2017 Speaker Series for Quants: Equity Algorithmic Trading Overview

Vimal Patel
Vincent Mao

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RBC Capital Markets

What is Electronic/Algorithmic Trading?

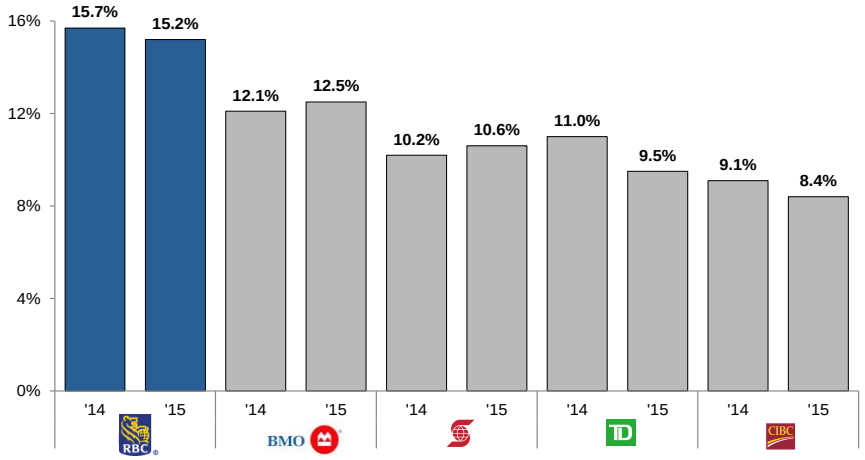
- Automated trading of financial securities electronically using an electronic trading platform
- Provides low touch execution services for buy side clients to access market
  - Execution Algorithms
  - Direct Market Access or Smart order router (SOR)
  - Transaction Cost Analysis and Execution Consulting
  - Market Structure and Regulatory landscape
- Allows sourcing of liquidity from multiple market places
- Significantly reduced human interaction and floor trading on exchanges

Advantages

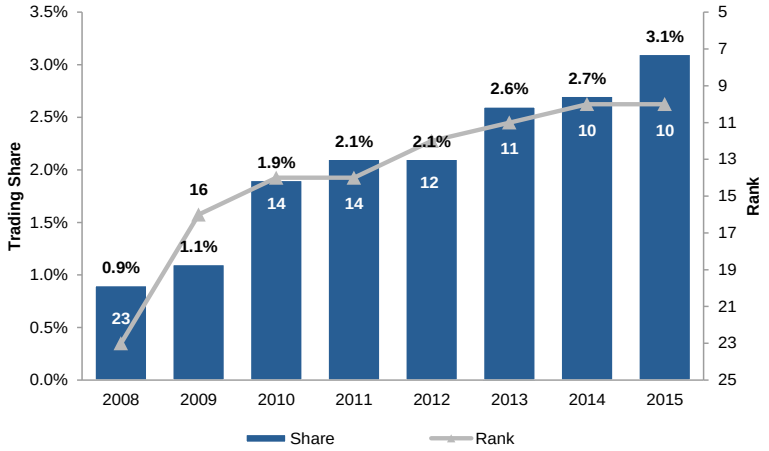
- **Lower Transaction Costs**
- **Greater Liquidity**
- **Greater competition**
- **Increased Transparency**
- **Reduced Spreads**
- **Increased speed**

Leading Equity Sales & Trading Franchise in North America

Equity Trading Market Share in Canada (1)



Improving Market Share in the U.S. (1)



#1

US Equity Electronic Trading Quality 2016 (2015)

GREENWICH ASSOCIATES

#1

Canadian Equity Trading Share 2016

GREENWICH ASSOCIATES

#1

Most Valuable Market Structure Related Services 2016 (2015)

GREENWICH ASSOCIATES

#1

Market Structure Team 2016

Institutional Investor

(1) Source: 2015 and 2016 Greenwich Associates Survey Results; an industry standard benchmarking survey that canvasses a broad cross-section of asset management firms. The buy side firms rank and rate their sell side counterparties in a comprehensive survey that covers all aspects of equities – from trading to sales and research

RBC is consistently ranked as a leading distributor of North American equities to institutional investors on a global basis

History

Electronic Trading has been around in some form since the early 2000's

- **Early 2000's**

  Program Trading
  Efficiently trade large baskets. Need to trade VWAP (avg price).

  Market Making
  Computers are faster at making decisions in a competitive landscape

  ETF trading
  Allows faster creation / redemption / hedging

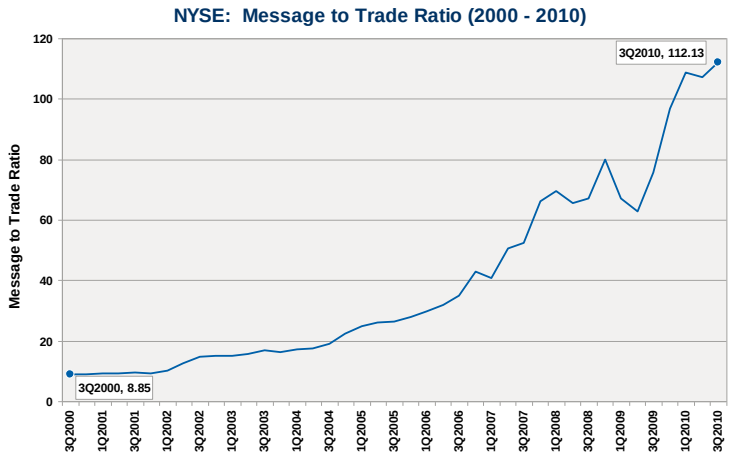
- **2007 - Regulation NMS & Dark Pools**

  Reg-NMS
  It aim is to foster "competition among individual markets and competition among individual orders" in order to promote efficient and fair price formation across securities markets.

  Dark Pools
  Market place to trade without showing the intended action, size or price.

- **2008 / 09 – Financial Crisis**

  Higher volatility, higher volumes, higher urgency to trade, short selling etc.



What Differentiates An Exchange?

Order Types / Order Handling Rules

- Exchanges are able to compete with one another through order types they offer or order handling rules
  - Emergence of HFT-focused order types:
    - **Direct Edge:** Hide Not Slide
    - **BATS:** Post Only @ Limit With Maximum Remove %
    - **NSX:** Order Delivery Firm

Technology

- Co-location
- Market Data:
  - **Direct Edge:** ID on reserves
  - **Nasdaq:** Cancel replace message
  - **NYSE:** RLP "liquidity identifier"

Rebates & Pricing

Add / Take Schedule

Tier 1 / Tape A Pricing

1 mil= $0.0001

Exchange	Post *	Take **
BATS-Y	**18**	**-15**
NASDAQ BX	**18**	**-17**
EDGA	**5**	**-2**
NSX	0	3
NYSE MKT	-16	28
EDGX	-20	29
BATS-Z	-20	30
CHX	-20	30
NYSE	-22	27.5
NASDAQ PSX	-31	28
NASDAQ	-30.5	30
NYSE ARCA	-31	30

as of 1/1/2016

Adjusting the Model

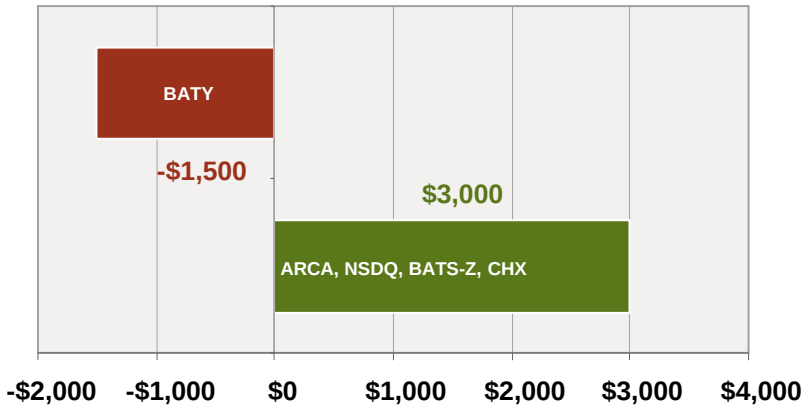
- 2011: 65 exchange pricing changes
- 2012: 97 changes year-to-date, primarily creating new "tiers" to incentivize routing
- 2013: 139 changes year-to-date, furthering volume pricing tier offerings
- ***There are >500 possible pricing scenarios across U.S. exchanges***

*** Post:** Cost for adding liquidity (in $0.0001)

**** Take**: Cost of removing liquidity (in in $0.0001)

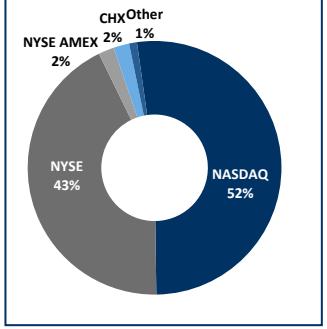
Negative number = a rebate

Comparing "Take" Economics at Least vs. Most Expensive Exchanges

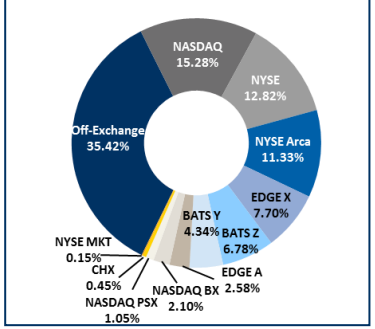


Exchange Evolution

1997 Market Share, by Exchange



2016 Market Share, by Exchange



** ***Off-exchange*** *trading includes all trades executed away from a stock exchange. This includes dark pools, internalized trades, block desk trades and all other ATSs (alternative trading systems).*

A Change In The Trading Landscape

Non-Profit to For-Profit – Exchanges moved to a for-profit model in early 2006. To generate earnings in an environment of declining volumes, exchanges have focused on new sources of revenue – such as co-location and various market data and technology products.

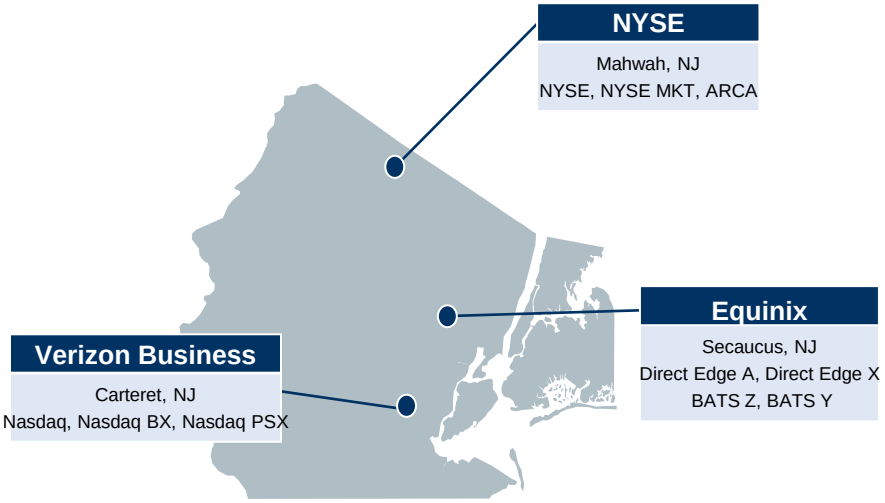
1997 Landscape

- 2 exchanges represented 95% of traded volume
- Advantages existed for NYSE specialists

2016 Landscape

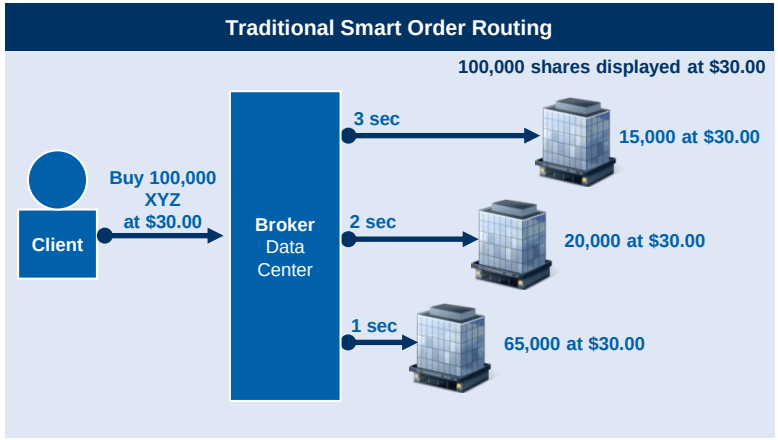
- 12 Exchanges represent 65% of traded volume
- All of the exchanges are located in 3 data centers in northern New Jersey
- Approximately 35% of all stock trading volume is executed off-exchange
  - Dark pools represent approximately 15% of overall traded volume
- Exchange technology has become a competitive differentiator

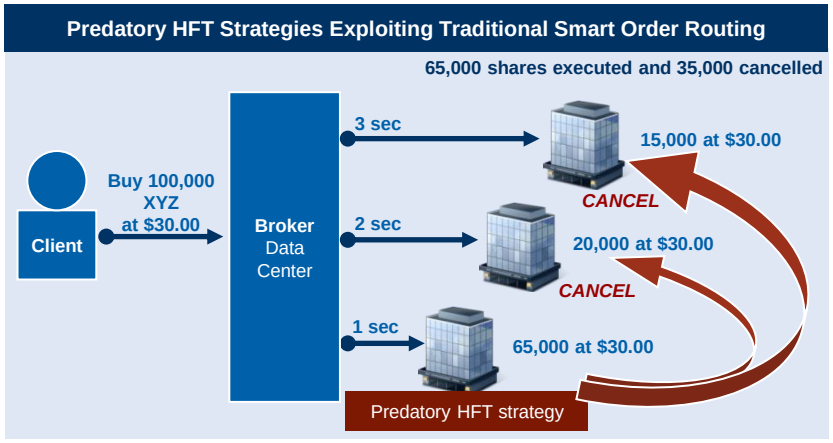
Exchange Data Centers



The U.S. equity marketplace has experienced significant fragmentation throughout the past decade, evolving from an effective duopoly to a myriad of Reg NMS protected venues.

The Notion of Disappearing Liquidity





WHAT:

- A traditional smart order router will slice large orders into smaller pieces and route them to the exchanges displaying the best price.
- Physical distance, computing power and network latency vary between brokers and exchanges, preventing orders from arriving simultaneously.
- Predatory high-frequency trading algorithms, utilizing advanced computing platforms, leverage their speed advantage to exploit execution signals. These algorithms recognize trading patterns, then take advantage of the lag time between orders reaching multiple exchanges. This is accomplished by canceling their unexecuted orders on other exchanges. This is called “latency arbitrage.”

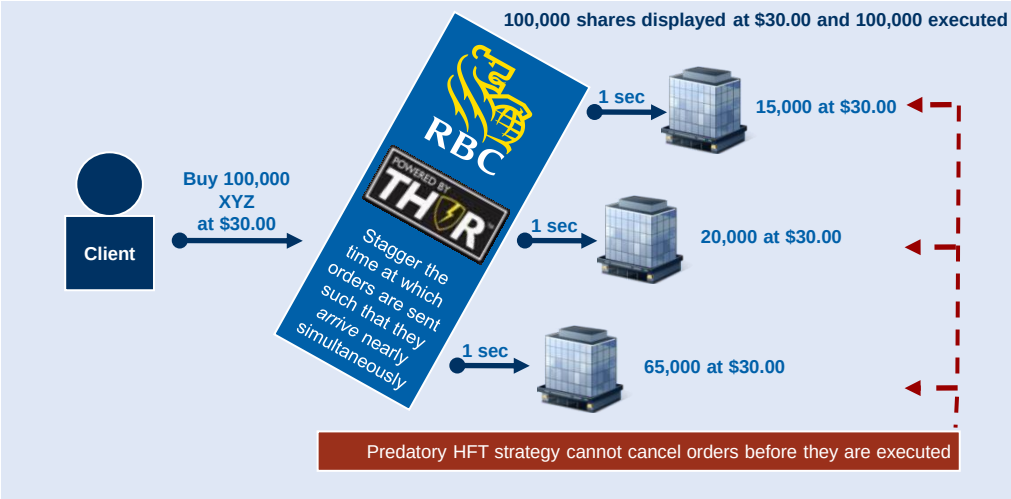
RESULT:

- This results in information leakage and disappearing liquidity as displayed quotes at a single price point are no longer available.

IMPACT:

- As liquidity disappears at a single price point, it will lead to lower fill rates and executions. This may lead to inferior execution prices (buying at a higher price or selling at a lower price over the course of trading a large order) causing a decline in trading profitability, otherwise known as slippage.

THOR



THOR Technology

- Tactical Hybrid Order Router ("THOR") addresses latency arbitrage by **synchronizing the individual slices of an order to arrive at all the exchanges nearly simultaneously**. This inhibits predatory HFT participants from canceling their orders, resulting in superior execution performance for our clients.

- Effectively, THOR works by minimizing the time differential between the first order arriving at the first exchange and the last order arriving at the last exchange. **As a result, there is not enough time for predatory high frequency participants to get ahead of an order being routed to multiple exchanges.**

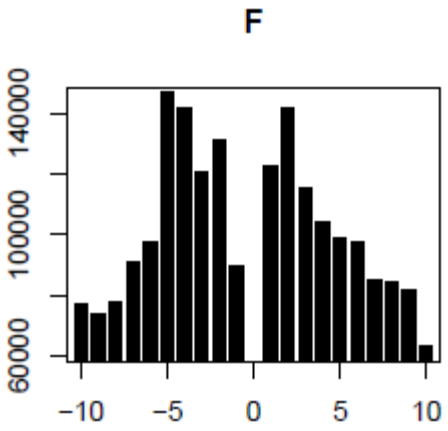
- THOR will **first route to the exchange with the highest latency, followed by the second highest, and so on**, all with the intent of the slices within the wave arriving at their destinations at the same time. This is all accomplished in a fraction of a second, thereby reducing information leakage and minimizing latency arbitrage opportunities.

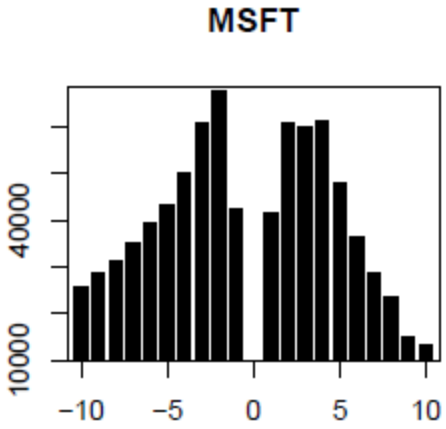
Components of Algorithmic Trading

- Parent Level Strategy: Scheduled or Opportunistic.
- How to Balance Market Impact and Timing Risk ?
- How to place a limit order ?
- Anti-Gaming measures
- Post Trade TCA (Transaction Cost Analysis)

Market Microstructure --- The Order Book

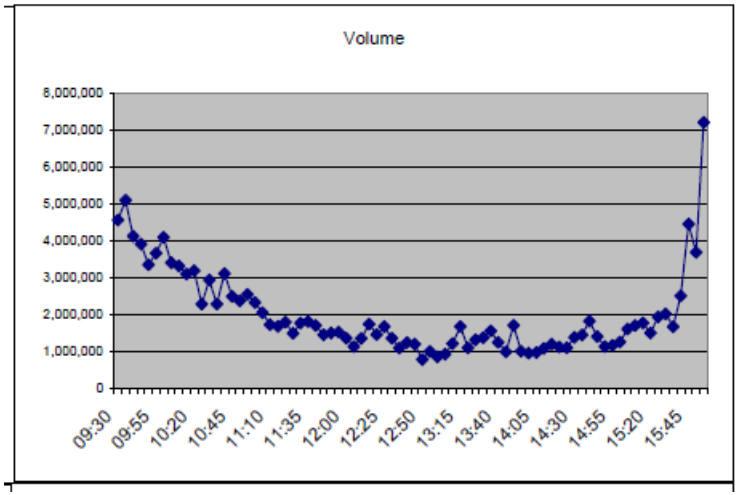
- Each symbol has a limit order book, Price-Time Priority, FIFO.
- Iceberg Orders: Only displayed quantities have priority. Non Displayed quantities are replenished to the back of the queue.
- Examples of Level II exchange order book:

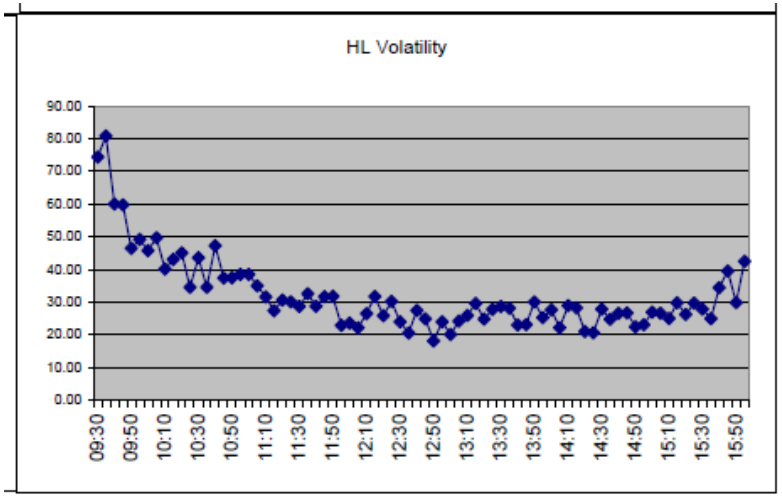




Market Microstructure

- Intraday seasonality exists. Volume shape resembles a smile, while volatility shape looks like a smirk.
- Volume spikes at 10AM (volatility reduces), 2PM, 3PM (human behavior), 3:50PM (Imbalance Feeds)
- Volatility reaches lowest level around 1PM and remains low.



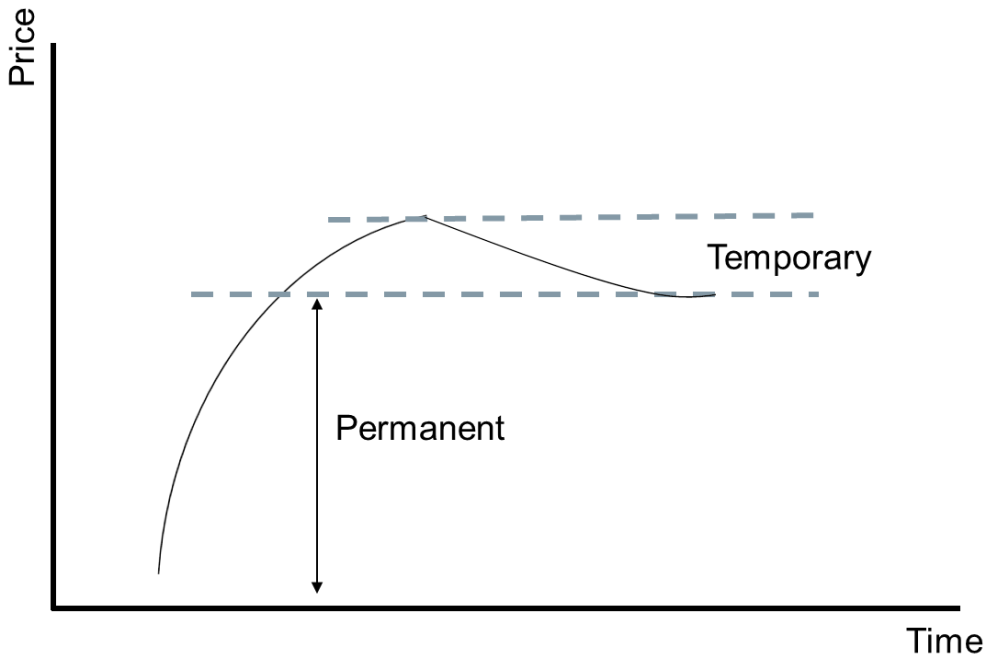


Research Topics -- Market Impact

- Market Impact:

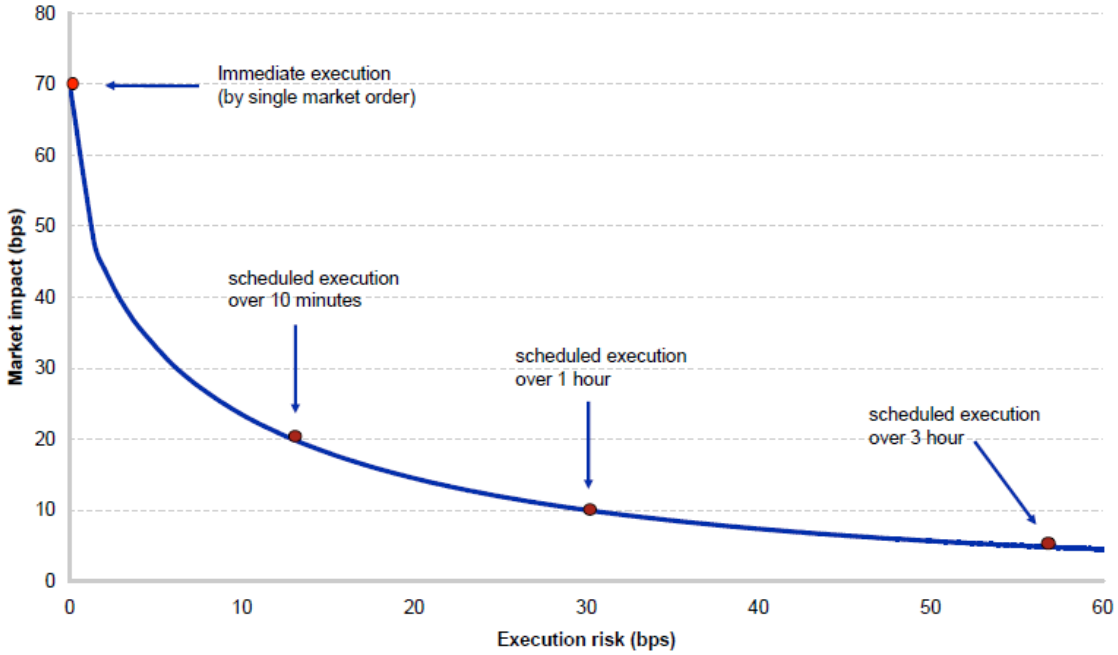
$$MIC = \beta * f(\%ADV) + \gamma * g(Participation) + \alpha * spread$$

- Total Impact = Permanent Impact + Temporary Impact + Spread Cost
- Research: *Almgren & Chriss, Optimal Execution of Portfolio Transactions*

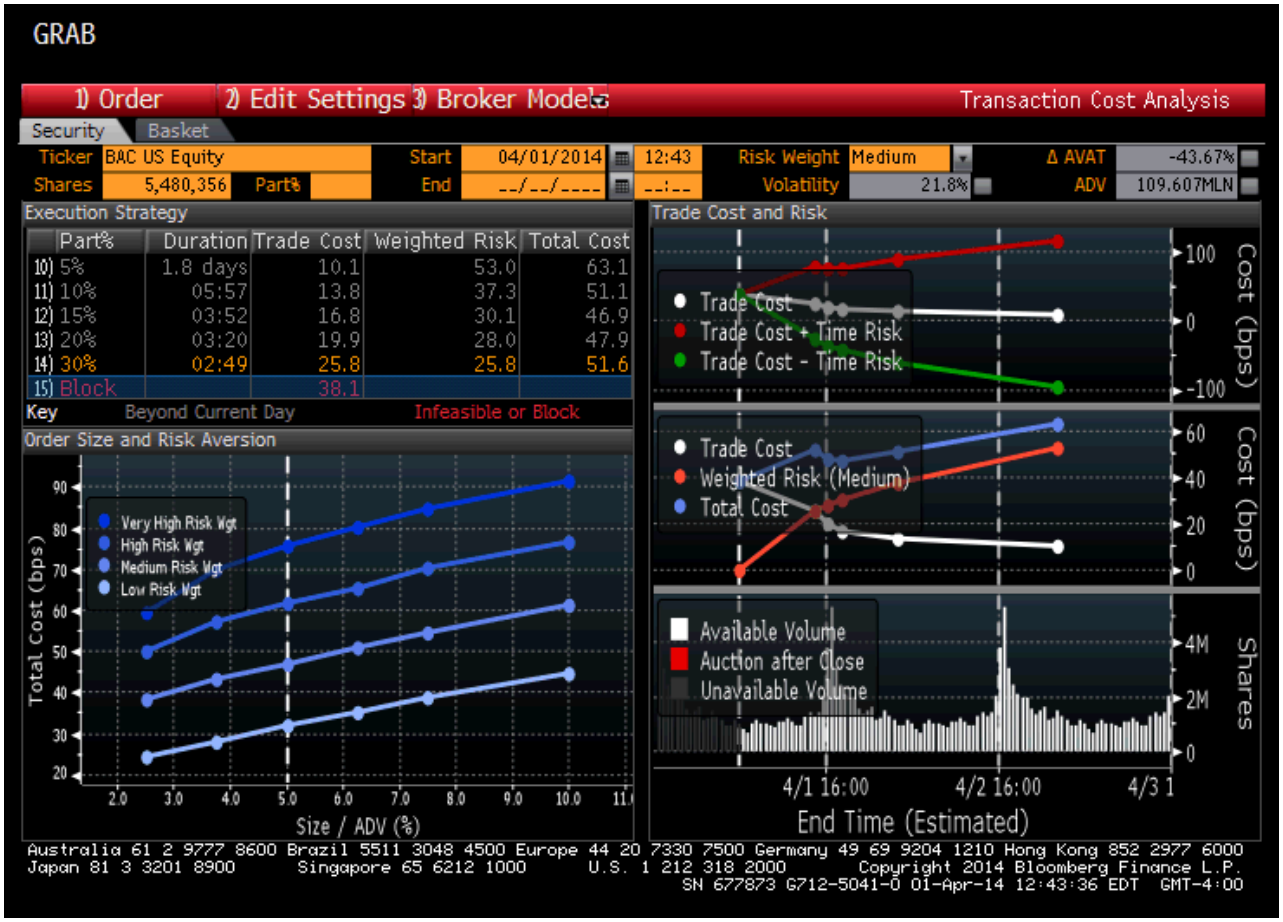


Research Topics -- Optimal Trading Frontier

- Balance Market Impact and Timing Risk
- Target = Total Market Impact COST + lambda*RISK



Bloomberg TCA Function



Anti-Gaming

- High Frequency Trading can front run DMA orders with speed advantages
- StatArb Traders can figure out Algo Orders' footprints and front run
- Certain venues may have more predators than other venues
- We set minimum fill size for certain venues
- Fair Value Model is one way to guard against suspicious price moves

RBC Capital Markets Algorithm Suite

RBC can develop strategies specifically tailored to your trading goals

		Algorithm	Description	Trade Examples	Works Best
THOR: Taking	Most Aggressive	RBC NOW™	Aggressively seeks liquidity while managing market impact Use of a limit price is strongly recommended (WILL COMPLETE IF MARKETABLE)	Buy 1,000,000 MSFT with a $24.25 top, I would.	▪ In aggressive/urgent situations ▪ With large-cap stocks / ETFs
		RBC Eclipse™	Uses stock-specific triggers to opportunistically source liquidity (MAY NOT COMPLETE)	Buy 250,000 HRZ, I would in-line or participate lightly with volume.	▪ With small- or mid-cap names
THOR: Posting		POV	Tracks volume at a specified participation rate (MAY NOT COMPLETE)	Buy 200,000 IBM, be 20% of the volume.	▪ In situations where a desired rate of participation is known
		Implementation Shortfall (IS)	Follows a front-loaded schedule quantitatively optimized to balance market impact and opportunity cost (WILL COMPLETE IF MARKETABLE)	Buy 200,000 DIS best way.	▪ When looking to balance market impact & opportunity cost ▪ When attempting to outperform pre-trade cost estimate
		Provider	Price-opportunistic strategy that uses Level 2 market data to intelligently interact with the market based on how a stock is currently trading (WILL COMPLETE IF MARKETABLE)	Buy 50,000 GME, trade passively for arrival price with variable discretion.	▪ When price-sensitive and willing to work the order throughout the day, particularly in small- or mid-cap names
		VWAP / TWAP	**VWAP** follows a schedule based on current market conditions and the stock's historical profile **TWAP** follows a straight-line schedule (WILL COMPLETE IF MARKETABLE)	Buy 100,000 XOM over the day.	▪ When executing an order over a specified time frame
	Most Passive	RBC Dark	Dark aggregator that actively accesses liquidity in 20+ pools (MAY NOT COMPLETE)	Buy 50,000 ZOLT with an $8.00 top. Do not display any part of the order.	▪ To intelligently access dark liquidity
Select	Varying Aggression Levels	RBC Select	Liquidity-seeking strategy that utilizes a single aggressiveness parameter to drive execution. Default setting is Level 3 - Neutral (LEVELS 4 & 5 WILL COMPLETE IF MARKETABLE)	Varies based on selected aggressiveness level: Level 1 – Least Aggressive Level 5 – Most Aggressive	▪ For capturing liquidity in lit and dark by using a single parameter

Execution Quality

- *Parent Order Level:*
- Slippage to Arrival --- The difference between average execution price and arrival midpoint price
- Slippage to VWAP Price
- Opportunity Cost --- If the order is not fully filled, assume the unfilled portion is filled at close price or other reasonable time period.
- Reversion --- How much did the price revert back after the order is finished ?
- *Child Order Level:*
- What happens after each fill from each venue ? Did price come back ? Are we being gamed ?
- Did price continue to move away ?
- *Consulting*
- Propose best execution algorithms for client flow based on characteristics