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Foundations · market mechanics from the ground up

Options: call, put, payoff, time value and put-call parity

Chapter 5 of 10

An option is the right to buy or sell at a fixed price, without the obligation to do so. This chapter explains call and put, works through the payoff at expiry, compares hedging with puts and with futures on a portfolio of 35 million USD, separates intrinsic value from time value and derives put-call parity, from which every position can be rebuilt out of the others.

Field	Value
Series	Futures, options and who makes the price
Scope	Chapter 5 of 10
Type	Explanation with worked examples, not a measurement
As of	11 November 2026
Author	Timon Krüger
Online	kruegeralgorithms.com/en/research/options-basics-payoffs-put-call-parity

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In one sentence: An option is insurance on a price, its buyer pays a premium up front and can only gain after that, and because a call can be rebuilt from a put and the index, the prices of call and put are firmly tied to each other.

What this chapter is: an explanation with worked examples. The option prices in the example are computed with the formula from chapter 6 (S&P 500 at 7,000, 30 days to expiry, 16 % volatility), not observed in the market. **Not a trading recommendation.**

Chapter 4 showed how a pension fund hedges its portfolio with futures and gives up gains in the process. The option solves exactly that problem.

1. What an option is

An option gives its buyer a **right**, but no obligation:

- A **call** is the right to **buy** an asset at a fixed price.
- A **put** is the right to **sell** an asset at a fixed price.

Five items describe an option completely:

Item	Meaning	In the example
Underlying	what the option is written on	S&P 500
Type	call or put	call
Strike	the fixed price	7,000 points
Expiry	until when the right holds	in 30 days
Multiplier	value of one point	100 USD

The price the buyer pays for this right is called the **premium**. He pays it immediately and never gets it back.

For every buyer there is a seller. He is called the **writer**. He receives the premium and carries the obligation in return: with a call he has to deliver, with a put he has to take delivery.

Options on the S&P 500 are settled in money at the end, like the future. They can only be exercised on expiry day. This design is called European. Options on individual shares can be exercised at any time, which is called American. For the mechanics of this series the difference does not matter.

2. The payoff at expiry

On expiry day the value of an option is simple. The index is then at S_T, the strike is K.

Call: The right to buy at 7,000 is only worth something if the index is above it. Then it is worth exactly the difference. Otherwise it expires worthless.

$$\text{Call payoff} = \max(S_T - K,\ 0)$$

Put: The right to sell at 7,000 is only worth something if the index is below it.

$$\text{Put payoff} = \max(K - S_T,\ 0)$$

The buyer's profit is the payoff minus the premium paid. In the example the call and the put with strike 7,000 each cost 128.09 points, that is 12,809 USD per contract.

Index at expiry	Call payoff	Call profit	Put payoff	Put profit
6,700	0	−128.09	300	+171.91
6,900	0	−128.09	100	−28.09
7,000	0	−128.09	0	−128.09
7,100	100	−28.09	0	−128.09
7,300	300	+171.91	0	−128.09

Three things stand out:

- **The buyer's loss is limited.** He cannot lose more than the premium, however far the market runs against him.
- **The gain is not.** With the call it grows with every point the index rises.
- **Being right is not enough.** At 7,100 the index has risen and the call buyer has still lost. He only earns above 7,128.09, the strike plus the premium. This level is called the **break-even**. For the put it is at 6,871.91.

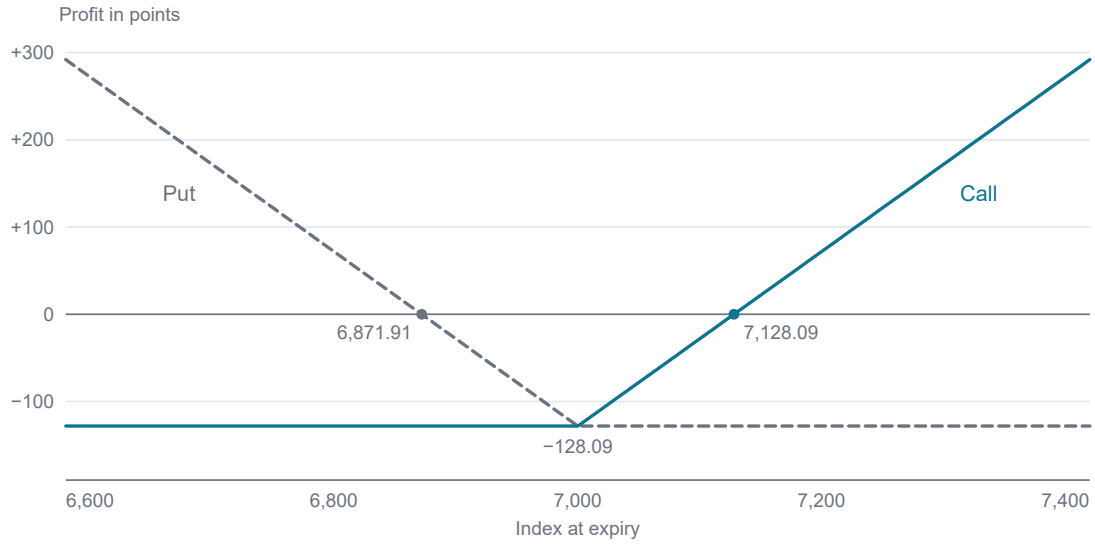


Fig. 1: Profit and loss on expiry day for a bought call and a bought put with strike 7,000 and a premium of 128.09 points. The kink is at the strike, the zero line is crossed at the break-even levels.

3. The four basic positions

Buy or sell, call or put: that makes four positions. The seller's view is the mirror image of the buyer's.

Position	Earns if the index	Largest gain	Largest loss
Call bought	rises sharply	unlimited	the premium
Call sold	does not rise sharply	the premium	unlimited
Put bought	falls sharply	strike minus premium	the premium
Put sold	does not fall sharply	the premium	strike minus premium

The buyer pays little and rarely gains a lot. The seller often takes in a little and rarely loses a lot. That is the relation between insured and insurer.

4. Hedging with puts instead of futures

The pension fund from chapter 4 holds shares worth 35 million USD. With 100 futures sold it was protected against losses, but also cut off from gains. Now it buys puts with strike 7,000 instead.

One contract covers 7,000 times 100 USD, that is 700,000 USD:

$$\frac{35{,}000{,}000}{700{,}000} = 50 \text{ contracts}, \qquad 50 \times 12{,}809 \text{ USD} = 640{,}450 \text{ USD premium}$$

That is 1.83 % of the portfolio for 30 days of protection. The comparison after one month, in million USD:

Index after 30 days	No hedge	With 100 futures sold	With 50 puts bought
−5 % (6,650)	−1.75	0.00	−0.64
unchanged (7,000)	0.00	0.00	−0.64
+5 % (7,350)	+1.75	0.00	+1.11

With puts the pension fund loses the premium in the worst case and keeps most of the gain in the good case. For that it pays 640,450 USD in every case. The future costs nothing and takes both sides away. The option costs something and takes only the bad side away. What this protection is worth, that is, why the premium is 128.09 points and not 50 or 300, is the question of chapter 6.

5. Intrinsic value and time value

Before expiry an option costs more than it would bring if exercised immediately. Its price has two parts.

- **Intrinsic value:** what the option would be worth if it expired now. For the call $\max(S - K, 0)$, for the put $\max(K - S, 0)$.
- **Time value:** the rest. It pays for the possibility that the price still moves favourably before expiry.

$$\text{Price} = \text{intrinsic value} + \text{time value}$$

Depending on where the strike lies relative to the current price, an option has one of three names:

- **In the money:** the option has intrinsic value. A call with a strike below the price, a put with a strike above it.
- **At the money:** strike and price are equal.
- **Out of the money:** the option has no intrinsic value and consists of time value only.

Three strikes at an index level of 7,000:

Strike	Call: price	of which intrinsic value	of which time value	Put: price	of which intrinsic value	of which time value
6,900	183.38	100	83.38	83.38	0	83.38
7,000	128.09	0	128.09	128.09	0	128.09
7,100	85.12	0	85.12	185.12	100	85.12

Two observations that become important later:

- **Time value is largest at the money.** That is where it is most uncertain whether the option will be worth something in the end.
- **Call and put with the same strike have the same time value.** That is no coincidence. It follows from put-call parity in the next section.

With every day that passes time value melts, until only the intrinsic value is left on expiry day. How fast is shown in chapter 7.

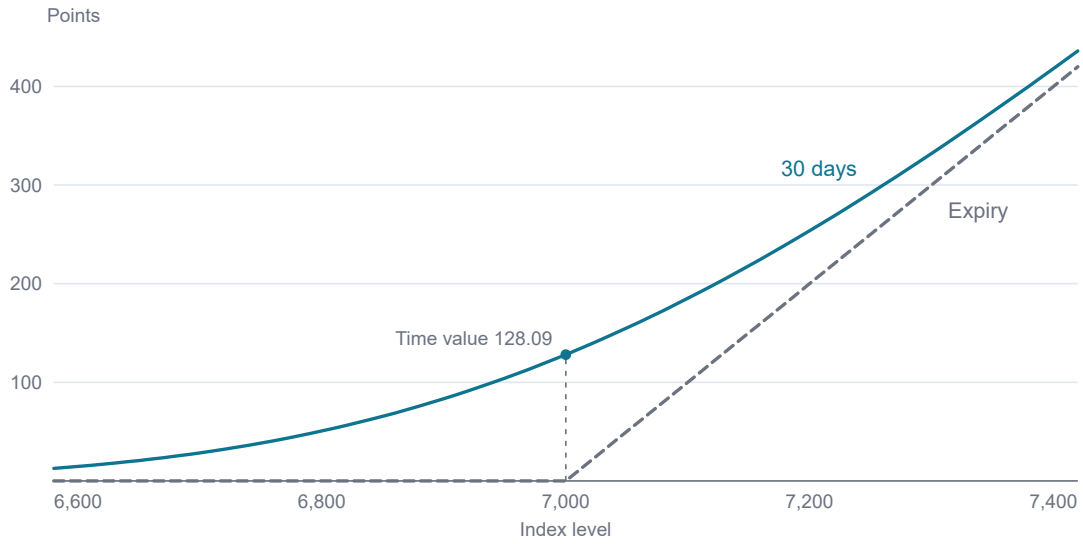


Fig. 2: Price of a call with strike 7,000 at 30 days to expiry (solid) and its payoff on expiry day (dashed), by index level. The distance between the two lines is the time value. It is largest at the strike.

6. Put-call parity: derivation

Call and put with the same strike and expiry are not independent products. The difference between their prices is fixed. The derivation needs only two portfolios and a comparison.

Portfolio A: a call with strike K, plus enough money in the account that with interest it amounts to exactly K on expiry day. Today that is the discounted amount $K \cdot e^{-rT}$.

Portfolio B: a put with the same strike, plus the index itself.

What are the two worth on expiry day?

On expiry day	Portfolio A: call and cash	Portfolio B: put and index
Index below K	call expires, cash is worth K: K	put pays $K - S_T$, index is worth S_T: K
Index above K	call pays $S_T - K$, cash is worth K: S_T	put expires, index is worth S_T: S_T

In both cases the portfolios are worth the same, namely the larger of the two values S_T and K. Two portfolios that are worth the same in every case at the end must cost the same today. Otherwise one could sell the dearer one, buy the cheaper one and keep the difference without risk.

$$C + K \cdot e^{-rT} = P + S$$

Rearranged:

$$C - P = S - K \cdot e^{-rT}$$

The difference between call and put price depends only on the index, the strike and the interest rate. Volatility does not appear, and neither does any view on direction.

Worked example without interest. In the examples of this series the interest rate is mostly zero. Then $C - P = S - K$. At the money ($S = K$) call and put cost the same: 128.09 and 128.09. At strike 6,900 the call is exactly 100 points dearer than the put: 183.38 against 83.38.

Worked example with interest. At 4 % interest and 30 days to expiry the discounted strike is

$$7{,}000 \times e^{-0.04 \times 30/365} = 6{,}977.02$$

So the call has to be $7{,}000 - 6{,}977.02 = 22.98$ points dearer than the put. Computed with the pricing formula the call costs 139.69 and the put 116.72. The difference is 22.98 (the prices are rounded to two decimals).

What happens if prices deviate? Suppose the call trades 5 points too high. An arbitrageur rebuilds the expensive side and sells it:

Trade today	Cash flow today
Sell call	+144.69
Buy put	−116.72
Buy index	−7,000.00
Take out loan	+6,977.02
Sum	+5.00 (rounded)

On expiry day everything cancels out, wherever the index is:

Index at expiry	Call sold	Put bought	Index	Loan repaid	Sum
6,800	0	+200	+6,800	−7,000	0
7,200	−200	0	+7,200	−7,000	0

The 5 points, that is 500 USD per contract, remain as a certain profit. Because anyone can do this, such deviations do not last.

7. Synthetic positions

Parity can be solved for each of its four quantities. So every position can be rebuilt from the other three. Such rebuilds are called synthetic. Without interest:

This position	can be rebuilt from
Index bought	call bought and put sold
Call bought	put bought and index bought
Put bought	call bought and index sold
Put sold	index bought and call sold

The first row says: whoever buys a call and sells a put with the same strike has the same position as with a future. If the index rises, the call gains. If it falls, the put sold loses. The right and the obligation together again make the contract that binds both sides.

The last row is the most important in practice. Holding shares and selling calls on them is called a **covered call** and is regarded as a cautious strategy for extra income. By parity it is the same position as a put sold: limited gain, and the full loss if the market falls.

For the further chapters one consequence matters above all: a call and a put with the same strike differ only by a position in the index. Everything that distinguishes an option from a future, the curvature of its payoff, is the same for both. That is why in chapters 8 and 9 it does not matter whether a dealer has calls or puts in his book. What counts is whether he has bought or sold them.

Common misconception

> **Common misconception:** "A call is a bet on rising prices, a put a bet on falling ones." For direction no option is needed, a future is enough. By parity a call is a put plus a position in the index. So the difference between the two is only the direction. What an option is really about is the kink in its payoff: limited loss with open gain. That is what the premium is paid for, and that is why the buyer earns from large moves and not merely from having picked the direction.

What you should understand now

- A call is the right to buy, a put the right to sell, each at the strike. The buyer pays the premium, the seller carries the obligation.
- At expiry a call pays $\max(S_T - K, 0)$ and a put $\max(K - S_T, 0)$. The buyer can lose the premium at most and only earns beyond the break-even.
- In hedging, a future takes both sides away and costs nothing. A put takes only the bad side away and costs the premium.
- The price of an option consists of intrinsic value and time value. Time value is largest at the money and the same for call and put with the same strike.
- Put-call parity $C - P = S - K \cdot e^{-rT}$ ties the prices to each other. Every position can be rebuilt from the others.

Limits of this account

- **European exercise.** Parity holds in this form for options that can only be exercised on expiry day, and without dividends. With dividends the price reduced by the dividends takes the place of S. For American options it holds only approximately.
- **Trading costs.** Every option has a spread between bid and ask (chapter 2). The arbitrage from section 6 only pays once the deviation is larger than these costs.
- **Collateral.** Whoever sells options has to post margin, as with the future. The seller's unlimited risk of loss is visible in the tables only as a word.
- **Not covered:** combinations of several options such as spreads, straddles and strangles.

Continue with chapter 6: how the price of an option comes about, from a coin toss to the Black-Scholes formula.

An explanation of market mechanics with worked examples. Not investment advice and not a trading recommendation. Trading futures and options involves the risk of loss up to and beyond the capital employed.