**KruegerAlgorithms**

*Foundations · market mechanics from the ground up*

# The market as an auction: order book, market makers and market takers

Chapter 2 of 10

*An exchange price is not a value that somebody sets but the result of a continuous auction in the order book. This chapter explains bid and ask, limit and market orders, who market makers and market takers are, what a market maker earns from and what he loses on, and derives how wide the spread between buying and selling price has to be at the very least.*

| Field | Value |
|---|---|
| Series | Futures, options and who makes the price |
| Scope | Chapter 2 of 10 |
| Type | Explanation with worked examples, not a measurement |
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| Online | kruegeralgorithms.com/en/research/order-book-market-makers-and-takers |

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**In one sentence:** The price forms where an order that wants to be executed immediately meets an order that has been waiting, and whoever waits demands a spread for it that is just large enough to cover his losses against better-informed traders.

**What this chapter is:** an explanation with a worked example, not a measurement. The order book in the example is made up to show the mechanics. The contract data of the E-mini future come from the CME. **Not a trading recommendation.**

Chapter 1 introduced the participants. This one is about the place where they meet.

## 1. An exchange is an auction that never ends

At an art auction there is one seller and many bidders. On an exchange there are many buyers and many sellers at the same time, and trading goes on without a break. The principle is the same: whoever wants to buy says what he will pay at most. Whoever wants to sell says what he wants at least. If two orders fit together, a trade happens.

The exchange collects all orders that are still waiting for a counterpart in a list. This list is called the **order book**. Every participant can see it.

## 2. Reading the order book

The example is the E-mini future on the S&P 500. Its price moves in steps of 0.25 points. One point is worth 50 USD, so one step is 12.50 USD per contract. Suppose the order book looks like this:

| Side | Price | Resting contracts |
|---|---|---|
| Sell | 7,001.00 | 310 |
| Sell | 7,000.75 | 260 |
| Sell | 7,000.50 | 180 |
| Sell (ask) | 7,000.25 | 120 |
| Buy (bid) | 7,000.00 | 110 |
| Buy | 6,999.75 | 170 |
| Buy | 6,999.50 | 240 |
| Buy | 6,999.25 | 300 |

Four terms are enough:

- **Bid:** the highest price at which someone wants to buy. Here 7,000.00.
- **Ask:** the lowest price at which someone wants to sell. Here 7,000.25.
- **Spread:** the distance between the two. Here 0.25 points, that is 12.50 USD per contract.
- **Depth:** how many contracts are resting at each price level.

There is no single "price" at this moment. There is a price for whoever wants to buy immediately (7,000.25) and one for whoever wants to sell immediately (7,000.00). What appears on the chart as the price is the price of the last trade.

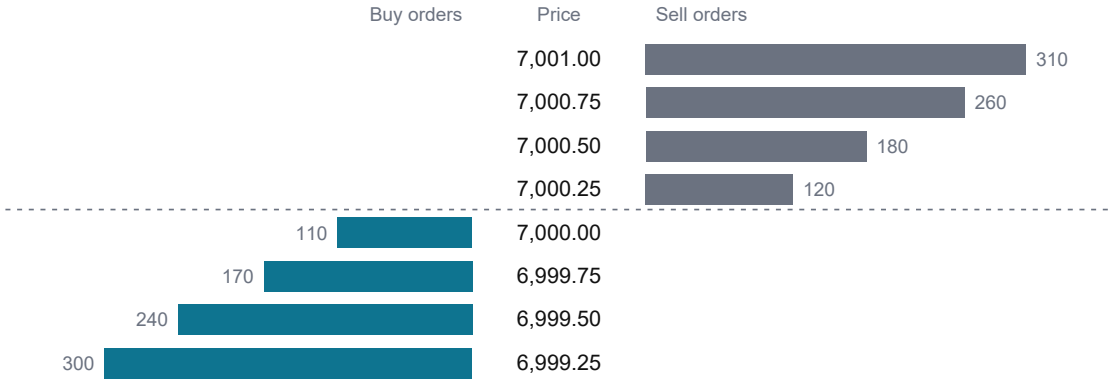



*Fig. 1: The order book from the table. On the left the resting buy orders, on the right the resting sell orders. The gap in the middle is the spread.*

## 3. Two kinds of orders

**Limit order:** "I buy 50 contracts, but at 6,999.75 at most." The order is placed in the order book and waits. The trader gets his price or nothing at all. He does not know whether and when he will be executed.

**Market order:** "I buy 200 contracts, now, at the best available price." The order is executed immediately against the resting sell orders, starting with the cheapest. The trader is certain to get his contracts. He does not know exactly at what price.

The market order for 200 contracts in the example:

- 120 contracts at 7,000.25. That empties this price level.
- 80 contracts at 7,000.50.

$$\text{Average price} = \frac{120 \times 7{,}000.25 + 80 \times 7{,}000.50}{200} = 7{,}000.35$$

After the trade the ask is at 7,000.50. The buyer has moved the price up by one level, simply by using up the cheapest offers. That is the basic mechanism of every price move: **the price moves when orders that want immediate execution empty a price level.**

## 4. Makers and takers

Two roles follow from the two kinds of orders:

- Whoever places a limit order in the book and waits **provides** liquidity. In this trade he is the **maker**.
- Whoever trades against a resting order with a market order **takes** liquidity. He is the **taker**.

Maker and taker are roles in a single trade, not fixed groups of people. A private investor who places a limit order is a maker at that moment. Nevertheless there are firms whose entire business is quoting prices. They are called **market makers**.

| | Market maker | Market taker |
|---|---|---|
| Who that typically is | trading firms such as Citadel Securities, Virtu, Optiver, Jane Street, trading desks of banks | funds, asset managers, hedgers, private investors |
| What he does | continuously quotes buying and selling prices | buys or sells when he needs to |
| What he wants | to earn the spread, many times | to build or reduce a position |
| View on direction | none | usually yes, or a need to hedge |
| What he gives up for it | control over when and against whom he trades | half the spread on every trade |

On some exchanges market makers have a contract: they commit to quoting prices almost continuously and get lower fees in return. On the large futures markets most quote voluntarily. This has a consequence that becomes important in chapter 3: they may withdraw their orders at any time.

## 5. What a market maker earns from

The market maker places a buy order at 7,000.00 and a sell order at 7,000.25 in the book at the same time. If first a seller comes and then a buyer, he has bought at 7,000.00 and sold at 7,000.25:

$$0.25 \text{ points} \times 50 \text{ USD} = 12.50 \text{ USD per contract}$$

Afterwards his inventory is back at zero. He has not earned from any price move, only from the spread. The amount per trade is tiny. The business pays through volume.

On stock exchanges there is a second source. Many exchanges pay the maker a small rebate per share and charge the taker a fee. This pricing model is called **maker-taker**. It was introduced in 1997 by an electronic trading platform that wanted to draw orders away from the established exchanges. In the US the taker fee is capped by regulation at a fraction of a cent per share, and the maker rebate lies slightly below it. At the CME, by contrast, both sides pay a fee per contract in the index futures.

## 6. What a market maker loses on

The market maker does not know who is trading against him. That is where his risk lies.

**Inventory risk.** He has bought at 7,000.00, but the buyer he wanted to sell on to does not come. Instead the price falls by one point. Loss: 50 USD per contract, as much as the income from four successful round trips.

**Adverse selection.** This is the bigger problem. Some takers know more than the market maker: they have read a piece of news faster, or they know that a much larger order follows behind theirs. Such traders only buy when the price is about to rise and only sell when it is about to fall. Against them the market maker loses every time. The term comes from insurance: whoever knows a risk that the insurer does not know is more likely to insure himself.

The market maker cannot tell the two groups apart. So he has to earn as much from the uninformed as he loses to the informed.

## 7. Derivation: how wide does the spread have to be?

The simplest model for this goes back to Lawrence Glosten and Paul Milgrom (1985). The assumptions:

- A share $\pi$ of the takers is informed. The rest trade for other reasons, for example because a fund has to invest money.
- An informed taker knows that the price is about to jump by $J$ points and trades in the right direction.
- The market maker sets his quotes half a spread $s/2$ away from the current value: buy at value minus $s/2$, sell at value plus $s/2$.

**Against an uninformed taker** the market maker earns half the spread:

$$\text{Gain} = \frac{s}{2}$$

**Against an informed taker** he sells, for example, at value plus $s/2$, and immediately afterwards the value has risen by $J$. He has sold too cheaply:

$$\text{Loss} = J - \frac{s}{2}$$

**The condition.** Under competition nothing is left for the market maker on average. Gain times frequency equals loss times frequency:

$$(1-\pi)\cdot\frac{s}{2} = \pi\cdot\left(J - \frac{s}{2}\right)$$

Multiplied out:

$$\frac{s}{2} - \pi\cdot\frac{s}{2} = \pi\cdot J - \pi\cdot\frac{s}{2}$$

The term $\pi\cdot s/2$ stands on both sides and drops out:

$$\frac{s}{2} = \pi\cdot J \quad\Longrightarrow\quad s = 2\,\pi\,J$$

So the spread is twice the share of the informed times the size of their advantage.

**Worked example.** Suppose every tenth taker is informed ($\pi = 0.1$) and his advantage is 1.25 points:

$$s = 2\times 0.1\times 1.25 = 0.25 \text{ points}$$

That is exactly one price level, the spread from the order book above. The check: out of ten trades, nine bring 0.125 points each, together 1.125. One costs 1.25 minus 0.125, that is also 1.125. The sum is zero.

Three things follow from the formula:

- **More informed traders, wider spread.** Before important economic data the danger of trading against someone who processes the number faster rises. Market makers set their quotes further apart or withdraw them.
- **Larger jumps, wider spread.** In turbulent markets $J$ is large.
- **The spread is not a profit.** It is the price all takers pay so that the market maker can carry the losses against the few who are informed.

## 8. From the floor to the computer

Until the 1990s market makers stood on the exchange floor as people. On the New York Stock Exchange one "specialist" was responsible for each share, in the pits of the Chicago futures exchanges the "locals" traded for their own account. Spreads were wide. US shares were quoted in sixteenths of a dollar until 2001, so the

smallest possible spread was 6.25 cents. Since the switch to decimal prices it has been 1 cent.

With electronic trading the profession became a computing problem: whoever adjusts his quotes to new information fastest is caught least often by informed traders and can quote the narrowest spread. This explains why a few highly technical firms dominate this market today and why speed matters to them. The formula from section 7 holds unchanged. Only $J$ has become smaller, because quotes are updated faster.

## Common misconception

> **Common misconception:** "Market makers move the price to where they want it." A market maker earns the spread and wants as little inventory as possible at the end of the day. A price move is a risk to him, not a goal. The price moves when takers empty price levels. The market maker reacts to that and requotes. We have tested trading rules built on the idea of liquidity being deliberately collected: they hit their targets as often as chance does (to the study).

## What you should understand now

- The order book is the list of all resting buy and sell orders. Bid and ask are its best prices, the spread is the distance between them.
- A limit order waits for its price, a market order takes the best available one. The price moves when market orders use up a price level.
- Maker and taker are roles in a trade. Market makers are firms that quote prices professionally and earn the spread.
- A market maker loses to traders who know more than he does (adverse selection) and to price moves while he holds inventory.
- In the simplest model the spread is $s = 2\,\pi\,J$: it grows with the share of informed traders and with the size of the price jumps.

## Limits of this account

- **Made-up order book.** The quantities in the example show the mechanics. Real books change many thousands of times per second, and a large part of the orders is cancelled before being executed.
- **Simplest model.** The derivation knows only one price jump of fixed size and no inventory. Real market makers also manage their inventory, hedge it in related markets and adjust their quotes to the order flow.
- **Minimum step.** The spread cannot be smaller than one price level. In the E-mini it is almost always exactly one level; competition there takes place through size and queue position in the book.
- **Not covered:** hidden orders, off-exchange trading and the routing of customer orders to market makers for payment.

**Continue with chapter 3:** what liquidity is, how far an order moves the price and when the resting orders disappear.

*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.*