Lecture 1: Spot Markets

Modeling and Marketing Making in Foreign Exchange

Course Overview

- Lecture 1: spot markets
  - Market structure, voice trading, and electronic trading
- Lecture 2: forward markets
  - Market structure, spot/forward arb, voice trading, and electronic trading
- Lectures 3 and 4: vanilla option markets
  - Market structure, volatility interpolation, vega risk management, correlation risk, volatility relative value, voice & electronic trading
- Lectures 5 and 6: exotic derivative markets
  - Stochastic volatility models, local volatility models, mixture models, jump diffusion models, barrier option pricing, derivatives with multiple assets, volatility products
- Lecture 7: algorithmic index markets
  - Index construction and backtesting

Your Instructor

- Mark Higgins (mark.higgins@wsq.io)
- Co-founder and COO of Beacon since May 2014
  - Fin-Tech company selling an institutional quant platform
- Managing Director at JPMorgan, 2006-2014
  - Co-headed Quantitative Research for the investment bank
  - Launched and delivered the Athena project
  - Traded currency options
- Vice President at Goldman Sachs, 1998-2006
  - Headed the currency and NY interest rate quant groups
- Lead developer at Contango Energy, 1996-1998
- PhD in theoretical astrophysics from Queen's University in Canada, 1996

Course Material and Pre-Reqs

- Black-Scholes pricing: you should know this very well
  - We will implement BS pricing for exotics
  - We will implement other models that are extensions to BS
- Python: each assignment will have at least one question that needs to be implemented in Python
- Stochastic calculus: you should understand how to solve standard SDEs, know what the forward and backward Kolmogorov equations mean
- Not an easy course

Admin Stuff

- TA: TBD
  - Will mark assignments
- Seven lectures, 6:05-8:50pm Wednesdays
  - 9/6, 9/11 (* 4-6pm instead), 9/13, 9/27, 10/4, 10/11, 10/18
  - Each lecture has an assignment, due at the start of the next class
    - We will go through solutions at the start of the class, so don't be late or you'll get zero
    - We will go through the final (seventh) assignment at the end of the final class, so nothing to hand in there
  - Final exam date TBD
- Course grade: assignments 25%, final exam 75%

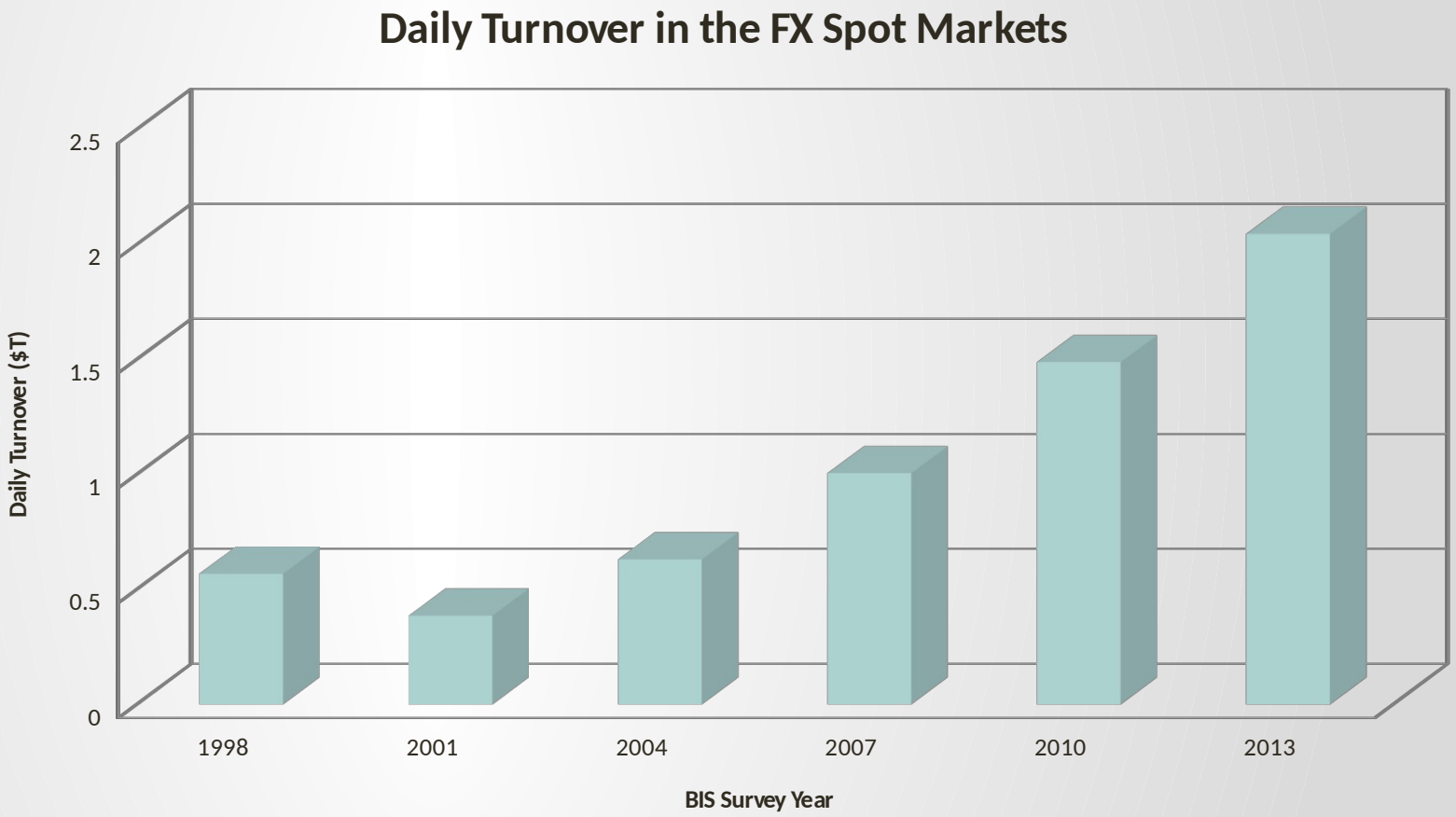
The FX Spot Markets

- A “spot” trade is an agreement to exchange some amount of one currency for another amount of another currency
  - Usually settles two business days after the trade date
- Bilateral, over-the-counter transactions
  - Not exchange traded, or even traded on SEFs
  - Currency futures exist – we’ll discuss next week – but only a small part of the market
- Not cleared
  - Typically settled through CLS to manage settlement risk, only guarantees that you get back your side of the trade

Spot Market Statistics

- The spot market is huge: $2T/day notional traded according to the 2013 BIS survey
  - http://www.bis.org/publ/rpfx13fx.pdf
  - Much larger than global equity markets: $3-400B/day
  - About the same as global bond markets: $2T/day
- Bid/ask spreads are tiny
  - ~0.2-0.5bp for most liquid markets in $1-5M notional
  - ~0.5-1bp for liquid markets in larger sizes ($50-100M notional)
- Most trading happens via dealer intermediation
  - London, NYC, Singapore, Tokyo, and Hong Kong are main centers

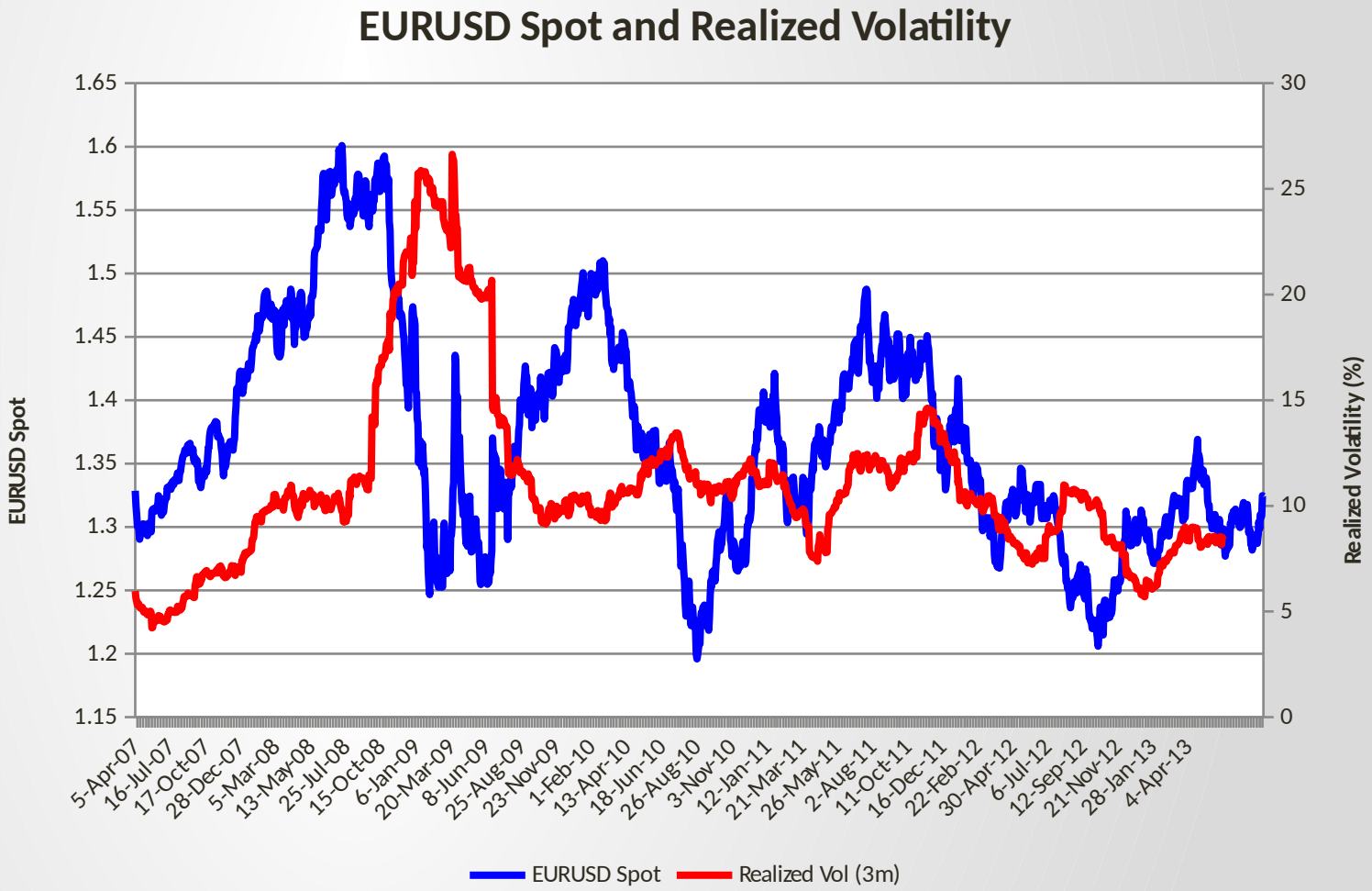
Spot Market Statistics



Spot Market Conventions

- Currency: a currency, like EUR
- Currency pair: a pair of currencies, like EURUSD
  - The first currency in the pair is the “asset” currency, and the second is the “denominated” currency
  - Market chooses a convention for which way around to quote
  - “EURUSD” means “the price of a EUR in USD” (currently around 1.13 USD per EUR)
  - “USDJPY” means “the price of a USD in JPY” (currently around 120 JPY per USD)
  - EURUSD, AUDUSD, NZDUSD, GBPUSD are quoted in USD per currency
  - USDJPY, USDCHF, and USDCAD are quoted in currency per USD
  - Normally convention is such that the price is >1.

Spot Market Dynamics



Spot Market Dynamics

- Spot is diffusive
  - Occasional small jumps around economic releases etc
  - But ~0.5% or less, once every month or two
  - Markets are never closed: global trading
- Realized volatility is normally in the 5-15% range
  - Occasionally runs higher eg during the credit crisis
- Some evidence for mean reversion in FX prices
  - Half life around 1 year
  - Quite weak
  - And regardless doesn’t affect derivatives pricing

Currency Crosses

- A “cross” is another term for a non-USD currency pair
  - eg EURJPY

- Can replicate a currency cross spot trade with trades in the underlying USD pairs
  - eg buy 10.0M EUR, sell 10.9M CHF for 2 days in the future
    - EURCHF spot price 1.0900
  - Replication: buy 10.0M EUR, sell 11.3M USD; buy 11.3M USD, sell 10.9M CHF
    - EURUSD spot price 1.1300, USDCHF spot price 0.9646
  - The “triangle” is the spot market for the three currency pairs that are linked by this arbitrage

Currency Crosses

- Tricky part: sometimes market-convention spot date is different for the three currency pairs in the triangle
  - Sometimes due to “spot days” convention differences
  - Mostly due to holiday differences

- Spot date convention for crosses (assumes 2 business days)
  - Move ahead one day, avoiding currency settlement holidays in each of the two non-USD currencies
  - Move ahead one more day, avoid currency settlement holidays in each of the two non-USD currencies **and** avoiding USD currency settlement holidays

Currency Crosses

- Triangle arbitrage still holds when spot dates are different; it's just that some of the trades are not exactly spot trades
  - They are forward trades to settlement dates that are not spot
  - When calculating the cross spot rate, need to make sure the USD forward rates are to the spot date of the currency cross

$$F = Se^{(R-Q)T}$$

  - F = forward FX rate to time T
  - R = denominated currency interest rate
  - Q = asset currency interest rate
  - T = time to settlement (measured from spot date, T=0)

Currency Crosses

- Currency cross spots often trade in their own markets, separate from the USD-pair markets but linked through the triangle arbitrage
  - Sometimes a cross is more liquid than a USD pair
    - EURCHF is more liquid than USDCHF in London hours
  - Generally executing the triangle arbitrage results in effective bid/ask spreads that are larger than the cross-specific market

- When making markets on currency crosses, traders need to look at the cross market but also at the triangle arbitrage to determine the best market to hedge their risk in

Voice Trading

- Traditional OTC market structure:
  - Clients: humans who are not dealers who want to trade FX
    - Corporates, hedge funds, pension and sovereign wealth funds (“real money”), smaller banks without global FX desks, retail channels
  - Salespeople: humans who talk to human clients on the phone (or over chat channels like Bloomberg) and take client requests for trades
  - Traders: humans who talk to human salespeople in response to a client trade request
    - Make markets to clients, based on where they can hedge, what their risk position is, and who the client is
    - Manage market risk that comes from taking the other side of client trades
- Inter-dealer market for traders to trade with each other

Voice Trading

- Traders are market makers, not execution traders
  - They execute at a pre-agreed price with a client and take the market risk on the other side of the trade
  - Not an execution model where they buy or sell at whatever price they can get and pass the executed trade to the client for a free
    - More common in equity markets
- Clients are market takers
  - Can leave orders but those are seen only by the dealer holding the order, not the broader market
- Dealers have a privileged position in the market
  - Typical for OTC markets

Voice Trading Example

- Hedge fund ABC wants to buy 10M EUR vs USD in spot
- ABC trader calls Dealer A
  - Talks on the phone to salesperson, and asks him for A's 2-way market on 10M EUR
  - Salesperson stands up and yells at the EURUSD trader and asks for the 2-way market on 10M EUR for hedge fund ABC
  - Trader looks at the inter-dealer market; looks at her current risk position; and considers historical trading behavior of ABC to make her price, and yells the bid & ask prices back to the salesperson
  - Salesperson quotes the bid & ask back to the ABC trader
- ABC trader calls Dealers B and C and checks the pricing and deals on the lowest offer price across the dealers

Voice Market Making

- What goes into the trader's decision to quote a particular bid & offer price in response to a client request?

- Inter-dealer market
  - Market where a dealer can hedge (if desired)
    - Dealing here is by voice as well, via brokers or "direct"
- Current risk position
  - Already long, bias down prices; already short, bias up
- Market views
  - Dealer wants to take risk one way or the other?
- Client behavior
  - Does the client typically buy vs sell? Is the client typically right about market direction?

Electronic Trading

- Over the last 15y, trading has massively moved to electronic channels
  - 65% by volume, >95% by ticket
- Single-dealer platforms: electronify voice dealing
  - Client requests a price through an app, can click to deal
  - Still a price from just one dealer
- Multi-dealer platforms: electronic auctions
  - Client requests a price from multiple dealers simultaneously through an app, who know who the client is when they quote
  - Client sees prices from many dealers at once, by name, and can click to deal with whomever they like

Electronic Trading

- Inter-dealer trading has also moved electronic
- ECNs (Electronic Communication Networks) are the machines they use to trade
  - EBS (Electronic Broker System) was the first and still one the most popular
  - But now dozens of ECNs available for trading
  - Many of them are open to non-dealers as well
  - Look very much like exchanges, but with no clearing

Electronic Price Making

- Computers at dealers now make prices automatically to clients via single dealer and multi-dealer platforms

- Price-making algorithms can get very complex and evolve over time but the main components are the same as for voice trading:
  - Inter-dealer market: aggregated across ECNs
  - Current risk position
  - Market views: manually specified or algorithmic
  - Client behavior: historical profitability of trades against the client over various interesting time intervals

Price Aggregation

- ECNs show resting bids and offers which define the inter-dealer marketplace
  - Level 1 data: best bid & best offer, maybe with sizes
  - Level 2 data: whole order book (bid & offer levels + sizes)
  - Level 3 data: individual order messages sent to ECN
  - Different ECNs expose different kinds of data to dealers
- Dealers have electronic connections to ECNs and stream in the market data
- Then aggregate the data to come up with an aggregated cross-market order book

Price Aggregation

- Example of order books from three ECNs at any particular moment (EURUSD):

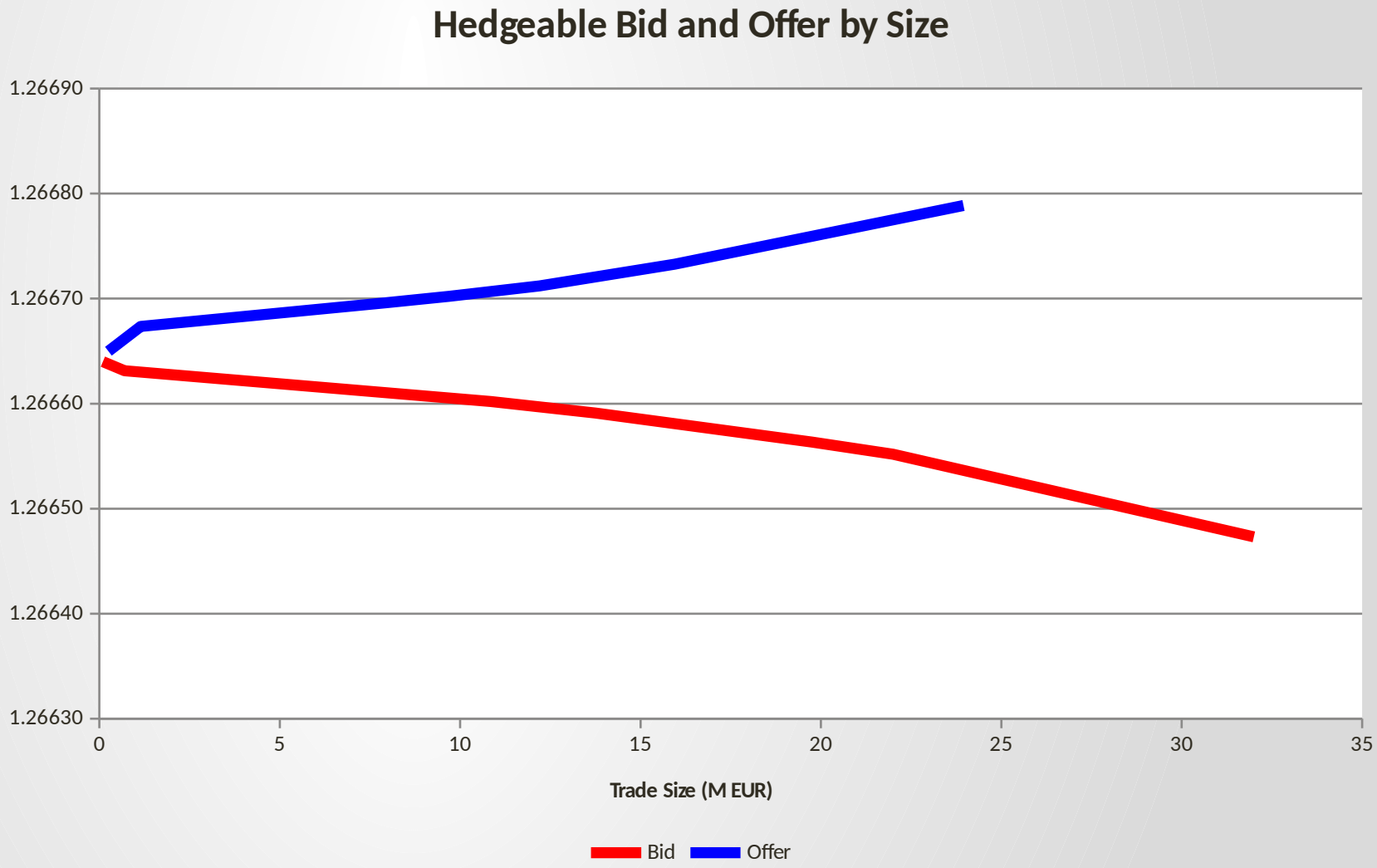
EBS			HotSpot			Lava	
Level	Size (M EUR)		Level	Size (M EUR)		Level	Size (M EUR)
1.26690	8.00		1.26673	1.50		1.26680	2.50
1.26680	1.25		1.26670	0.30		1.26673	0.25
1.26675	2.50		1.26668	0.75		1.26670	1.75
1.26670	4.75		1.26665	0.25		1.26668	0.15
1.26660	7.50		1.26663	0.15		1.26664	0.10
1.26650	6.00		1.26660	0.85		1.26663	0.45
1.26645	2.25		1.26655	2.50		1.26660	1.80
1.26630	10.00		1.26653	0.85		1.26655	0.40

Price Aggregation

- Aggregated book:

Aggregated		
Level	**Size (M EUR)**	**ECNs**
1.26690	8.00	EBS
1.26680	3.75	EBS & Lava
1.26675	2.50	EBS
1.26673	1.75	HotSpot & Lava
1.26670	6.80	EBS & HotSpot & Lava
1.26668	0.90	HotSpot & Lava
1.26665	0.25	HotSpot
1.26664	0.10	Lava
1.26663	0.60	HotSpot & Lava
1.26660	10.15	EBS & HotSpot & Lava
1.26655	2.90	HotSpot & Lava
1.26650	6.00	EBS
1.26645	2.25	EBS
1.26630	10.00	EBS

Price Aggregation



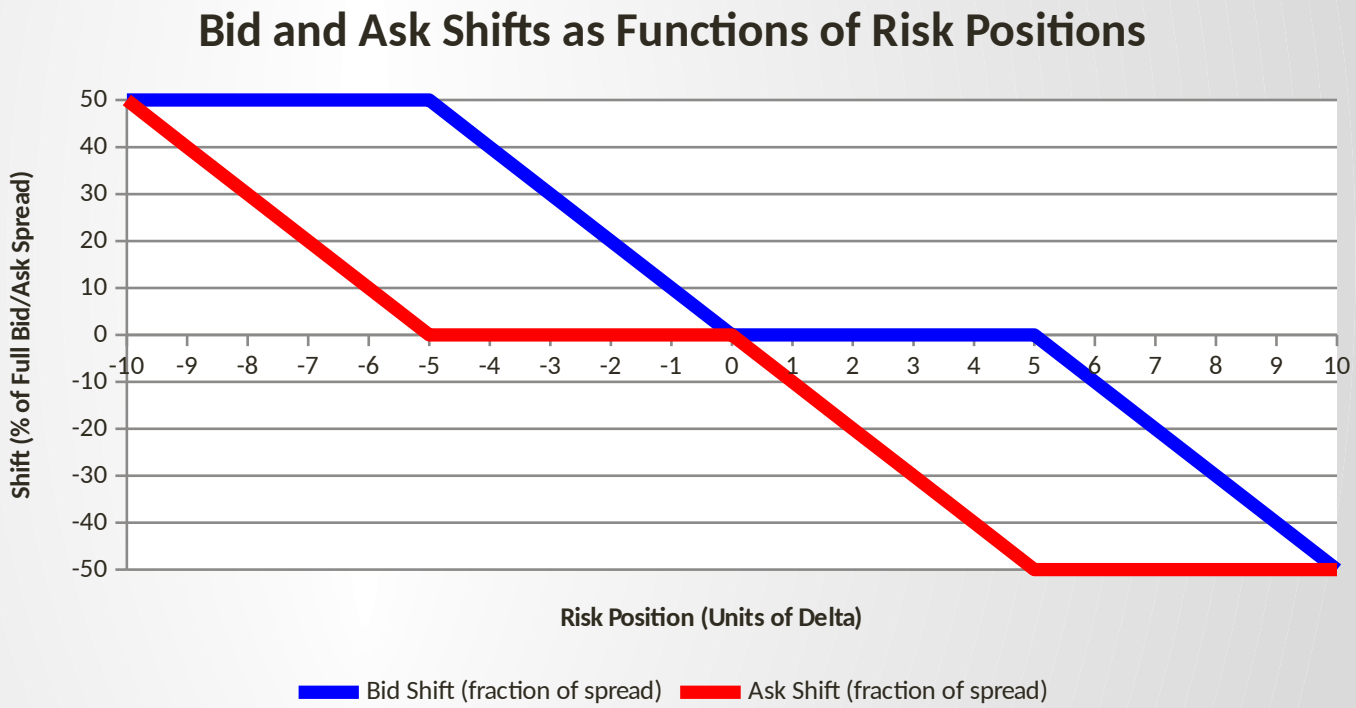
Risk Position

How do you know how much to “skew” your bid and/or offer when you have a net risk position?

- Real answer depends on market microstructure
  - Moving bid up increases the probability you’ll buy
  - Moving offer down increases the probability you’ll sell
  - How much those probabilities change depend on complex details
- Usually dealers do not bother with microstructure models
  - Ad hoc algorithm for moving bid and/or offer as a function of net risk position

Risk Position

- Here is one approach that some dealers take:



- End up tightening the client bid/ask spread for intermediate risk positions, widening back out for large risk positions

Market Views

- The time scale of a view on the market is approximately the average risk holding time
  - Order one minute or less, usually
- Economics and fundamentals don't matter on those time scales, just technical signals
  - Momentum signals
  - Mean reversion signals
  - Directional signals based on order book structure and other types of market microstructure analysis
  - Directional signals based on informational advantage due to seeing trades of big clients before the rest of the market

Client Behavior

- Two types of client behavior matter
- Ability to predict (short-term) direction of the market
  - Not always because the client is good – sometimes just because they are big and move the market
  - Sometimes due to latency arbitrage
- Price sensitivity
  - Some clients deal with many dealers and are always putting prices in competition on every trade
  - Others trade with only a small number of dealers and try to spread out their trades between dealers

Electronic Hedging

Typical evolution of market making:

1. Voice trading market
2. Clients can click to trade, but humans set prices and manage portfolio risk
3. Price-making is automated, but humans manage portfolio risk
4. Hedging is automated as well; humans monitor the machine but do not get involved in individual trades

Electronic Hedging

- Two extremes of risk management:
  - Don’t hedge at all
    - Take market risk
    - Get paid bid/ask spread on each client trade
    - Client trades hopefully net against each other so get paid the spread to close out risk
  - Hedge every trade
    - No material market risk
    - Get paid bid/ask spread on each client trade
    - Pay inter-dealer bid/ask spread to hedge each client trade

- Inter-dealer bid/ask spread is often **wider** than the bid/ask spread shown to clients to be competitive

Electronic Hedging

- Typical approach taken by modern dealers: break up positions into two buckets
- Bucket 1: trades against clients who are generally right on the direction of market moves
  - Hedge their trades aggressively
- Bucket 2: trades against everyone else
  - Do not hedge each trade, and hope for netting
  - Monitor net risk position and hedge when a risk limit is exceeded

Electronic Hedging

What does “right on the direction of market moves” mean?

- Time scale is determined by average risk holding period
  - In turn determined by average time between client trades
  - Typically order seconds
- Clients who hold risk positions over much longer periods (eg global macro traders) are not relevant here
- Clients who are right on short timescales are relevant
  - High frequency traders, or big names whose trades move the market

Electronic Hedging

What risk limits do hedging engines monitor?

- Individual currency delta
  - “Delta” means “PNL for a unit move in a currency spot rate”
  - No model involved: just net amount of currency long or short
  - Risk limits set by currency by human risk managers
- Value-at-risk
  - **Model-based** estimate of PNL standard deviation over some representative period (eg 1 day)
  - Allows for approximate hedging between positions on highly correlated assets
    - eg EUR and CHF vs USD

Electronic Hedging

What is the right delta limit to use? (Single currency case)

- Use a model to simulate trading and optimize over a Monte Carlo simulation (or closed form solution)
  - Simple, easy to implement and understand, but often overly simplistic
- Backtest hedging simulations against historical data and optimize over backtested PNL
  - Very useful, but risk over-fitting on historical data, and real trading can change market conditions
- Run production experiments with real trading and optimize over realized PNL
  - Most accurate, but lots of statistical noise and paying real money, and limited by the actual market conditions

Electronic Hedging

Toy simulation approach

- Brownian motion process for spot
  - Constant volatility, zero drift
  - Simple model but drift, lognormal behavior etc doesn't impact dynamics over intraday trading
- Poisson process for realized client trades
  - Constant frequency of a trade happening
  - Even odds of it being long or short when it happens
  - Every trade is of unit size
- Break time up into fixed-length interval
  - Any trades happen at the start of the interval
  - Use a short enough interval that odds of > 1 trade happening are very small

Electronic Hedging

Toy simulation approach (cont'd)

- When a client trade happens, you make a PNL equal to half the bid/ask spread typically shown to a client
  - Assume that client-facing bid/ask spread is constant
- When the hedging engine trades against the inter-dealer market to hedge its risk, it pays the inter-dealer bid/ask spread
  - Assume that the inter-dealer bid/ask spread is constant (and typically higher than the client-facing bid/ask spread)
  - When a hedge happens, hedge the position back to zero

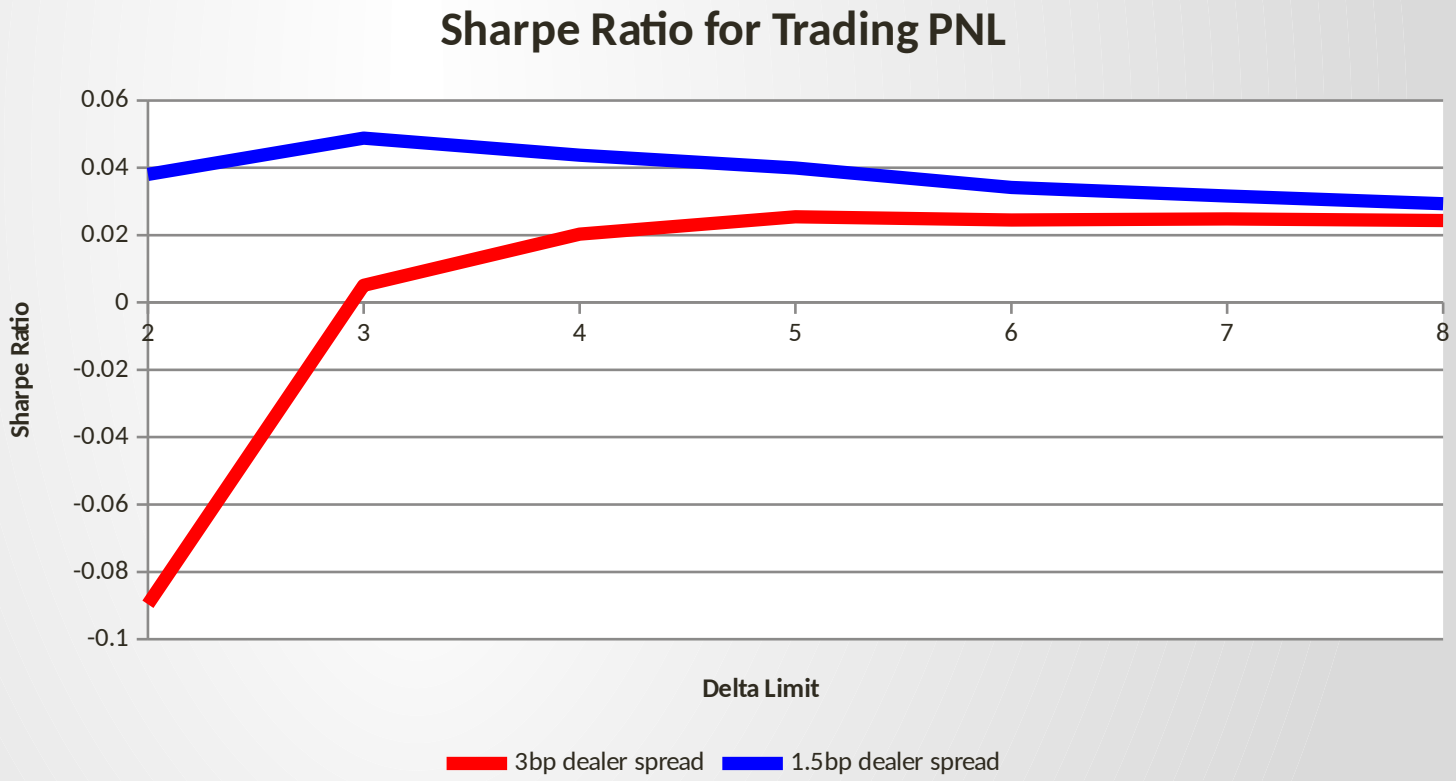
Electronic Hedging

Toy simulation algorithm:

1. At start of time step, generate a uniform random number in (0,1) and check if it's less than the trade probability. If so, randomly generate the sign of the trade and update the position by +/- one unit. Get paid half the client bid/ask.
2. Check whether net position is outside the delta limit (+ or -). If so, pay half the dealer bid/ask on the whole position to hedge to zero.
3. Advance the spot by one step in the simulation. PNL = position at start of time step * change in spot over time step
4. Go back to 1, keep looping until the end of the simulation happens.
5. Re-do the whole thing for a bunch of different simulation runs.
6. Look at PNL distribution across the runs.

Electronic Hedging

- Can use the simulation to estimate optimal delta limit
  - eg based on Sharpe ratio of PNL mean:standard deviation



Electronic Hedging

- Target risk position may be non-zero if a relative value metric suggests a net position
- In that case, the engine tries to “hedge” to the target risk position instead of a flat position
  - Everything else is the same, though
- When analyzing hedger performance, need to split out PNL due to (static) target position from PNL due to hedger
  - Allows you to determine whether your relative value metrics are performing
  - Allows you to determine whether your hedging algorithm is effectively hedging