\text{fixed}} - D_{\text{floating}} > 0$$

The greater the value of gamma the more risk in the position (i.e., the more variability in the value of the option.)

The gamma of an at-the-money option is greatest near the expiration. When gamma is large, option values are subject to large changes, the position faces the most risk, and the investor is most likely to use a two-option hedge. In this situation, two options are used to force both delta and gamma to zero.

The duration of a portfolio with a swap position is

$$V_P \cdot MD_T = V_P \cdot MD_P + NP \cdot MD_{\text{swap}}$$

where:

V_P = original value of the portfolio

MD_i = modified duration

NP = notional principal of the swap

Usually the maturity of the swap is set, which fixes MD_{swap} , so solving for NP gives

$$NP = V_P \left(\frac{MD_T - MD_P}{MD_{\text{swap}}} \right)$$

This is a variation of the basic hedging formula set up to notional principal rather than number of contracts.

Entering into a fixed-payer swap reduces cash flow risk because future floating-rate payments are converted to certain fixed payments. However, this converts the low-duration floating payments to high-duration fixed payments. As a result, interest rates now affect the market value of the liability.

Conversion of Foreign Cash Receipts into Domestic Cash Receipts

Risks of Equity Swaps

Swaps for International Diversification

Use Swaps to Change Allocations

- Counterparty risk if the swap dealer is unable to make payments.
- Basis risk if the return on the stock portfolio doesn't exactly match the index payments made to the swap dealer.
- Cash flow risk in that the firm must have cash on hand in the event of a netted payment. This risk wouldn't exist had the firm sold stock and bought fixed-rate securities.

Swaps can be used to synthetically change portfolio allocation. E.g., to allocate more heavily to large-cap stocks in a small-cap portfolio, a manager can enter into a swap paying the small-cap return and receiving the large-cap return.

This can also be used for bond portfolios to, e.g., reallocate from high- to low-grade bonds. This is different than an interest rate swap because of the total return aspect.

Dealers will use contracts to create currency swaps which do not require exchange of principal. This is essentially a series of exchange-rate purchases in the future at a fixed exchange rate. The amounts exchanged are a function of the current exchange rate and the interest rate of the countries involved.

1. Divide the foreign cash flow received by the foreign interest rate to get the foreign-denominated NP. This is the foreign NP that would have produced the foreign cash flow at the given exchange rate.
2. Using the current exchange rate, convert the foreign NP into the corresponding domestic NP.
3. Enter the swap with this NP.
 - (a) Pay the foreign cash flows received on the assets, and receive the equivalent domestic amount.
 - (b) The amount of each domestic cash flow is determined by the domestic interest rate times the domestic NP.

Swaps can be used to create international diversification by paying the return on a domestic index and receiving the return on an international index. This creates extra cash flow risk compared to a fixed-receiver swap because of the possibility of both indices declining and having to make two payments.

Benefits of using these swaps are

- Costs are generally lower than selling domestic and buying international stock.
- Can be defined for a temporary period of time for which exposure is desired.
- Can be paid in U.S. dollars to avoid foreign currency exposure.

Payer and Receiver Swaptions

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- **Payer swaption.**

- Gives the buyer the right to be the fixed-rate payer in a prespecified swap at a prespecified date. Similar to a protective put in that it allows payment of a fixed-rate, even if rates have increased.
- If interest rates rise enough at expiration such that the new SFR is above the swaption SFR, the holder will exercise the swaption. The swaption swap has positive value.
- If interest rates fall so that the new SFR is below the swaption SFR, the holder will let the swaption expire. The swaption swap has negative value.
- Can be used to convert a future floating-rate loan into a fixed-rate loan.

- **Receiver swaption.**

- Gives the buyer the right to be the fixed-rate receiver in a prespecified swap at a prespecified date. The holder expects rates to fall, and the swap pays a higher fixed rate while paying a lower floating rate.
- If interest rates move high enough and the new SFR is above the swaption SFR, the holder will let the swaption expire. The swap has negative value.
- If interest rates fall and the new SFR is below the swaption SFR, the holder will exercise the swaption. The swap has positive value.
- Can be used to convert a future fixed-rate loan to a floating-rate loan.