Electronic Bond Trading

Robert Almgren

quantitativebrokers

EPFL SwissQuote

Nov 7, 2014
Thesis

1. Fixed income markets are becoming electronic
   phone call → RFQ → LOB

2. Electronic markets require algorithms to achieve good trade execution

3. Algorithms should be provided by agency-only brokers (like QB)

4. Development of these algorithms requires a wide range of quantitative tools (simulator)
NASDAQ OMX to Acquire eSpeed Platform for Trading of U.S. Treasuries

By GlobeNewswire, April 01, 2013, 04:01:00 PM EDT

NEW YORK, April 1, 2013 (GLOBE NEWSWIRE) -- The NASDAQ OMX Group, Inc. (Nasdaq:NDAQ) today announced it has entered into an agreement with BGC Partners, Inc. to acquire the eSpeed platform for a purchase price of $750 million in cash plus certain contingent issuances of stock that approximate certain tax benefits to NASDAQ OMX. eSpeed operates a fully executable central limit order book for electronic trading in U.S. Treasuries, which will give NASDAQ OMX a strong entry point in the electronic fixed income business - one of the largest and most liquid cash markets in the world.

NASDAQ OMX expects U.S. Treasury volumes - already one of the largest markets in the world with over $500 billion in daily trading volume - to increase, as core drivers gain momentum and economic headwinds subside. Positive market trends such as the stability in the issuance of new Treasuries, the continued electronification of the U.S. Treasury market and the resolution of fiscal uncertainty will drive volume growth. In addition, government intervention through quantitative easing and other market operations has artificially depressed the natural volatility in the U.S. Treasury market. eSpeed is well positioned, through the independent ownership of NASDAQ OMX, to benefit from the normalization of the U.S. government bond market and the cyclical drivers of volumes.
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
Humans Lose to Machines in $500 Billion-a-Day Bond Market

By Lisa Abramowicz 2014-10-02T21:42:32Z - Comments Email Print

While investors traditionally negotiated prices for U.S. Treasuries by telephone, they’re increasingly turning to computer-based marketplaces for a range of price quotes from different dealers. A record 48 percent of trades in U.S. government debt have occurred on electronic platforms this year, up from 31 percent in 2012, according to a Greenwich Associates study released yesterday.

“Investment firms are much more focused on being able to prove they’re getting good execution than ever before,” said Kevin McPartland, head of research for market structure and technology at research firm Greenwich Associates. “In Treasuries, the market seems ripe for electronic trading.”

Nasdaq Goes to Light Speed With Treasuries Trading

By Matthew Leising | 2014-05-28T11:55:00Z | - Comments  Email  Print

Nasdaq OMX Group Inc. is revving the engine of its ESpeed U.S. Treasuries platform.

Bond dealers that use ESpeed are gaining access to a microwave network connecting Nasdaq’s data center near New York City to a CME Group Inc. (CME) facility just outside Chicago, permitting almost light-speed buying and selling of U.S. debt. Nasdaq will also acknowledge receipt of traders’ orders more than 25 percent faster, and the exchange operator will speed up delivery of market data by more than 100 microseconds, or 100 millionths of a second, according to a statement today.
Automated market making in corporate bonds

Rates products easier to trade electronically

Swaps are a big new frontier

The rise of Q.M.M. points to sweeping changes in one of the most profitable and powerful corners of Wall Street: the fixed-income trading desks where bonds and derivatives like interest rate swaps are bought and sold, generating $80 billion of revenue at the biggest banks last year.

Government bonds are easier to automate because they come in standard denominations, while mortgage bonds and corporate bonds are issued in a less standardized fashion and thus are harder to hand over to computers.

The Dodd-Frank financial overhaul legislation required that most types of swaps move onto new electronic trading areas known as swaps execution facilities, or SEFs. The move is not taking place all at once, but about 20 percent of all trading of interest rate swaps is now automated, up from 2 percent a year ago, according to JPMorgan.
Robots haven’t taken over the bond market yet

By Ben Eisen
Published: Oct 21, 2014 7:56 a.m. ET

As the Times story notes, the quickest changes are happening in interest-rate swaps, where new regulations mandate trading take place on platforms known as swap execution facilities. U.S. Treasurys are also relatively simple to automate because, like swaps, they have elements of standardization.

“If we think twenty years ago, the only way to get a quote on a bond trade was for an investor to call a sell-side broker,” said Kevin McPartland, head of the market structure and technology group at Greenwich Associates. “Now, what this is talking about is basically the customer can enter into one of the trading platforms, and the machine can automatically [give a] quote.”

But much of the bond market isn’t being transformed by automation. Corporate bonds, for example, come in all flavors, which make pricing and trading much harder for a computer. Same with many types of asset-backed securities.

“The Treasury market and the corporate bond market are two completely different animals,” said McPartland.

A tale of two bond markets
Share of U.S. client trading volume executed electronically

- U.S. Treasurys: 48%
- Interest-rate derivatives: 17%
- Investment grade corporate bonds: 16%
- High yield corporate bonds: 4%

Source: Greenwich Associates
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.
Treasury bonds' 'flash crash'

Oct 15, 2014: John Authers reports at the end of a Wall Street trading 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
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 Stilwell, Bloomberg
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 futures on CME, Eurex, LIFFE, Montréal

Cash Treasuries live May 2014

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

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

Our fills

Our limit orders

Order book (direct + implied)

VWAP 98.812

Cumulative market volume

Filled quantity

Aggressive quantity

Cumulative VWAP

Cointegration

Microprice

Bid-ask

Limit orders

Cumulative exec

Market trades

Limit orders

Cumulative VWAP

Cointegration

Microprice

Bid-ask

Our limit orders

BML 1000 lots

20,000 lots

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

Chicago time

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

Aggressive fills
Midpoint fills
Working quantity
Filled quantity
Aggressive quantity

Butterfly middle leg midpoint liquidity

Executed and working quantity


12:57:07

Done at 13:07:01

50 100 150 200 259

64% mkt 0 passv 82 midpt 83 aggr

Cointegration signal indicates up move:
aggressive buy

Butterfly middle leg midpoint liquidity

Exec 9955.88
VWAP 9955.82

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

Strike 100–25¼

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

Baker Hughes U.S. Rig Count

100–26
100–25+
100–25
100–24+
100–24
100–23+
100–23
100–22+
100–22
100–21
100–20
100–19
100–18
100–17
100–16
100–15
100–14
100–13
100–12
100–11
100–10
100–9
100–8
100–7
100–6
100–5
100–4
100–3
100–2
100–1
100–0
50 lots

16:51  16:53  16:55  16:57  16:59  17:01  17:03

17:02:42

Done at 17:02:42

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

BUY 10 CT10
SELL 100 ZN

Exec = $23.359  Cost to target = $0.019 = -$17.61 per lot, -$1,937.50 total

LegRiskTolerance: 0%

66 ZNM4 @ 124−01+
6 CT10 @ 100−22
24 ZNM4 @ 124−01+
10 ZNM4 @ 124−01+
1 CT10 @ 100−22

5,000 lots

Cash Treasury note trading on eSpeed in New Jersey

Treasury futures trading on CME in Chicago

Produced by QB from CME and internal data
Differences between rates futures and equities

• No market fragmentation (more or less)
  simple routing, good market data
• Trading rules more complicated
  pro rata 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
Shift from pit to electronic (CME rates products)
Interest rate cash products

US Treasury notes & bonds
  on-the-run
  trade on "interdealer brokers"
    Brokertec
eSpeed

Corporate bonds not yet centrally traded
Track slippage obsessively

Slippage cost to bid-ask midpoint as fraction of minimum price increment

- Eurodollar (GE)
- 10 Year USD Deliverable Interest Rate Swap (N1U)
- 30 Year USD Deliverable Interest Rate Swap (B1U)
- 5 Year USD Deliverable Interest Rate Swap (F1U)
- 2-year (ZT)
- 5-year (ZF)
- 10-year (ZN)
- T-Bond (ZB)
- Ultra (UB)

Size-weighted exponential moving average over 10 calendar days.
Live and die by transaction costs

Algorithm Performance Comparison

<table>
<thead>
<tr>
<th>Market</th>
<th>Bid/Ask</th>
<th>Bulge Bracket Banks</th>
<th>Quantitative Brokers</th>
<th>$/lot</th>
<th>QB Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>AP</td>
<td>I-VWAP</td>
<td></td>
<td>AP</td>
</tr>
<tr>
<td>US 5-yr Note</td>
<td>7.81</td>
<td>3.86</td>
<td>2.89</td>
<td>1.59</td>
<td>-0.88</td>
</tr>
<tr>
<td>US 10-yr Note</td>
<td>15.63</td>
<td>8.22</td>
<td>6.02</td>
<td>2.32</td>
<td>-1.13</td>
</tr>
<tr>
<td>US 30-yr Bond</td>
<td>31.25</td>
<td>14.94</td>
<td>11.20</td>
<td>2.90</td>
<td>-1.72</td>
</tr>
<tr>
<td>Eurex Bobl</td>
<td>13.33</td>
<td>4.32</td>
<td>2.39</td>
<td>1.97</td>
<td>-0.98</td>
</tr>
<tr>
<td>Eurex Bund</td>
<td>13.33</td>
<td>6.98</td>
<td>2.30</td>
<td>3.94</td>
<td>-1.00</td>
</tr>
<tr>
<td>LIFFE Long Gilt</td>
<td>12.5</td>
<td>6.42</td>
<td>2.20</td>
<td>7.68</td>
<td>-3.07</td>
</tr>
<tr>
<td>E-mini S&amp;P</td>
<td>12.5</td>
<td>6.74</td>
<td>4.21</td>
<td>3.95</td>
<td>-1.82</td>
</tr>
<tr>
<td>E-mini NASDAQ</td>
<td>5</td>
<td>4.11</td>
<td>1.50</td>
<td>2.35</td>
<td>-1.46</td>
</tr>
<tr>
<td>NYMEX Heating Oil</td>
<td>4.2</td>
<td>17.80</td>
<td>4.84</td>
<td>12.61</td>
<td>-1.71</td>
</tr>
<tr>
<td>NYMEX Crude Oil</td>
<td>10</td>
<td>18.35</td>
<td>3.03</td>
<td>11.78</td>
<td>-4.67</td>
</tr>
<tr>
<td>Weighted Average</td>
<td></td>
<td>8.32</td>
<td>4.01</td>
<td>4.45</td>
<td>-1.67</td>
</tr>
</tbody>
</table>

Performance difference is 96 bp annual return
Period studied is 5.5 months from August 15, 2013, through January 31, 2014.

Slippage to arrival price in ticks

All Eurodollar outrights

<table>
<thead>
<tr>
<th>Client</th>
<th>QB</th>
<th>Total</th>
<th>Diff. (tick)</th>
<th>Diff. ($/lot)</th>
<th>Potential savings ($MM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Outrights</td>
<td>577</td>
<td>479</td>
<td>1,056</td>
<td>0.53</td>
<td>0.37</td>
</tr>
<tr>
<td>White</td>
<td>245</td>
<td>210</td>
<td>455</td>
<td>0.35</td>
<td>0.26</td>
</tr>
<tr>
<td>Red</td>
<td>298</td>
<td>223</td>
<td>521</td>
<td>0.65</td>
<td>0.46</td>
</tr>
<tr>
<td>Green</td>
<td>27</td>
<td>39</td>
<td>65</td>
<td>0.76</td>
<td>0.42</td>
</tr>
<tr>
<td>Blue</td>
<td>7</td>
<td>8</td>
<td>14</td>
<td>0.99</td>
<td>0.44</td>
</tr>
</tbody>
</table>

Potential savings considers that the entire quantity was executed either using CCP algorithms, or using QB algorithms, at the average slippage achieved for the corresponding subset. For example, for "All Outrights", potential savings is calculated as follows:

- Slippage to arrival price: 2.14
- Slippage to sweep price: 1.82

Thus, for example, a slippage improvement of 0.25bp. Thus, for example, a slippage improvement of 0.25bp. Thus, for example, a slippage improvement of 0.25bp.
Size is not most important variable for rates

For rates products, order size is not most important factor in slippage
For rates, slippage is largely controlled by ability to forecast price motion (and passive fills).

Price change during execution

Slippage to Arrival Price

Thousands of lots executed

BOLT CME IR

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

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

Natural gas futures

Parent order size in lots

Slippage cost to midpoint as fraction of minimum price increment

NG -- Fri 04 Apr 2014 to Thu 02 Oct 2014
Impact cost model

**SP500 futures**

Slippage as fraction of min px incr

Executed size in lots

ES from Thu 02 Jan 2014 to Thu 02 Oct 2014

mean = 0.423

Produced by QB from CME and internal data
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.

“Skate 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 much of the value, they say, derives from what comes before any trades are even made.

“... 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

SALIENT POINTS

- 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.
Computational fluid dynamics

Examples of CFD applications

CFD simulations by Löhner et al.

Smoke plume from an oil fire in Baghdad

CFD simulation by Patnaik et al.

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
Merge real market data

Orders

Algorithm

Fills

Market data

Market data
(real-time or historical)

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

 Simulator (artificial market)
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.
assumption!that!in!a!FIFO!market,!tra
Interleave algo orders with market

Interleave algo orders and market orders, respecting time priority and implementing exchange match rules.
Mkt data | Algo order | Book
---|---|---
quote=100 lot | 40 lot bid | 100
quote=150 lot | | 140
trade=30 lot (20%) | 8 lot fill | 190
quote=120 lot | | trade=38 lot
quote=110 lot (10 lot cancel) | | pro rata
cancel from back of queue
Simulator Assumptions

• Child orders always joining back of the queue
• Child orders use pessimistic queue position model, where;
  • Market Trades - reduce quantity from front of queue
  • Market Quote decreases - reduce quantity from back of queue
• Child orders receive passive fills based on matching algorithm:
  • Aggressive child orders are fully executed at sweep price
  • Child orders cannot establish a new price level
  • If a price level is traded through, child orders at that level are filled
• Hidden liquidity (BML) is recreated from QB calculations
• Implied quotes are treated equally to direct quotes
• Static latency of 2ms on market data and 8ms on execution
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 evaluation

BUY 500 CLH4 BOLT

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

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

CST on Mon 10 Feb 2014
Splitting of actual orders in real time

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

- Parent orders
- Child orders
- Quotes
- Trades
Simulator slippage (min px incr) vs Production slippage (min px incr)
Simulator crosses spread because of extra volume on bid side

Remaining size at much lower price level following event

Buy 148 ZNH4, 2014-02-05
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
Disclaimer

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.