Electronic Bond Trading

Robert Almgren

Stevens Institute of Technology
High Frequency Finance and Data Analytics
Oct 29, 2015
Main points

1. Bond trading is big, electronic, and of very active interest
2. Algorithmic execution is important
3. Techniques for achieving good execution
Outline

1. Rates trading is becoming electronic
   futures first, then cash
2. Business of algo execution
   new in futures and fixed income
3. How to get good results
   understanding of market microstructure
Fixed Income markets are bigger than equities

US average daily traded volume in $Billion
2015 Jan-Sep

Fixed Income

501.2 Treasury
199.9 Agency MBS
27.1 Corporate
  9.2 Muni
  3.3 Non-agency MBS
  1.5 ABS
  4.5 Agency

746.7 Total

Equity

187.1 Total

Source: SIFMA
Pit trading → electronic

Pit

position traders

floor brokers

Electronic

HFT & Market Makers

algorithmic brokers (QB)
CME rates futures shift to electronic

Futures

Eurodollar Futures

Treasury Futures

Options

Eurodollar Options

Treasury Options

All CME futures pits closed July 6 2015

Produced by QB from CME data
Cash Treasury products shift to electronic

Automated Trading in Treasury Markets

April 9, 2015

In recent years, electronic trading has taken on an increasingly prominent role in the U.S. Treasury market, beyond the Treasury futures market, where it has been well-established since the late 1990s. In the dealer-to-client market, electronic transmission of orders has largely displaced traditional voice brokerage, while trading in the inter-dealer market for on-the-run Treasury securities is already almost entirely electronic. Trading in the most liquid on-the-run Treasury securities in the inter-dealer market has witnessed an increasing presence of automated trading, and high-frequency trading (HFT) in particular. This paper describes the growth of automated trading in the secondary market for Treasury securities and the potential benefits and risks associated with this evolution.

The Treasury Market Practices Group (TMPG) is a group of market professionals committed to supporting the integrity and efficiency of the Treasury, agency debt, and agency mortgage-backed securities markets. The TMPG is composed of senior business managers and legal and compliance professionals from a variety of institutions—including securities dealers, banks, buy side firms, market utilities, and others—and is sponsored by the Federal Reserve Bank of New York. Like other Treasury Market Practices Group publications, this document represents the views of the private-sector members. The ex-officio members do not express a position on the matters herein. More information is available at www.newyorkfed.org/tmpg.
Evolution of Automated Trading in the Treasury Market

Automated trading in the cash Treasury market has grown rapidly over the past decade, following developments in equities, futures, and over-the-counter foreign exchange markets. The initial move toward automated trading in fixed income markets occurred in the early 2000s, when inter-dealer brokers first launched their electronic platforms for Treasuries and allowed trading instructions to be entered by algorithms, instead of manually. The next important change occurred in the mid-2000s, when sophisticated automated trading firms began to have a significant presence on the electronic platforms. Estimates from the major inter-dealer platforms show that automated trading strategies now typically account for more than half of trading activity in on-the-run Treasury securities that occurs on such platforms. Of this automated activity, a significant percentage is generated from firms specializing in an HFT model, with the balance coming from banks and non-banks that employ a number of sophisticated trading methodologies.

The evolution of automated trading in the Treasury securities market is also likely to be influenced by innovation in the Treasury futures market and the interest rate swaps market, in which execution is becoming increasingly automated. The Treasury futures and interest rate swap markets are closely linked to cash Treasury securities markets by active spread trading between the markets.\(^{14}\)

\(^{14}\) A key difference between Treasury futures, Treasury securities, and interest rate swaps is their individual market infrastructures. Trading in Treasury futures is limited to the Chicago Mercantile Exchange (CME), with all trading activity subject to the rules of the CME and the Commodity Futures Trading Commission (CFTC). Over-the-counter trading in the Treasury securities market is not centralized in one execution venue, and each electronic trading platform has a different set of rules.
High-frequency trading now accounts for roughly 40% to 50% of the daily volume in Treasuries, compared to a "negligible amount" just five years ago, according to research firm Tabb Group.

The enormous size of the Treasuries market makes it appealing to firms that make money from huge volumes of trades.

As with stocks, the fear is that flash crashes could cause sharp plunges in Treasury prices. That would lead to soaring yields, from all-time lows below 1.5%, to as high as 4%.

Some of the biggest players in high-frequency trading, DRW Holdings, Sun Trading, Virtu Financial, Hudson River Trading, Jump Trading and GSA Capital Partners, have all been expanding their reach to Treasuries, according to numerous trading sources.

The Treasury Department wasn't able to provide recent breakdowns on trading in government debt.

"It's been less profitable for high-frequency firms to trade equities, so these firms are looking at other asset classes," said Justin Schack, a managing director at the institutional brokerage Rosenblatt Securities. "Treasuries are one of the most liquid markets in the world, so it's very fertile ground for high-frequency market making."

That liquidity has attracted hedge funds that use computer driven formulas to capture profits from tiny price movements.
The New Bond Market: Algorithms Trump Humans

High-speed trading accounts for increasingly large portion of volumes

By KATY BURNE

Sept. 23, 2015 7:35 p.m. ET

“Technology has introduced a whole new set of market participants into Treasurys and this makes the market more prone to move in unexpected ways,” said Amar Reganti, strategist at Boston-based asset manager Grantham Mayo Van Otterloo & Co. and former deputy director in the office of debt management at the U.S. Treasury Department.

Others are worried the algorithms are sniffing out one another and feeding off each other’s strategies in a way that is making trading move too quickly in one direction. These people say the result is “toxic” prices in professional trading venues that have made it more expensive and difficult to hedge.
Market & Investing: 1:56 min

Treasury bonds' 'flash crash'

Oct 15, 2014: John Authers reports at the end of a Wall Street trading day that saw 10-year Treasury yields drop 35 basis points in minutes, and then retrace most of that fall in a matter of hours. What does it mean for equities, and for the world economy?

Credits: Filmed By John Authers and edited by Gregory Bobillot
Bond Swings Draw Scrutiny

Focus Is on Oct. 15 Plunge in Treasury Yield

By TOM LAURICELLA and KATY BURNE
Nov. 9, 2014 7:59 p.m. ET

Wild Ride

Investors and regulators are trying to identify the reasons behind a plunge in Treasury yields.

On Oct. 15, the yield on the 10-year Treasury note tumbled to its biggest one-day decline since 2009.

Intraday low: 1.873%

Trading volumes in Treasury futures surged that day...

Volume doubled from prior day

...raising questions about the role of high-speed traders.

Electronic trading of Treasurys as a share of total trading volumes

Sources: Tradeweb (intraday yields); CME Group (futures volume); TABB Group (trading share)

*Estimate The Wall Street Journal
13 Oct 15, 2014, NY time

Treasury "flash crash"?

08:30: Retail sales dropped more than forecast in September on a broad pullback in spending that indicates American consumers provided less of a boost for the economy in the third quarter.

Victoria Stillwell, Bloomberg

09:33 09:40

OECE 09:40 10:00 10:20 10:40 11:00

Oct 15, 2014, NY time

Treasury Price Swings on October 15, 2014

Robert Almgren
June 18, 2015

Produced by QB from CME and cash market data
No flash crash: Paulson, Pimco and the US Treasury meltdown

/risk-magazine/feature/2384515/no-flash-crash-paulson-pimco-and-the-us-treasury-meltdown

08 Dec 2014, Kris Devasabai, Risk magazine

Financial markets witnessed one of the biggest, weirdest moves in their history on October 15 – the intraday collapse and rebound of US Treasury yields – prompting an immediate inquest. In the days that followed, regulators on both sides of the Atlantic quizzed banks, hedge funds and other big trading firms about the causes. What they heard surprised them.

On October 15, dealers were the first to realise what was happening. "A few funds had that merger arb position on in huge size and it created a significant risk-reduction moment. We had no idea what positions would be cut next and it turned out to be rates," says the head of global markets at a large international bank in London.

Traders that find themselves in a gamma trap have to buy or sell the underlying as it moves against them. "If you're short Treasury calls and want to hedge that exposure, you have to buy Treasuries as they go up, and sell as they go down. It forces you to trade badly – essentially buy high and sell low. This hedging action can lead to sharp V-shaped moves like the one we saw in October," says Pravit Chintawongvanich, a derivatives strategist at Macro Risk Advisors in New York, which provides risk analysis and derivatives trade structuring services to investors.
Fed official warns ‘flash crash’ could be repeated

Robin Wigglesworth in New York

The “flash crash” in US Treasuries of last autumn could happen again because of the changing nature of the US government debt market, a senior Federal Reserve official has warned.

Banks, investors and exchanges should adopt a revised set of guidelines in response to the turmoil, said Simon Potter, executive vice-president of the Federal Reserve Bank of New York.
On October 15, 2014 (“October 15”), the market for U.S. Treasury securities, futures, and other closely related financial markets experienced an unusually high level of volatility and a very rapid round-trip in prices. Although trading volumes were high and the market continued to function, liquidity conditions became significantly strained. The yield on the benchmark 10-year Treasury security, a useful gauge for the price moves in other, related instruments that day, experienced a 37-basis-point trading range, only to close 6 basis points below its opening level. Intraday changes of greater magnitude have been seen on only three occasions since 1998 and, unlike October 15, all were driven by significant policy announcements. Moreover, in the narrow window between 9:33 and 9:45 a.m. ET, yields exhibited a significant round-trip without a clear cause, with the 10-year Treasury yield experiencing a 16-basis-point drop and then rebound. For such significant volatility and a large round-trip in prices to occur in so short a time with no obvious catalyst is unprecedented in the recent history of the Treasury market.
Appendix B: Cross-Market Activity between Cash and Futures Markets

The cross market activity for the 10-year note and 10-year note futures contract indicates that trades by the top 10 PTFs on the CME are frequently followed by trades by the same group of firms in the cash market with a lag of roughly 5 milliseconds (Figure B.2). The time gap between these trades is just above the theoretical minimum latency between the Chicago area, where the CME matching engine is located, and eastern New Jersey, where the cash platform matching engines are located. Similarly but less frequently the inverse occurs, with trades in the cash market by the largest PTFs followed by trades at the CME by the same group of firms with a similar level of latency. For bank-dealers, the activity is much less pronounced. But in both cases it is clear that the cross market activity is elevated on October 15 compared to the control days, which may be consistent with the hypothesis that more trading opportunities arise between the two markets at times of extreme volatility and high volume.
The U.S. Treasury market is the deepest and most liquid government securities market in the world. However, the events of October 15 of last year, when yields experienced an unusually high level of volatility and rapid round-trip in prices without a clear cause, highlight the need to better understand the factors that impact the liquidity of the Treasury market, especially during stressed market conditions. Because of the Treasury market's unique role in the global economy, its liquidity and functioning have implications for the cost of financing the government, the market's role as a risk-free benchmark for pricing financial instruments, the costs borne by investors transacting in the Treasury market, and the implementation of monetary policy.

The U.S. Department of the Treasury, Board of Governors of the Federal Reserve System, Federal Reserve Bank of New York, Securities and Exchange Commission, and Commodity Futures Trading Commission invite you to a conference to explore the key factors underlying the evolution of the Treasury market's structure and liquidity. The conference will consist of a variety of panels on subjects ranging from the October 15th Joint Staff Report, automated and algorithmic trading, market making, liquidity, end investor perspectives on market structure, operational risks, repo markets, academic and practitioner perspectives on potential improvements to market structure, and regulatory requirements applicable to the government securities market. It will include prominent industry and academic experts and will feature remarks by several authorities in the official sector.
Regulators focus on opaque Treasury trading

Joe Rennison in New York

The $13tn US Treasury market likes to keep things hidden. That is a problem for US regulators trying to analyse what is driving buying and selling flows behind the market’s $500bn in daily volume.

Central bankers, high-frequency traders, academics, hedge funds and policymakers gathered this week in New York to dig into the operating structure of the largest government bond market.
High Frequency Trading

Last updated: October 21, 2015 9:05 pm

US regulator signals bid to curb high-speed trading
Gregory Meyer and Joe Rennison in New York

A major US financial regulator has signalled the first serious effort to curb high-speed automated trading in the futures market, which increasingly influences benchmark assets such as equities, commodities and government bonds.

The plans detailed by Timothy Massad, chairman of the Commodity Futures Trading Commission, come with concern growing among regulators over the sudden large price movements that have plagued a number of markets in recent years.

Such so-called “flash events” have become linked with the growing popularity of high-speed, computerised trading, which has been criticised by institutional investors for fuelling volatility.

Mr Massad made his comments on Wednesday at a conference examining the market for US Treasury bonds, a bedrock of the financial system which last October swung wildly in a 12-minute span, unnerving investors and regulators.

A July report by the US Treasury and regulators into the so-called “flash event” found the growth of rapid electronic trading had played a central role in the abrupt price and yield swings.

Automated traders account for about 67 per cent of 10-year Treasury futures listed on the Chicago Board of Trade, Mr Massad said. They are on at least one side of half the trades in metals and energy futures, he added.
Dealers claim they are victims of predatory behaviour in US Treasury markets dominated by high-frequency traders

The interdealer US Treasury markets have long been a sanctuary for primary dealers – a safe place to lay off the risks of their client-facing activities among themselves. But an influx of high-frequency traders has changed all that. Non-banks armed with speedy algorithms and superior technology are now the dominant players on the main interbank platforms, Icap's BrokerTec and Nasdaq-owned eSpeed. Dealers claim they are being pushed out of what has always been one of their core markets.

"BrokerTec and eSpeed have become markets where the fastest player wins and everyone else comes last," says a senior rates trader at a primary dealer in New York. "The banks are just not set up to compete in that scenario. We've been crowded out of those markets, and we're not actively making markets there anymore."
Investor lawsuits pile up claiming US Treasury market is rigged

Joe Rennison in New York

Investors have filed a flurry of court cases claiming banks and brokers have been rigging the Treasury bond market and increasing the cost of selling debt for the US government.

Twenty-three related cases have been filed, alleging the primary dealers that underwrite the US government’s debt colluded to manipulate the price of US Treasuries to their benefit. US Treasury securities are sold through an auction process in which banks and brokers listed as “primary dealers” place bids for the number of bonds they wish to buy and at what price. Investors can use primary dealers to buy at the auction or purchase them directly.
10-year note auction, $21B

$200MM

EDT on Wed 09 Sep 2015
UNITED STATES DISTRICT COURT
SOUTHERN DISTRICT OF NEW YORK

CLEVELAND BAKERS AND TEAMSTERS PENSION FUND, CLEVELAND BAKERS AND TEAMSTERS HEALTH AND WELFARE FUND, AND MASTERINVEST KAPITALANLAGE GMBH, on behalf of themselves and all others similarly situated, VS.

BANK OF NOVA SCOTIA, NEW YORK AGENCY; BMO CAPITAL MARKETS CORP.; BNP PARIBAS SECURITIES CORP.; BARCLAYS CAPITAL INC.;

***

9. The data shows that the yields for these identical securities indeed repeatedly diverged as between the auction and secondary markets, almost always in the direction of a higher yield (lower price) in the auction relative to the lower yield (higher price) in the secondary market. Across all tenors (i.e., lengths of time to maturity) of Treasuries, the yields of reissued Treasuries in the primary market were inflated in 69% of the auctions, by 0.91 basis points, a clearly significant disparity. This repeated bias cannot be explained as a result of random chance; instead, the only plausible explanation is that Defendants coordinated artificially to influence the results of the auctions in the primary market.

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Note:
*** Designates statistical significance at the 99% confidence level. ** Designates statistical significance at the 95% confidence level. * Designates statistical significance at the 90% confidence level.
Algorithmic trading set to transform the bond market

by Peter Lee

Intermediating the bond markets is shifting from a principal risk-taking business for banks to a brokerage business. At a time when the IMF is warning of bond market illiquidity, innovative solutions are springing up. In the high-volume government bond markets, trade-execution algorithms will be new drivers of efficiency. In the corporate bond markets, new systems will drive efficient internalizing of orders and matching across networks of dealers.

Quantitative Brokers (QB) is an agency broker in the interest rate futures markets that has grown quickly in its six-year history as some of the biggest hedge funds in the business have employed its trade-execution algorithms to reduce transaction costs and slippage.

It is now poised to bring versions of these algorithms to the cash market in US treasuries in what might prove to be a pivotal development for the bond markets.

Further reading
- Three radical new shifts in bond-market structure
- Corporate bond market goes back to broking
- Here comes the great bond liquidity drought
Quantitative Brokers

Algorithmic execution and cost measurement
No prop trading or market making

Interest rate products, starting with futures
Equities, FX already well served
Live on 5 futures exchanges (all products
Cash Treasuries: eSpeed, BrokerTec, dealer pools
basis trading futures vs cash

Good execution depends on
microstructure expertise
BUY 129 GEH6 BOLT

Exec = 98.806  Cost to strike = -0.31 tick = -$3.92 per lot

Midpoint liquidity

Cointegration signal (indicating down move)

Benchmark = Arrival price

Our limits

Our fills

Order book (direct + implied)

Midpoint fills
Passive fills
Cumulative exec
Market trades
Limit orders
Cumulative VWAP
Cointegration
Microprice
Bid-ask

GEH6

Midpoint liquidity

Strike 98.8075

Sweep 98.8100

BML 1000 lots

20,000 lots

98.795

98.800

98.805

98.810

98.815

98.820

98.825

98.829

Chicago time

09:22 09:24 09:26 09:28 09:30 09:32 09:34

Produced by QB from CME and internal data
SELL 362 ZNU3 BOLT

Exec = 125–07.71 Cost to strike = −0.92 tick = −$14.33 per lot

passive fills

aggressive cross based on signal
BUY 165 GEM4 BOLT

Exec = 9955.88  Cost to strike = 0.25 tick = $3.14 per lot

Cointegration signal indicates up move: aggressive buy

Butterfly middle leg midpoint liquidity

Aggressive fills
Midpoint fills
Cumulative exec
Market trades
Limit orders
Cumulative VWAP
Cointegration
Microprice
Bid–ask

Sweep 9956
Strike 9955½
BML 500 lots

20000 lots


Done at 13:07:01

82 @ 9956
12 @ 9955
¾
18 @ 9955
¾
52 @ 9955
¾
1 @ 9956

64% mkt
0 passv 82 midpt 83 aggr

Cointegration signal indicates up move: aggressive buy

Butterfly middle leg midpoint liquidity

Executed and working quantity

Produced by QB from CME and internal data
Example bond execution

BUY 67 CT10 BOLT

Exec = 100–24.90  Cost to strike = −0.71  tick = −$110.77 per lot

Produced by QB from CME and internal data
Multi-asset trades

Treasury futures trading on CME in Chicago

Cash Treasury note trading on eSpeed in New Jersey

Produced by QB from CME and internal data
Fixed income platform from RiskVal and Quantitative Brokers weds real-time analytics with algo execution

January 29, 2015 | By Renee Caruthers

FierceFinanceIT

A new fixed-income trading platform jointly developed by RiskVal and Quantitative Brokers merges real-time relative value analytics with advanced algorithmic execution of relative value trades. The RVQB platform, currently in beta with a select group of clients, was unveiled in a demonstration at RiskVal offices Wednesday.

For Quantitative Brokers, the joint platform will give users access to a front end deployed on desktops through the industry with an easy-to-use graphical user interface for modeling sophisticated trades.

Trading Technologies’ Platform to Support Quantitative Brokers’ Best Execution Algorithms

CHICAGO and NEW YORK, February 18, 2015 - Trading Technologies International, Inc. (TT), a global provider of high-performance professional trading software, and Quantitative Brokers, a leading provider of fixed income and futures algorithms, today announced TT will provide access to Quantitative Brokers’ best execution algorithms from the next-generation TT platform. In addition, TT is planning to add support for other broker algorithms.
http://www.ctaservicesawards.com/

Best trading and execution technology
Quantitative Brokers


THE 2015 MARKETS CHOICE AWARDS
The 2015 Markets Choice Awards span more than 25 categories across exchanges, sell-side desks, institutional buy-side investors, hedge funds, and technology providers. Our methodology in selecting nominees and then winners was simple yet thorough, and kept the focus on the important opinions: those of market participants, not ours.

Best Fixed-Income Algorithm Provider
Quantitative Brokers
Differences between rates futures and equities

• No market fragmentation (futures)
  simple routing, good market data
• Trading rules more complicated
  match algorithms
  implied quoting
• Large tick size (bid-ask spread)
• High degree of interrelation
  cointegration
  multidimensional algorithms
  basis trading, substitutions, etc
• Round the clock trading
  Information events
Conclusions

Bond trading is becoming electronic
Lots of interesting microstructural issues
Match algorithms

• Pro rata (short-term rates products)
• Mixed time / pro rata
• Workups (BrokerTec)
Pro rata order matching

Incoming volume divided among *all* resting orders at best price

Versions of pro rata matching are common in short-term interest rate products, because of large tick size and low volatility.
1. Orders placed during the “pre-opening” or at the indicative opening price (IOP) will be matched on a price and time priority basis. **Note that implied orders are not taken into consideration, as they are only active during the continuous trading session.**

2. Priority is assigned to an order that better the market, i.e. a new buy order at 36 betters a 35 bid. Only one order per side of the market (buy side and sell side) can have this TOP order priority. There will be situations where a TOP order doesn’t exist for one or both sides of the market (for example, an order betters the market, but is then canceled). There will never be a situation that results in two orders on the same side of the market having TOP order status.

3. Only outright orders can be TOP orders, however the TOP orders of underlying orders that are creating implied orders will be taken into consideration during the matching process so as not to violate the TOP order rule in any market.

4. TOP orders are matched first, regardless of size.

5. After a TOP order is filled, Pro Rata Allocation is applied to the remainder of the resting orders at the applicable price levels until the incoming order is filled.

6. The Pro Rata algorithm allocates fills based upon each resting order’s percentage representation of total volume at a given price level. For example, an order that makes up 30% of the total volume resting at a price will receive approximately 30% of all executions that occur at that price. Approximate fill percentages may occur because allocated decimal quantities are always rounded down (i.e. a 10-lot order that receives an allocation of 7.89- lots will be rounded down to 7-lots).

7. The Pro Rata algorithm will only allocate to resting orders that will receive 2 or more contracts.

8. After percentage allocation, all remaining contracts not previously allocated due to rounding considerations are allocated to the remaining orders on a FIFO basis.

   - Outright orders will have priority over implied orders and will be allocated the remaining quantity according to their timestamps.
   - Implied orders will be then allocated by maturity, with the earliest expiration receiving the allocation before the later expiring contracts. If spread contracts have the same expiration (i.e., CONTRACT A-CONTRACT B and CONTRACT A-CONTRACT C), then the quantity will be allocated to the earliest maturing contracts making up that spread (i.e., the CONTRACT A-CONTRACT B will get the allocation before the CONTRACT A-CONTRACT C because the CONTRACT B expires before the CONTRACT C).
Mixed time priority / pro rata

\[
f_j = \frac{(V - P_{j-1})^k - (V - P_j)^k}{V^k}.
\]

LIFFE

\(P_j = \text{volume preceding order } j\)

\(k = 1: \text{pro rata}\)

\(k = \infty: \text{time priority}\)

![Graph showing mixed allocation algorithms for small market order sizes; LIFFE's STIR products; CME's and some Treasury calendar spreads.](image)
BrokerTec workup

(10) Patent No.: US 8,005,745 B1
(45) Date of Patent: Aug. 23, 2011

(54) SYSTEM AND METHOD FOR PROVIDING WORKUP TRADING WITHOUT EXCLUSIVE TRADING PRIVILEGES

(75) Inventors: Daniel Cleaves, Summit, NJ (US); Arthur Robert D’Arcy, Basking Ridge, NJ (US)

(73) Assignee: ICAP Services North America LLC, Jersey City, NJ (US)

( *) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 105 days.

OTHER PUBLICATIONS


Liquidity Provision with Limit Orders and Strategic Specialist; Duane J. Seppi; The Review of Financial Studies; vol. 10, No. 1 (Spring, 1997), pp. 103-150.*


Conceptually, a workup is considered a single deal extended in time. This conception was reflected historically in several interesting aspects of workup trading. For example, because all trading during workup was considered part of a single deal, all such trading occurred at a single price point set by the initial hit or lift that triggered the workup. In addition, the initial aggressor’s side of the market (i.e., the sell side in the case of a hit and the buy side in the case of a lift) was designated the “aggressive” side of the workup. Similarly, the passive side of the workup. This designation played a key role in determining which entities would pay commission, historically paid only by the aggressive side of the market.

In addition to commission-free trades, inter-dealer brokers in the secondary market for U.S. government treasuries also rewarded buyers and sellers by developing a number of trading protocols or conventions which granted certain buyers and sellers certain trading options or “rights.” One such convention is commonly referred to as “workup.” In general terms, this convention permits buyers and sellers to “work up” the size of a trade from the quantity traded as a result of an initial “hit” or “lift.” Historically, certain traders, including the first aggressive-side and passive-side traders, were granted an option or right to increase their size, and to trade that additional size ahead of other traders.

(Workups are now largely inactive)
Trading through information events

Events cause price jumps

Need to locate and characterize these event reactions systematically from historical market data

Goal is to forecast “something” happening
### Intraday forecast curves

**Volume – 2015.04.07**

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<td>Consumer Credit</td>
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**Volatility – 2015.04.07**

<table>
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<tr>
<th>time</th>
<th>NYtime</th>
<th>UKtime</th>
<th>Gtime</th>
<th>event</th>
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<td>19:00</td>
<td>Consumer Credit</td>
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Slippage measurement

Live or die by transaction costs
Look at main determinants of good slippage
Algorithm Performance Comparison

April 2013 through Jan 2015

<table>
<thead>
<tr>
<th>Market</th>
<th>Bid/Ask</th>
<th>1.4MM orders Bulge Bracket Banks</th>
<th>1.2MM orders Quantitative Brokers</th>
<th>$/lot QB Improvement</th>
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<td></td>
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<td>AP</td>
<td>I-VWAP</td>
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<td>US 5-yr Note</td>
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<td>Eurex Bobl</td>
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<td>Eurex Bund</td>
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<td>E-mini S&amp;P</td>
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<td>6.51</td>
<td>4.06</td>
<td>3.52</td>
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<td>E-mini NASDAQ</td>
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<td>3.79</td>
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<td>NYMEX Heating Oil</td>
<td>4.20</td>
<td>15.71</td>
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<td>NYMEX Crude Oil</td>
<td>10.00</td>
<td>15.31</td>
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<td>NYMEX Nat. Gas</td>
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<td>Weighted Average:</td>
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<td>7.69</td>
<td>3.75</td>
<td>4.39</td>
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$8.5MM in 21 months: 88 bp annual improvement in return
All Eurodollar outrights

Cumulative volume fraction

Slippage to arrival price in ticks

CCP: mean = 0.53

QB: mean = 0.37

Thu 15 Aug 2013 to Fri 31 Jan 2014

$2MM savings in 6 months
Size is not most important variable for rates

For rates products, order size is not most important factor in slippage

10-year Treasury futures

ZN -- Fri 04 Apr 2014 to Thu 02 Oct 2014

Parent order size in lots

Slippage cost to midpoint as fraction of minimum price increment
Slippage to Arrival Price

For rates, slippage is largely controlled by ability to forecast price motion (and passive fills).

Price change during execution

Produced by QB from CME and internal data
Size matters more for non-rates

Natural gas futures

For non-rates products, slippage depends on order size (market impact)
Impact cost model

ES from Thu 02 Jan 2014 to Thu 02 Oct 2014
mean = 0.423

Produced by QB from CME and internal data
What does performance depend on?

Passive fills
Short term price signals
Reliable performance in different mkt conds
Futures vs cash

Basis = CF x Bond - Futures

Strongly mean-reverting: price signal
How to develop and improve algos?

1. Pure theory and quant modeling
2. Experiment with real client orders
3. Simulator
A potent mixture of in-house, futures commission merchant, and boutique brokerage-provided algorithms now play a part in commodity trading advisors’ and managed futures funds’ trading activities. Tim Bourgaize Murray examines why a new cadre of simulation tools is helping to organize—and perhaps re-mold—these buy-side specialists’ order flow.

“S"kate to where the puck is going to be, not where it has been,” Wayne Gretzky once told an interviewer. As the Great One described it, what cuts certain players a level above isn’t native instinct alone, so much as endless practice seeing the ice and, frankly, the hard work of getting to where a scoring opportunity will be, before it reveals itself.

Gretzky’s advice is one of Robert Almgren’s favorite lines—but not because the co-founder of Quantitative Brokers (QB) is a hockey fan. Instead, he says a similar idea applies to the business of algorithmic futures execution: the more you see, the more you mature your offerings and continue bundling futures algos with other execution and clearing services.

“We do perform reviews on all algos internally using our own simulator, and are always keen to compare these results with those of the provider. If they cannot provide a simulator, it takes a lot longer to see if we believe their story.” Murray Steel, AHL

Managed Futures’ ALGO CHASE

Managed futures specialists are increasingly taking advantage of boutique agency brokers’ algorithms, citing their ability to be opportunistic and adjust to markets’ behavior, as well as faster speed to implementation and greater alpha realized through price slippage.

Rates futures, particularly, are ripe for these applications given their correlation and the characteristics of the complexes within which they’re traded, and are well-serviced by Quantitative Brokers (QB), among other independent shops. Hedge fund AHL and CTA Revolution Capital Management are among QB’s users for rates.

Another value-added feature at smaller shops like QB is their simulation environments, which mimic the matching engine logic of relevant futures exchange venues and can test new adjustments to algorithms with real-time market data before putting the algos into production.

Sources expect a greater variety of such brokers to crop up in coming years, while sell-side futures commission merchants (FCMs), sensing greater competition, are also expected to mature their offerings and continue bundling futures algos with other execution and clearing services.

SALIENT POINTS
Introduction to Computational Fluid Dynamics

Instructor: Dmitri Kuzmin
Institute of Applied Mathematics
University of Dortmund
kuzmin@math.uni-dortmund.de
http://www.featflow.de
Computational fluid dynamics

Complete simulation is impossible
Discretize to capture key features:
• Conservation of mass, momentum, etc
• Positivity of density, etc
• Vortex dynamics
• Chemical reactions
• 2-D, 3-D, axisymmetric, etc
• Nonlocal effects (incompressible flow)
Computational market simulation
Complete simulation is impossible
(Human reaction is very complicated)

Key features to include:
- queue position and match algorithms
- price movement

Features to neglect for simplicity:
- market impact

(Literature on agent-based markets)
Market simulator

Tool for developing and testing execution algorithms for interest rate products.

Capture essential features of main markets:
• matching algorithms and passive fill probabilities
• short term pricing signals

Will have limitations -- useful anyway

Does not embody model of market impact

The one most natural way to build a simulator
What did not work

Algo being tested

No real market data: no price signals

Random order sizes and times

Dummy algos

CME Test Environment

Dummy algos

(ZI)

(Santa Fe zero-intelligence market algorithm)
Merge real market data

Algorithm

Orders

Fills

Market data

Simulator (artificial market)

Market data
(real-time or historical)

Quote volume at each level and number of orders (CME does not give detailed order info)
Criteria for simulator

• If no algo orders, reproduce market data
• If no market data, reproduce match engine
• Challenge: combine market data with orders
Project Report

Combining historical data with a market simulator for testing algorithmic trading

Huang, Wensheng
Su, Li
Zhu, Yuanfeng

Advisor
Dr. Robert Almgren

Abstract

In algorithmic trading field, it is very important to have a good market simulator to for back testing trading algorithms or trading strategies. Before trading algorithms or trading strategies are used in production environment, they are often required to be tested against historical data in a market simulator. One of the challenges is to merge the orders generated from algorithms or strategies into market quotes and trades. This project develops an algorithm to merge orders into historical data so that people can pragmatically back testing trading algorithms or strategies. This algorithm is applied to US Treasury Futures on CME and results are proved to be promising.
How to use simulator

Historical
- rerun scenarios for algo improvement
- backtests for potential clients

Real-time
- clients can connect to “test-drive” algos

Algorithm development
- test new signals on historical orders
- multi-market legging trades

Real-time splitting for testing
- compare simulator executions with real
Signal development

1. Propose idea
   plausibility tests
2. Statistical tests on historical market data
   nonzero correlation with future price movement
3. Rerun actual orders executed
   show improvement in slippage
Signal evaluation

Buy/sell signals based on short-term mean reversion and trading ranges

BUY 500 CLH4 BOLT

Exec = 99.66 Cost to strike = -6.47 tick = $64.72 per lot

CST on Mon 10 Feb 2014

Produced by QB from CME and internal data
Splitting of actual orders in real time

Client → QB Algo’s → QB simulation matching engine → exchange matching engine

- Parent orders
- Child orders
- Quotes
- Trades
Comparison of simulator with real execution

Simulator slippage (min px incr)

Production slippage (min px incr)

Wed 01 Oct 2014 to Thu 01 Oct 2015

Eurodollar
Ultra
T-Bond
5-year
10-year
2-year
Simulator crosses spread because of extra volume on bid side

Buy 148 ZNH4, 2014-02-05

Remaining size at much lower price level following event
Pessimistic fill assumptions

Production receives passive fills at 10:37, simulator does not

2014-01-27: Buy 56 GEU6
Main differences simulator/production:

- quote imbalance
- timing and latency
- random number sequences
- pessimistic fill model
Summary

Fixed income trading is becoming electronic

Need full range of algo execution tools:

- Transaction Cost Analysis (TCA) reporting
- Market microstructure analysis
- Algorithm optimization
- Market simulator
This document contains examples of hypothetical performance. Hypothetical performance results have many inherent limitations, some of which are described below. No representation is being made that any account will or is likely to achieve profits or losses similar to those shown. In fact, there are frequently sharp differences between hypothetical performance results and the actual results subsequently achieved by any particular trading program. One of the limitations of hypothetical performance results is that they are generally prepared with the benefit of hindsight. In addition, hypothetical trading does not involve financial risk, and no hypothetical trading record can completely account for the impact of financial risk in actual trading. For example, the ability to withstand losses or to adhere to a particular trading program in spite of trading losses are material points which can also adversely affect actual trading results. There are numerous other factors related to the markets in general or to the implementation of any specific trading program which cannot be fully accounted for in the preparation of hypothetical performance results and all of which can adversely affect actual trading results.

The reader is advised that futures are speculative products and the risk of loss can be substantial. Futures spreads are not necessarily less risky than short or long futures positions. Consequently, only risk capital should be used to trade futures. The information contained herein is based on sources that we believe to be reliable, but we do not represent that it is accurate or complete. Nothing contained herein should be considered as an offer to sell or a solicitation of an offer to buy any financial instruments discussed herein. All references to prices and yields are subject to change without notice. Past performance/profits are not necessarily indicative of future results. Any opinions expressed herein are solely those of the author. As such, they may differ in material respects from those of, or expressed or published by or on behalf of, Quantitative Brokers or its officers, directors, employees or affiliates. Quantitative Brokers, LLC, 2010.