COMPUTATIONAL FINANCE & RISK MANAGEMENT

UNIVERSITY *of* WASHINGTON

Department of Applied Mathematics

Recap and Further Discussion: Algorithmic Trading Market Microstructure Market Impact

CFRM 522 (004c)

Introduction to Trading Systems

References

- This set of slides will provide more details on topics we have already discussed
- The primary reference is Kissell:
  - Ch 1 (Algorithmic Trading): pp 1-23, pp 37-45 (will be covered later)
  - Ch 2 (Market Microstructure): pp 47-61, pp 76-85 (Flash Crash)
  - Ch 4 (Market Impact Models): pp 129-39
  - ***This is a reading assignment***
- Remark: Ch 3 covers trading costs; this is a very important topic for trading strategies, but we will refer to Narang's Ch 5 for this (also ***part of the reading assignment***)
- Narang's discussion is more of an overview, which will serve our purposes; a more detailed look at transaction costs will likely be covered in CFRM 523.
- Barry Johnson, Algorithmic Trading and DMA: An introduction to direct access trading strategies, pp 119-130: Impact-Driven (Order) Algorithms (pdf provided – not available in UW library)
- Interactive Brokers video on VWAP: https://www.interactivebrokers.com/en/?f=16230

Algorithmic Trading (Kissell Ch 1)

- Kissell uses the term "Algorithmic Trading", rather than "HFT" (Aldridge)
- Classifications of Algorithms (p 16~)
  - Aggressive:
    - "get me done"
    - market order, or marketable limit order
    - capture as much liquidity as possible at a specified price or better, sweep
  - Working Order:
    - Balance trade-off between cost and risk
    - Balance between appropriate usage of limit and market orders
  - **Single Stock (or Asset) Algorithms:**
    - **Take advantage of favorable market conditions only when in best interest of order or investor**
    - **Independent of each other (eg, correlations not considered)**
  - Basket Algorithms (aka Portfolio Algorithms): Do take into consideration correlations between assets, risk, and optimization
  - **Black Box Algorithms:**
    - **Make investment decisions based on market signals**
    - **Execute decisions in the marketplace**
  - Others: VWAP, TWAP, Volume, Arrival Price, Implementation Shortfall, Passive (Dark Pools to avoid leaving market footprint) – stay tuned

- Trading Venue Classification
  - Displayed Market
    - Discloses order book information
    - Bid/offer prices, share quantities, depth of book
    - Examples: NYSE, NASDAQ, CME
  - Dark Pool
    - A crossing network or other type of matching system
    - Does not display or disseminate order information
    - Order is only executed if there is a match

Algorithmic Trading

- Types of Orders
  - Market Order
    - Buy or sell at the best available price
    - Likely to be executed (quickly)
    - Possible to be executed well away from bid/offer at time order placed
    - Takes away liquidity
  - Limit Order
    - Specifies that the algorithm buy or sell at the specified limit price or better
    - Usually entered into the order book of the exchange or venue
    - Not guaranteed to execute, but ensures execution will not be at price worse than the pre-specified price
    - Adds liquidity to the market (important!)
  - Marketable Limit Order
    - Also specifies that the algorithm buy or sell at the specified limit price or better, but placed above current bid for buy, or below current offer for sale
    - Will either be executed at the specified price or better, or canceled
  - Rebates
    - Investors may receive a rebate for adding liquidity to the exchange (limit order)
    - However, some exchanges may offer rebates for taking away liquidity (market order)
  - Stop-Loss Orders (not in Kissell Ch 1) : In Guy Yollin's notes (004b); will return later

Market Microstructure (Kissell Ch 2)

- Market Microstructure:
  - The study of financial markets and how they operate
  - Understand not only the price discovery process and *market liquidity*
  - But also how prices change with the arrival of new information and competing orders (ties in with *market impact*)
  - As well as market inefficiencies that are not present in more traditional modeling

Market Microstructure

- Equity Exchanges:
  - Four exchange groups operating ten exchanges
  - Three independent venues
  - Dark pools (trades reported by FINRA TRF - Financial Industry Regulatory Authority)

Table 2.6 Trading Venue Pricing Rules

Parent	Name	Short	Pricing Rules			Priority Trading Rules	
			Maker-Taker	Taker-Maker	Per Share	Price-Time	Price-Size
NYSE EuroNext	New York Stock Exchange	NYSE	√			√	
	American Stock Exchange	AMEX	√			√	
	Archipelago	ARCA	√			√	
NASDAQ OMX	NASDAQ	NASDAQ	√			√	
	NASDAQ/Philly	PSX	√				√
	NASDAQ/Boston	BX		√		√	
Bats	Bats X	BZX	√			√	
	Bats Y	BYX		√		√	
DirectEdge	Direct Edge A	EDGA	√			√	
	Direct Edge X	EDGX	√			√	
Regionals	National Stock Exchange	NSX	√			√	
	Chicago Board Options Exchange	CBSX			√	√	
	Chicago Exchange	CHX	√			√	
Finra	Finra TRF	TRF			√	√	

Source: NYSE, as of 1Q-2012.

Market Microstructure

- Transaction costs and price determination (previously discussed)
- From pp 61-76, author presents section on Empirical Evidence
  - Results of author's research
  - Interesting results, but not required reading

- Flash Crash (pp 76-85 – read this)
  - 6 May 2010
  - Debt crisis in Greece
  - SEC report, Sep 2010
  - Many theories and hypothesis, but lacked statistical evidence
  - Author provides his own take, concluding with "market crashes happen"
  - Empirical Evidence (author's research results): pp 79-83 (you need not read this in detail
  - Wraps up with recommendations to regulators, and comparison with other crashes, pp 83-85

Market Impact Models (Kissell, Ch 4)

- Market impact is the change in price caused by a particular trade or order.
- It is one of the more costly transaction cost components and always causes adverse price movement.
- Market impact is often the main reason managers lag behind their peers.
- Market impact costs will occur for two reasons:
  - liquidity needs and urgency demands (temporary)
  - information content (permanent)

Market Impact Models

- Temporary impact:
  - Represents the liquidity and urgency cost component
  - The price…
    - …premium buyers have to provide the market to attract additional sellers
    - …discount sellers need to provide to attract additional buyers
  - This cost component can be effectively managed during implementation of an investment decision
- Permanent Impact:
  - Represents the information cost component
  - Whether real or perceived, causes market participants to adjust their prices to a new perceived fair value
    - As participants observe buy orders their perception is that the stock is undervalued and they will adjust their offer prices upwards, or
    - As participants observe sell orders their perception is that the stock is overvalued and they will adjust bid prices downward
    - An unavoidable trading cost
- See examples, pp 130-31 (to follow in the slides)

Market Impact Models

- Mathematically, we define market impact as the difference between the actual price trajectory after the order is released to the market and the price trajectory that would have occurred if the order were never released.
- Regrettably, we cannot observe both price trajectories simultaneously and it is not possible to construct a controlled experiment to measure both trajectories at the same time.
- There is no way to construct a controlled experiment that will observe both situations simultaneously (at least without the assistance of time travel).

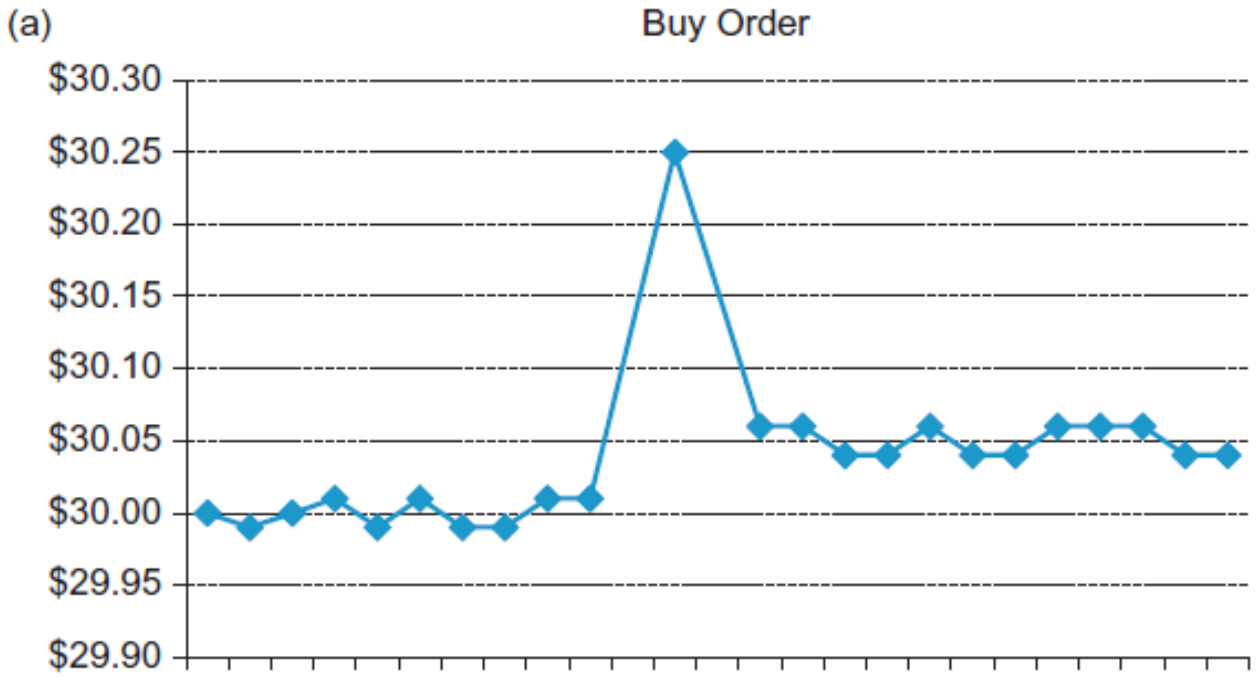
Star Trek: Tomorrow is Yesterday (1967)

https://en.wikipedia.org/wiki/Tomorrow_Is_Yesterday

- As a result, market impact is often referred to as the *Heisenberg uncertainty principle of finance*.

Market Impact Models

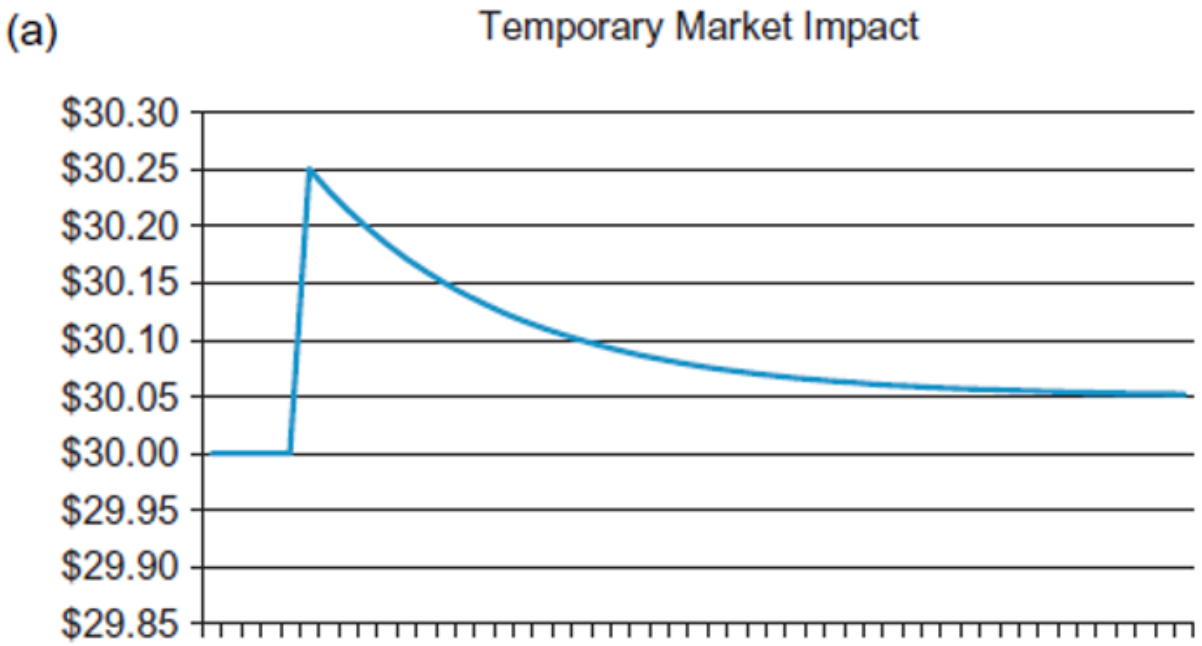
- Graphical Illustrations of Market Impact
  - Price trajectory (Kissel Illustration 1):
    - Buy order: Following a $30.00 opening trade, the stock fluctuates between $29.99 and $30.01. Note both temporary and permanent impact.
    - The price reverts to $30.05, and not the original price of $30.00. Market participants inferred this trade as information based, due likely to the stock being undervalued. Fig 4.1 (a), p 131:



  - Similar example for sell order, Fig 4.1 (b), p 131

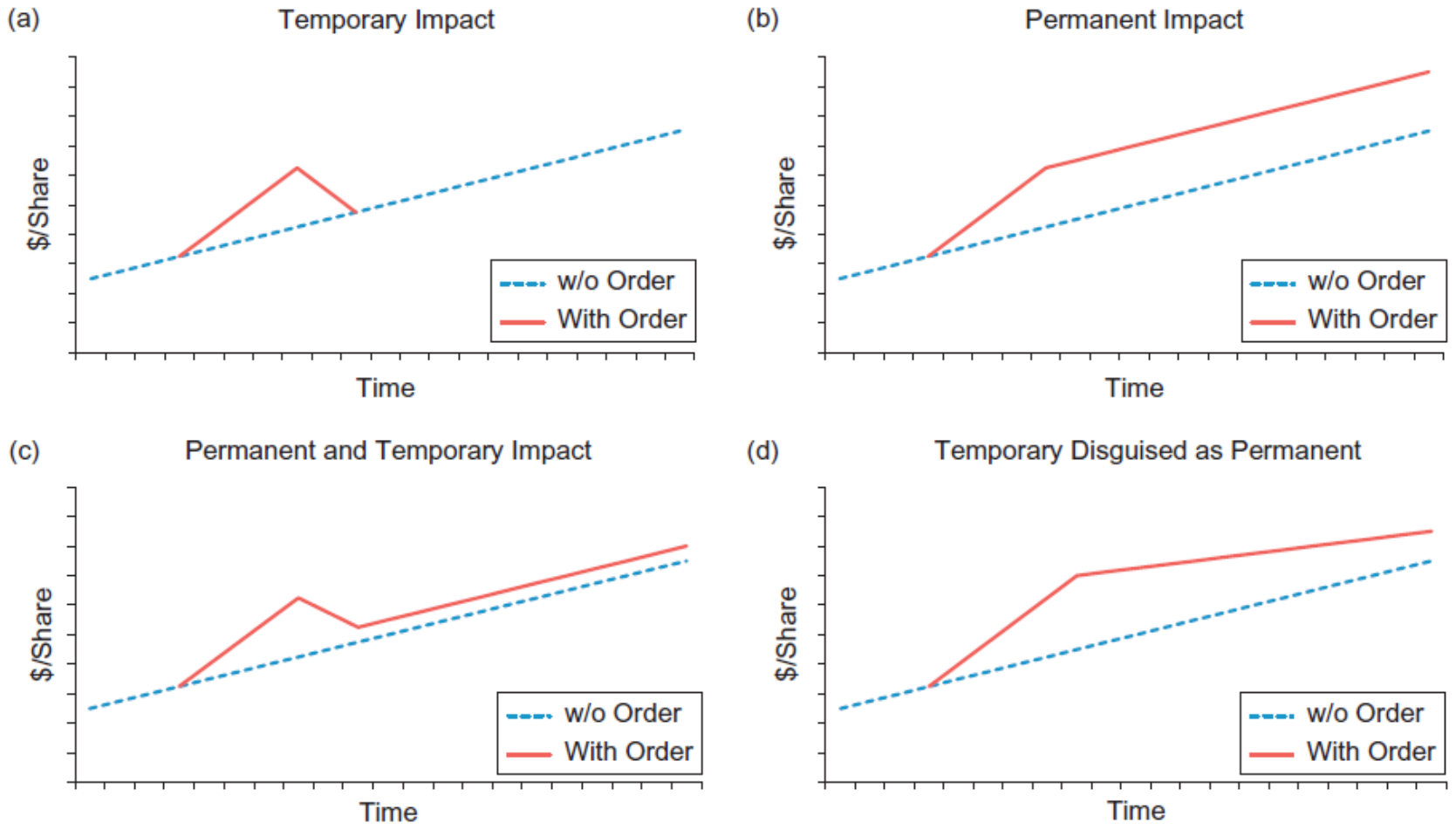
Market Impact Models

- Graphical Illustrations of Market Impact
  - Supply-Demand Equilibrium (Kissel Illustration 2 – read in book)
  - Temporary Impact Decay Function (Kissel Illustration 3)
    - We saw this example in the Aldridge text
    - Same buy example as in Illustration 1, but the price does not revert in a single jump but rather over time
    - Decay functions can be estimated, as discussed in Kissell (Ch 4, pp 137-38, subject of research by the author and others)
    - Arguably, there could be permanent market impact present here as well:



Market Impact Models

- Graphical Illustrations of Market Impact
  - Various Market Impact Price Trajectories (Kissel Illustration 4)
    - See Fig 4.4, p 139
    - Remember the Heisenberg Uncertainty Principle of Finance here



Market Impact Models

- Remainder of Ch 4 covers
  - Developing a Market Impact Model
  - Derivation of Market Impact Models
  - The I-Star Market Impact Model
  - Market Impact Model Formulation
  - Parameter Estimation Techniques
- More work with the math and statistics – but unfortunately is beyond the scope of this course (could probably devote half an academic quarter to this topic alone)
- Certainly an area that is researched in academia and incorporated into modeling in practice
- Also covered in more detail in CFRM 523

Trading Costs (Narang, Ch 5)

- Types of Transaction Costs
  - Commissions and Fees
  - Slippage
  - Market Impact

Commissions and Fees

- Paid to brokerages, exchanges, and regulators for the services they provide:
  - Access to other market participants,
  - Improved security of transacting, and
  - Operational infrastructure
- Typically small on a per-trade basis (direct market access)
- Broker's fees
  - Clearing:
    - regulatory reporting and monitoring
    - tax handling
    - handling failure
    - must take place in advance of settlement
  - Settlement:
    - delivery of securities in exchange for payment in full
    - the final step in the life of a trading transaction
    - fulfills the obligations of both parties involved in the transaction
- Commissions and fees are not negligible, but nor are they the dominant component of transaction costs

Slippage

- Change in the price between the time a trader (or quant system) decides to transact and the time when the order is actually at the exchange for execution
- Example: Strategy decides to sell at $100/share, but by time order goes through, market is at $99.90/share
- Can be positive, however; suppose share price goes up to $100.10
- Slippage, compared to commissions and fees, is considerably trickier to measure, model, and manage (same for market impact – next slide)
- Trend-following strategies (very popular) tend to suffer most from slippage ***because they are seeking to buy and sell instruments that are already moving in the desired direction***
- Slippage for mean-reverting strategies, however, can sometimes be positive ***because these strategies are usually trying to buy and sell instruments that are moving against them when the order is placed***
- Slippage can also be modeled as a function of volatility

Market Impact

- The third and final major component of transaction costs
- The difference between the price at the time a market order enters the exchange (caused by the order itself; note difference with slippage) and the price at which the trade is actually executed
- Perhaps the most important trading cost for quants
- We have seen examples previously
- If the trader sells, the price may go down as he attempts to complete his trade
  - At small order sizes, this price movement usually bounces between the current best bid and offer
  - However, for larger orders, the price move can be substantial, ranging in the extremes, even to several percentage points

Trading Order Algorithms (Johnson, Ch 5)

- In the previous section, we saw how orders, especially large ones, can affect trading costs due to causing market impact going against the trader
- Large trades also are a source of information that can be used by other traders (example: insurance company hedging)
- We saw earlier that one solution is the use of dark pools
- Another is to use trading algorithms to split up large trades
- We will look at a few basic types, called impact-driven algorithms, as described in Johnson, Ch 5)
  - Time Weighted Average Price (TWAP)
  - Volume Weighted Average Price (VWAP)
  - Percent of Volume (POV)
- These, along with others, are available in TWS for placing orders

TWAP

- The TWAP benchmark is an average price reflecting how the asset's market price has changed over time
- Attempts to match this benchmark are often based on a uniform time-based schedule
- Unaffected by other factors such as market price or volume
- Example: Buy 10,000 shares of an equity
  - Case 1: Each child order is for 500 shares for every 15-minute period over five hours
  - Case 2: Double to 1000 shares for each child order in half this time

- Fig 5-1, Johnson:

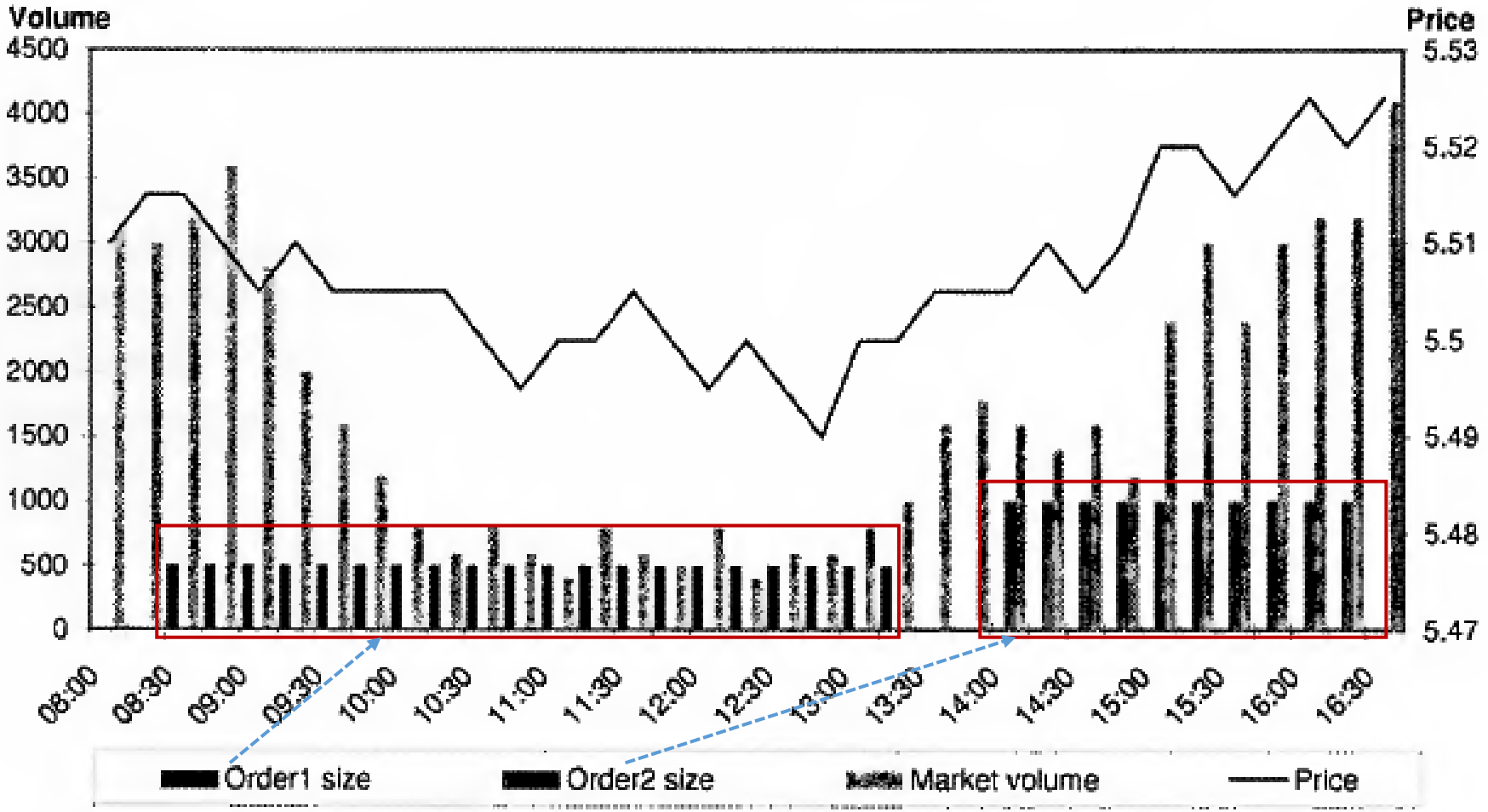


Figure 5-1 Two example TWAP orders

TWAP

- Trading in such a predictable way can lead to considerable signaling risk
- Other participants may game this order strategy
- Even if not, it can still suffer poor execution quality due to the rigid adherence to the time schedule (if prices become unfavorable or liquidity drops)
- One possible improvement is to randomize the order sizes
- Note that in some periods, no order is placed at all:

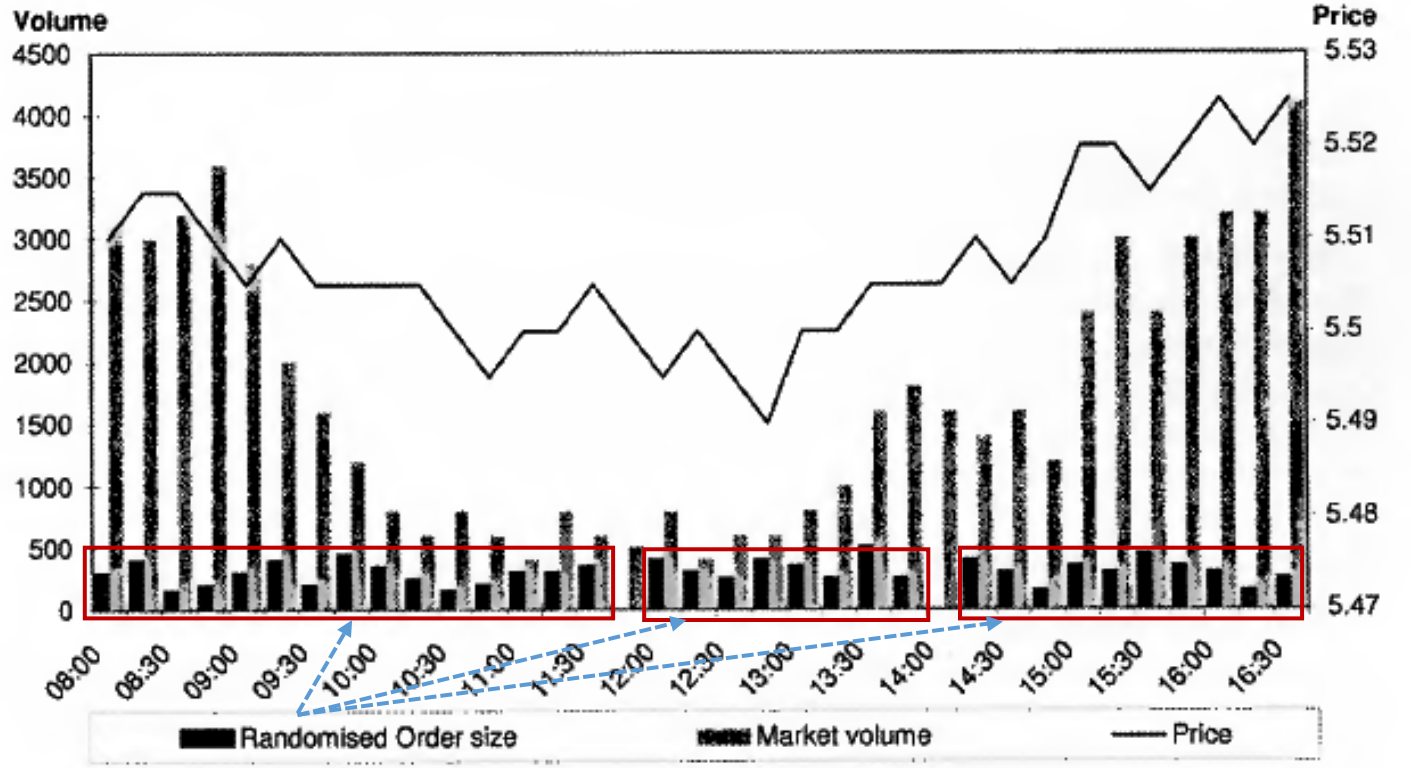


Figure 5-3 A more randomised TWAP order

TWAP

- On IB, used TWAP to buy 5000 shares of MSFT:

+/-	Time	Fin Instrument	Action	Quantity	Price	Exch. C...	Account	Commission
⊟	12:58:45	MSFT	BOT	5,000	119.16	ISLAND + 4	DI658056	13.88
	12:58:45	MSFT	BOT	100	119.18	ISLAND	DI658056	0.67
	12:57:18	MSFT	BOT	100	119.08	ISLAND	DI658056	0.16
	12:55:01	MSFT	BOT	100	119.08	ISLAND	DI658056	0.67
	12:53:57	MSFT	BOT	100	119.19	ISLAND	DI658056	0.67
	12:50:09	MSFT	BOT	100	119.30	ISLAND	DI658056	0.16
	12:43:05	MSFT	BOT	100	119.29	ISLAND	DI658056	0.16
	12:34:29	MSFT	BOT	100	119.31	ISLAND	DI658056	0.67
	12:28:31	MSFT	BOT	100	119.14	ARCA	DI658056	0.67
	12:19:05	MSFT	BOT	100	119.10	EDGEA	DI658056	0.13
	12:08:48	MSFT	BOT	100	119.08	ISLAND	DI658056	0.16
	11:58:08	MSFT	BOT	100	119.07	DRCTEDGE	DI658056	0.17
	11:47:14	MSFT	BOT	100	119.02	ISLAND	DI658056	0.16

VWAP

- Benchmark: Total traded value divided by the total volume
- Given n trades in a day, each with a specific price p_n we can express the daily VWAP as:

$$VWAP = \frac{\sum_n v_n p_n}{\sum_n v_n}$$

- Where v_n is the volume in period n
- Large trades will have more impact on the benchmark than small ones
- Place larger trades during high volume periods, and smaller trades during low volume periods
- This does require, however, prediction estimates based on historical volume profiles

VWAP

- Johnson Fig 5-6 shows a sample daily VWAP trading pattern
  - Dependent only on the historical volume profile
  - Not affected by the actual market volume or by price changes

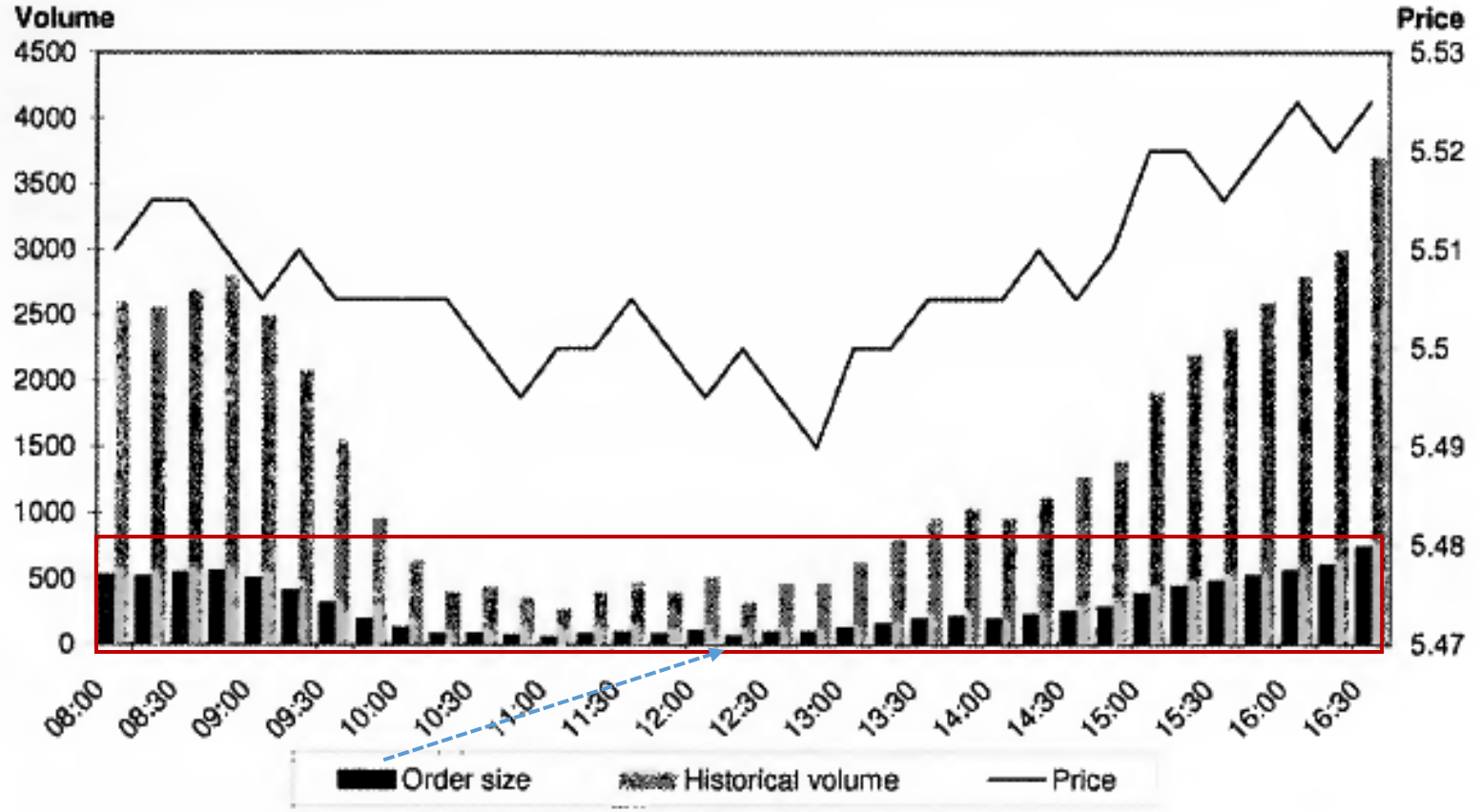


Figure 5-6 An example VWAP order

VWAP

- Modern VWAP algorithms often
  - incorporate complex logic to determine whether they may get ahead of their schedule, and
  - how best to catch up if they are behind their target

- Common variations are discussed on p 126 of Johnson

POV

- Unlike TWAP and VWAP, in which the trading schedule is typically predetermined, POV algorithm trading schedules are dynamically determined
- The target trade size is driven solely by the observed market volume (no relationship with market price)
- Example in Johnson (Fig 5-8), the order size is set to 20% of the trading volume at each 30-minute interval:

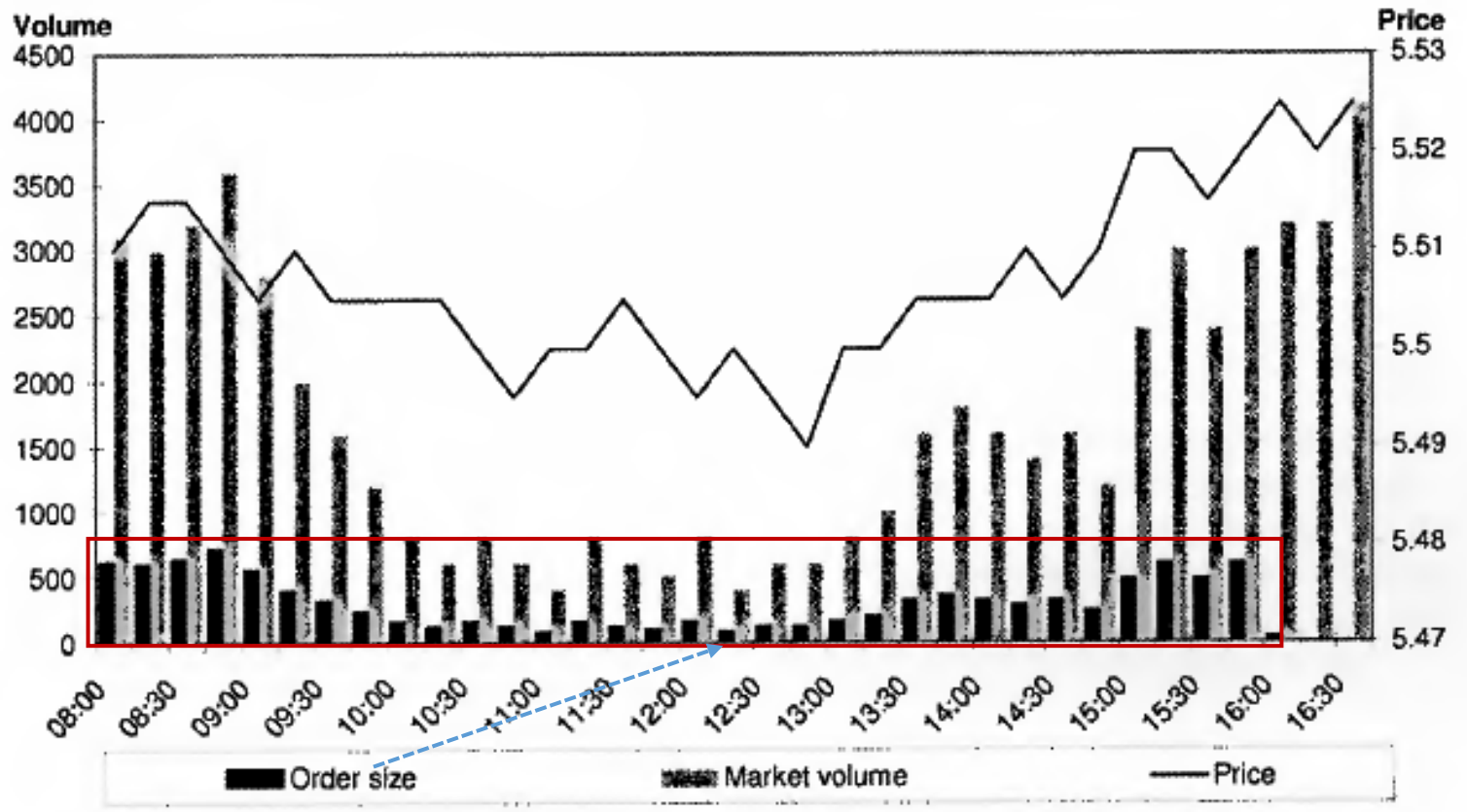


Figure 5-8 An example POV order

Summary

- We haven't gotten to actual trading strategies yet, but note the immense peripheral considerations necessary for quantitative trading we have covered so far:
  - Market Microstructure
  - Market Impact
  - Trading Costs (commissions, slippage, market impact)
  - Trading Order Algorithms
- In addition, any one of these topics is extremely rich in research activity
- One more point: Trading algorithms often contain instructions to avoid buying up liquidity so as to not incur penalties; this is just one example of interaction effects between these four aspects of trading
- One can set up any of the three order algorithms we discussed here in Interactive Brokers (among many others)

[END]