• KRG I-Star Impact Model
• Multi-Asset Trading Costs
• High Frequency Trading (HFT)
• KRG Real-Time Cost Index
• Portfolio Management
• Q & A
R = Expected Returns Vector (N x 1)
  • To solve for model parameters

C = Covariance Matrix (N x N)
  • Stock variances and all pairs of covariance.

I = Trading Costs (N x S x T)
  • Trading costs are a three dimensional matrix, stock, size, and strategy.
  • Trading costs for each stock is two dimensional, size and trading time (e.g., strategy, schedule, pov, etc.)

• N = Number of Stocks
• S = Size Categories
• T = Time Categories
### Trading Cost Dimensions

<table>
<thead>
<tr>
<th>SP500 Index</th>
<th>Trading Strategy</th>
<th>1-day Percentage of Volume (POV Rate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Order Size</td>
<td>%ADV VWAP 5% 10% 15% 20% 25% 30% 35% 40%</td>
<td></td>
</tr>
<tr>
<td>1%</td>
<td>2 3 4 5 6 7 8</td>
<td></td>
</tr>
<tr>
<td>5%</td>
<td>10 13 16 18 19 21 22 24</td>
<td></td>
</tr>
<tr>
<td>10%</td>
<td>20 21 25 29 32 34 36 39</td>
<td></td>
</tr>
<tr>
<td>15%</td>
<td>32 28 34 38 42 45 48 51</td>
<td></td>
</tr>
<tr>
<td>20%</td>
<td>43 35 41 47 51 55 59 63</td>
<td></td>
</tr>
<tr>
<td>25%</td>
<td>54 40 48 60 65 69 73 79</td>
<td></td>
</tr>
<tr>
<td>30%</td>
<td>66 46 62 68 79 83 89 93</td>
<td></td>
</tr>
<tr>
<td>35%</td>
<td>77 51 69 76 82 88 93</td>
<td></td>
</tr>
<tr>
<td>40%</td>
<td>88 56 76 83 96 102</td>
<td></td>
</tr>
<tr>
<td>45%</td>
<td>99 61 82 90 105 111</td>
<td></td>
</tr>
<tr>
<td>50%</td>
<td>110 66 88 97 105 113 119</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>R2000 Index</th>
<th>Trading Strategy</th>
<th>1-day Percentage of Volume (POV Rate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Order Size</td>
<td>%ADV VWAP 5% 10% 15% 20% 25% 30% 35% 40%</td>
<td></td>
</tr>
<tr>
<td>1%</td>
<td>5 10 14 17 19 22 24 26 28</td>
<td></td>
</tr>
<tr>
<td>5%</td>
<td>20 29 36 41 46 51 55 59</td>
<td></td>
</tr>
<tr>
<td>10%</td>
<td>39 40 49 57 64 71 76 82</td>
<td></td>
</tr>
<tr>
<td>15%</td>
<td>56 49 60 69 78 85 93 99</td>
<td></td>
</tr>
<tr>
<td>20%</td>
<td>72 56 69 79 89 98 106 114</td>
<td></td>
</tr>
<tr>
<td>25%</td>
<td>88 62 76 88 99 109 118 126</td>
<td></td>
</tr>
<tr>
<td>30%</td>
<td>104 83 96 108 119 129 138</td>
<td></td>
</tr>
<tr>
<td>35%</td>
<td>118 73 89 104 116 128 138 148</td>
<td></td>
</tr>
<tr>
<td>40%</td>
<td>133 78 95 110 124 136 147 158</td>
<td></td>
</tr>
<tr>
<td>45%</td>
<td>146 82 101 117 131 144 156 167</td>
<td></td>
</tr>
<tr>
<td>50%</td>
<td>160 86 106 123 137 151 164 176</td>
<td></td>
</tr>
</tbody>
</table>

- Cost Curves are calculated by stock for all global markets (US & International) and by instrument for various asset classes (ETF, Futures, Fixed Income, Commodities FX, etc.).
- Data can be provided in .csv format, or generated by the investor on their own site from KRG model parameters.
Trading Cost Determinants

• **Order Characteristics**
  • Instrument, Side, Value, Trading Strategy / Time (Urgent, Normal, Passive)

• **Market Conditions**
  • Volatility, Volumes, Intraday Patterns

• **Natural Investors**
  • Investors seeking to earn investment profits
  • Aggregated buying and selling pressure

• **High Frequency Trading**
  • Investors seeking to earn a profit from Natural Investor’s trading.
  • Also known as, Toxic Order Flow, Predatory Investors, Scalping, Flash Boys.
  • What & How much is happening in the market?
  • 60 Minutes Special (3/30/2014), Michael Lewis

• **Broker Inefficient Order Placement** is also hurting investors and costing firms millions and millions and millions (POV rate, maker-taker, rebates).
SECTION 1

KRG I-Star Impact Model
M.I. Model – Current State

- Non-Transparent, Black-Box, Functional Form???
- Explanatory Factors
  - Size, Volatility, Strategy/Algorithm, Spreads
  - Liquidity (?), Market Cap (?), Parameters (?), Others (?)
- How often are parameters are updated, analyzed?
- Available via Web, System Connection, FTP (data only)
- Only uses vendor calculated variable calculations
  - ADV, Volatility, and current “point-in-time” only
- Can not incorporate own views (liquidity, volatility, and alpha)

- Is this useful enough for Stock Selection & Portfolio Construction?
  - E.g., Factor Screens / Portfolio Optimization / Back-Testing
- Are these back-box models useful enough to uncover HFT activity?
The I-Star Model

\[ I_{bp}^* = \hat{a}_1 \cdot \text{Size}^{\hat{a}_2} \cdot \sigma^{\hat{a}_3} \]

\[ MI_{bp} = \hat{b}_1 \cdot I_{bp}^* \cdot \text{POV}^{\hat{a}_4} + \left(1 - \hat{b}_1\right) \cdot I_{bp}^* \]

Variables:
Size = % ADV (expressed as a decimal)
σ = annualized volatility (expressed as a decimal)
POV = percentage of volume (expressed as a decimal)
\( a_1, a_2, a_3, a_4, b_1 \) = model parameters

Constraints: \( a_k > 0; \ 0 \leq b_1 \leq 1 \)

Estimating Model Parameters

- Tic Data
  - Inferred Buy/Sell Imbalance
  - Bid & Offer
  - Price Appreciation / Market Movement
- End of Day / Point in Time
  - Log Price Change
  - Volume, Buy Volume, Sell Volume
  - Average Daily Volume
  - Volatility
- Non-Linear Regression
  - Convergence Algorithm
  - Non-R2

Variables

\[ \text{Side} = \text{sign}(\text{Buy Volume} - \text{Sell Volume}) \]

\[ X = \text{Side} \cdot (\text{Buy Volume} - \text{Sell Volume}) \]

\[ \text{POV} = \frac{X}{\text{Volume}} \]

\[ \text{Size} = \frac{X}{\text{ADV}} \]

\[ \text{MI} = \text{Side} \cdot \ln \left( \frac{\text{VWAP}}{P_0} \right) \cdot 10^4 \text{bp} \]

We ran an iterative optimization process in MATLAB to determine the model’s sensitivity to changing parameters. Each parameter was held constant at specified value, and we determined the best fit non-linear regression model for the other parameters.

For example:

- set $a_1 = 200$ solve for $a_2, a_3, a_4, b_1$
- set $a_1 = 225$ and solve for $a_2, a_3, a_4, b_1$
- Repeat for all feasible values of $a_1$, continue for other parameters

Non-Linear R2 was our evaluation statistic.

The results of this test showed that there are ranges of feasible values provide “equivalent” solutions.
Estimating Parameters: Non-Linear R2

Sensitivity Analysis - "a1"

Sensitivity Analysis - "a2"

Sensitivity Analysis - "a3"

\[ I_{bp}^* = \hat{a}_1 \cdot Size^{\hat{a}_2} \cdot \sigma^{\hat{a}_3} \]

\[ MI_{bp} = \hat{b}_1 \cdot I^* \cdot POV^{\hat{a}_4} + \left(1 - \hat{b}_1\right) \cdot I^* \]

Estimating Parameters: Non-Linear R2

Sensitivity Analysis - "a4"

\[ I_{bp}^* = \hat{a}_1 \cdot \text{Size}^{\hat{a}_2} \cdot \sigma^{\hat{a}_3} \]

\[ MI_{bp} = \hat{b}_1 \cdot I^* \cdot POV^{\hat{a}_4} + \left(1 - \hat{b}_1\right) \cdot I^* \]

SECTION 2

Multi-Asset Trading Costs
## Equity Trading Cost - Model Parameters

### Exhibit 1
Global Equity Market Trading Cost Analysis, 2011

<table>
<thead>
<tr>
<th>Parameter</th>
<th>U.S. Large</th>
<th>U.S. Small</th>
<th>Canada Large</th>
<th>Canada Small</th>
<th>Developed Europe</th>
<th>Emerging Europe</th>
<th>Developed Asia</th>
<th>Emerging Asia</th>
<th>Latin America</th>
<th>Frontier</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a_1$</td>
<td>1,507.5</td>
<td>1,831.7</td>
<td>1,525.6</td>
<td>1,701.8</td>
<td>1,772.7</td>
<td>1,945.9</td>
<td>2,141.4</td>
<td>2,431.9</td>
<td>2,356.0</td>
<td>2,756.0</td>
</tr>
<tr>
<td>$a_2$</td>
<td>0.38</td>
<td>0.45</td>
<td>0.41</td>
<td>0.43</td>
<td>0.60</td>
<td>0.56</td>
<td>0.52</td>
<td>0.52</td>
<td>0.52</td>
<td>0.42</td>
</tr>
<tr>
<td>$a_3$</td>
<td>0.94</td>
<td>0.91</td>
<td>0.95</td>
<td>0.93</td>
<td>0.81</td>
<td>0.74</td>
<td>1.12</td>
<td>0.92</td>
<td>1.05</td>
<td>1.05</td>
</tr>
<tr>
<td>$a_4$</td>
<td>1.05</td>
<td>1.04</td>
<td>0.94</td>
<td>1.03</td>
<td>1.05</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.80</td>
<td>0.80</td>
</tr>
<tr>
<td>$b_1$</td>
<td>0.97</td>
<td>0.93</td>
<td>0.97</td>
<td>0.94</td>
<td>0.90</td>
<td>0.83</td>
<td>0.91</td>
<td>0.84</td>
<td>0.81</td>
<td>0.82</td>
</tr>
<tr>
<td>Size (%ADV)</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>Volatility</td>
<td>25%</td>
<td>25%</td>
<td>25%</td>
<td>25%</td>
<td>25%</td>
<td>25%</td>
<td>25%</td>
<td>25%</td>
<td>25%</td>
<td>25%</td>
</tr>
<tr>
<td>POV Rate</td>
<td>9%</td>
<td>9%</td>
<td>9%</td>
<td>9%</td>
<td>9%</td>
<td>9%</td>
<td>9%</td>
<td>9%</td>
<td>9%</td>
<td>9%</td>
</tr>
<tr>
<td>I-Star (bps)</td>
<td>169.6</td>
<td>183.1</td>
<td>159.0</td>
<td>174.2</td>
<td>144.1</td>
<td>192.1</td>
<td>136.9</td>
<td>205.1</td>
<td>166.0</td>
<td>244.4</td>
</tr>
<tr>
<td>MI (bps)</td>
<td>18.4</td>
<td>27.0</td>
<td>21.0</td>
<td>24.3</td>
<td>24.8</td>
<td>46.8</td>
<td>23.6</td>
<td>48.5</td>
<td>51.3</td>
<td>73.4</td>
</tr>
</tbody>
</table>

Note: Quantity expressed in terms of Order Size (%ADV).
Source: Kissell Research Group.

Source:
Journal of Trading, “Multi-Asset Trading Costs,” Fall 2013
Multi-Asset Trading Cost - Model Parameters

**Exhibit 5**
Multi-Asset Trading Cost Analysis, 2011

<table>
<thead>
<tr>
<th>Parameter</th>
<th>U.S.-LC</th>
<th>U.S.-SC</th>
<th>Liquid ETF</th>
<th>Illiquid ETF</th>
<th>Futures</th>
<th>Government Bond</th>
<th>Corporate Bond</th>
<th>Commodity</th>
<th>Currency</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a_1)</td>
<td>0.97</td>
<td>1.13</td>
<td>0.24</td>
<td>0.41</td>
<td>0.22</td>
<td>0.19</td>
<td>2.76</td>
<td>0.54</td>
<td>0.15</td>
</tr>
<tr>
<td>(a_2)</td>
<td>0.38</td>
<td>0.45</td>
<td>0.38</td>
<td>0.40</td>
<td>0.38</td>
<td>0.37</td>
<td>0.38</td>
<td>0.38</td>
<td>0.41</td>
</tr>
<tr>
<td>(a_3)</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>(b_1)</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>(b_2)</td>
<td>0.97</td>
<td>0.93</td>
<td>0.99</td>
<td>0.94</td>
<td>0.99</td>
<td>0.99</td>
<td>0.99</td>
<td>0.99</td>
<td>0.90</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dollars</th>
<th>$10,000,000</th>
<th>$10,000,000</th>
<th>$10,000,000</th>
<th>$10,000,000</th>
<th>$10,000,000</th>
<th>$10,000,000</th>
<th>$10,000,000</th>
<th>$10,000,000</th>
<th>$10,000,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volatility</td>
<td>25%</td>
<td>25%</td>
<td>25%</td>
<td>25%</td>
<td>25%</td>
<td>25%</td>
<td>25%</td>
<td>25%</td>
<td>25%</td>
</tr>
<tr>
<td>POV Rate</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>(\delta)</td>
<td>110.9</td>
<td>399.6</td>
<td>27.7</td>
<td>65.2</td>
<td>24.7</td>
<td>18.9</td>
<td>314.9</td>
<td>62.1</td>
<td>27.7</td>
</tr>
<tr>
<td>MI (bp)</td>
<td>14.1</td>
<td>65.1</td>
<td>3.0</td>
<td>10.0</td>
<td>2.7</td>
<td>1.9</td>
<td>88.2</td>
<td>6.8</td>
<td>5.3</td>
</tr>
</tbody>
</table>

*Note: Quantity expressed in terms of constant US$ Value.*

*Source: Kissell Research Group.*

Source:


Journal of Trading, “Multi-Asset Trading Costs,” Fall 2013
Multi-Asset Trading Cost Analysis

Cost to Acquire Factor Exposure

Journal of Trading, “Multi-Asset Trading Costs,” Fall 2013
## Multi-Asset Trading Cost Analysis - Example

### Trade Order Characteristics:
- **Buy SPY:** $20,000,000,000
- **Volatility:** 11.89%
- **Size of SPY (%ADV):** 98.64%
- **Size of Total (%ADV):** 11.99%

### Shadow Liquidity

<table>
<thead>
<tr>
<th>Code</th>
<th>Financial Instrument</th>
<th>Avg. Notional</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPY</td>
<td>SPDR S&amp;P 500 ETF Trust</td>
<td>$20,276,415,644</td>
</tr>
<tr>
<td>SPYG</td>
<td>SPDR S&amp;P 500 Growth ETF</td>
<td>$723,381</td>
</tr>
<tr>
<td>SPYV</td>
<td>SPDR S&amp;P 500 Value ETF</td>
<td>$976,523</td>
</tr>
<tr>
<td>IVV</td>
<td>iShares S&amp;P 500 Index Fund/US</td>
<td>$694,854,709</td>
</tr>
<tr>
<td>IVW</td>
<td>iShares S&amp;P 500 Growth Index Fund</td>
<td>$57,783,397</td>
</tr>
<tr>
<td>IVE</td>
<td>iShares S&amp;P 500 Value Index Fund</td>
<td>$61,200,933</td>
</tr>
<tr>
<td>VOO</td>
<td>Vanguard S&amp;P 500 ETF</td>
<td>$120,489,588</td>
</tr>
<tr>
<td>VOOG</td>
<td>Vanguard S&amp;P 500 Growth ETF</td>
<td>$628,670</td>
</tr>
<tr>
<td>VOOV</td>
<td>Vanguard S&amp;P 500 Value ETF</td>
<td>$616,676</td>
</tr>
<tr>
<td>RSP</td>
<td>Guggenheim S&amp;P 500 Equal Weight ETF</td>
<td>$32,145,818</td>
</tr>
<tr>
<td>RPG</td>
<td>Guggenheim S&amp;P 500 Pure Growth ETF</td>
<td>$2,615,697</td>
</tr>
<tr>
<td>RPV</td>
<td>Guggenheim S&amp;P 500 Pure Value ETF</td>
<td>$1,734,476</td>
</tr>
<tr>
<td>Subtotal</td>
<td>$21,250,185,513</td>
<td></td>
</tr>
</tbody>
</table>

### Trade Cost Analysis

<table>
<thead>
<tr>
<th>Param</th>
<th>SPY Analysis</th>
<th>Factor Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>a1</td>
<td>1507.5</td>
<td>1507.5</td>
</tr>
<tr>
<td>a2</td>
<td>0.38</td>
<td>0.38</td>
</tr>
<tr>
<td>a3</td>
<td>0.94</td>
<td>0.94</td>
</tr>
<tr>
<td>a4</td>
<td>1.05</td>
<td>1.05</td>
</tr>
<tr>
<td>b1</td>
<td>0.97</td>
<td>0.97</td>
</tr>
</tbody>
</table>

- **Size:** 99% 12%
- **Volatility:** 12% 12%
- **POV:** 50% 11%
- **I-Start:** 203 91
- **MI:** 100 11

**Trade Cost = 11bp**

Much lower than the 100bp estimate (w/o shadow liquidity)

Co-integration Effect

---

Shadow Liquidity is Key! They may be additional costs due to creation/redemption, EFP, b/d commission
SECTION 3

High Frequency Trading
What is High Frequency Trading?

• Any market participate who is looking to earn a Trading Profit. These are revenues that are earned throughout the trading day simply from buying at a lower price and selling at a higher price. These participants for the most part will net out their positions by end of day. They do not carry any over-night risk.

  • HFT trading includes: profiting from rebates, market making activities, short-term mis-pricings and stat-arb opportunities.

• An Investment Profit, on the other hand, is the revenues earned from a stock increasing in value and/or from paying dividends. These participants do not have to net their position by end of the day and will carry over-night positions and risk.

• Who are the HFT players?

  • HFT firms, Days Traders, High Velocity Traders, Broker Auto Market Making, Broker Principal Desks, Hedge Fund Quants, Hedge Fund Stat-Arb, Traditional Quants.
Brief History of HFT “Terminology”

• Informed Investors
• SOES Bandits & Day Traders
• Penny Jumping
• Adverse Selection
  • ECN’s, ATS’s, Dark Pools, Crossing Networks
• Toxic Liquidity
• High Frequency Trading (HFT), and now,
  • “The Flash Boys”
HOW MUCH VOLUME IS HFT?
How Much is High Frequency Trading?

Volumes by Market Participants

How Much is High Frequency Trading?

Volumes by Market Participants

How much is High Frequency Trading?

- How much of market volumes is HFT (1Q-2014)?
  - Flash Boys = 32%, AMM = 13%, Quant Trading = 16%.
  - Total HFT = 32% to 61%.

- HFT will continue to Increase!
  - HFT has increased 15% in two years.
  - HF Quant (w/ HFT techniques) increased 25% in two years.
  - B/D AMM has decreased -25% in same period.

- What is the Future of High Frequency Trading?
  - The future is very, very, very bright!
  - All participants need to remain competitive.
  - B/Ds, Research Firm, Asset Managers, Portfolio Construction.
SECTION 4

KRG Real-Time Cost Index
KRG Cost Index with HFT Activity Indicator

- Provides **all investors** with insight into actual trading activity and real time costs.

- **KRG Price** – The price that the investor should have paid in the market given market conditions, and HFT activity.

- **Imbalance** – Net buying and selling pressure from all other investors.

- **TCA Cost** – The Fair Value TCA Cost on the day based on market imbalances, order impact, and market movement.

- **HFT Cost** – The incremental trading cost due to High Frequency Traders.

- **HFT Activity Level** - The amount of HFT activity in the stock at that point in time.
## KRG Cost Index with HFT Activity Indicator

**Real-Time @ the End of Day (4/4/2014)**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>KRG TCA Price</th>
<th>Imbalance Side</th>
<th>Imbalance Shares</th>
<th>Imbalance (%Adv)</th>
<th>Market Impact (bp)</th>
<th>Mkt Cost (bp)</th>
<th>KRGI Cost (bp)</th>
<th>HFT Cost (bp)</th>
<th>HFT Activity Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>$58.30</td>
<td>Sell</td>
<td>-1,150,461</td>
<td>-47.2%</td>
<td>-107.62</td>
<td>-103.41</td>
<td>-211.03</td>
<td>-77.06</td>
<td>High</td>
</tr>
<tr>
<td>AA</td>
<td>$12.72</td>
<td>Buy</td>
<td>1,764,295</td>
<td>7.3%</td>
<td>-18.80</td>
<td>92.41</td>
<td>73.61</td>
<td>-143.87</td>
<td>High</td>
</tr>
<tr>
<td>AAN</td>
<td>$31.57</td>
<td>Sell</td>
<td>-134,043</td>
<td>-13.7%</td>
<td>-52.17</td>
<td>-57.55</td>
<td>-109.72</td>
<td>-37.67</td>
<td>High</td>
</tr>
<tr>
<td>AAON</td>
<td>$28.81</td>
<td>Sell</td>
<td>-59,817</td>
<td>-44.2%</td>
<td>-174.61</td>
<td>-131.98</td>
<td>-306.59</td>
<td>-81.18</td>
<td>Med</td>
</tr>
<tr>
<td>AAP</td>
<td>$127.61</td>
<td>Sell</td>
<td>-451,155</td>
<td>-56.7%</td>
<td>-111.45</td>
<td>-85.81</td>
<td>-197.26</td>
<td>-57.42</td>
<td>High</td>
</tr>
<tr>
<td>AAPL</td>
<td>$546.50</td>
<td>Sell</td>
<td>-4,362,073</td>
<td>-50.3%</td>
<td>-73.04</td>
<td>-50.88</td>
<td>-123.92</td>
<td>-49.91</td>
<td>High</td>
</tr>
<tr>
<td>AAT</td>
<td>$33.98</td>
<td>Buy</td>
<td>24,825</td>
<td>13.6%</td>
<td>-26.63</td>
<td>81.91</td>
<td>55.29</td>
<td>-116.74</td>
<td>High</td>
</tr>
<tr>
<td>AAWW</td>
<td>$35.82</td>
<td>Buy</td>
<td>83,876</td>
<td>27.8%</td>
<td>-101.37</td>
<td>89.52</td>
<td>-11.85</td>
<td>-4.86</td>
<td>Low</td>
</tr>
<tr>
<td>ABAX</td>
<td>$40.20</td>
<td>Sell</td>
<td>-77,861</td>
<td>-59.0%</td>
<td>-112.62</td>
<td>-83.31</td>
<td>-195.93</td>
<td>-8.26</td>
<td>Low</td>
</tr>
<tr>
<td>ABBV</td>
<td>$55.03</td>
<td>Sell</td>
<td>-3,274,997</td>
<td>-56.0%</td>
<td>-125.78</td>
<td>-106.58</td>
<td>-232.36</td>
<td>-85.46</td>
<td>High</td>
</tr>
<tr>
<td>ABC</td>
<td>$66.60</td>
<td>Sell</td>
<td>-339,721</td>
<td>-19.0%</td>
<td>-24.35</td>
<td>-67.64</td>
<td>-91.99</td>
<td>-20.77</td>
<td>Med</td>
</tr>
<tr>
<td>ABFS</td>
<td>$39.36</td>
<td>Sell</td>
<td>-92,541</td>
<td>-27.2%</td>
<td>-87.85</td>
<td>-164.85</td>
<td>-252.70</td>
<td>-62.54</td>
<td>Med</td>
</tr>
<tr>
<td>ABM</td>
<td>$29.71</td>
<td>Sell</td>
<td>-106,547</td>
<td>-42.7%</td>
<td>-121.81</td>
<td>-82.79</td>
<td>-204.59</td>
<td>-65.46</td>
<td>High</td>
</tr>
<tr>
<td>ABMD</td>
<td>$26.80</td>
<td>Sell</td>
<td>-160,264</td>
<td>-30.7%</td>
<td>-146.59</td>
<td>-91.25</td>
<td>-237.85</td>
<td>-33.49</td>
<td>Low</td>
</tr>
<tr>
<td>ABT</td>
<td>$38.69</td>
<td>Buy</td>
<td>1,922,832</td>
<td>23.4%</td>
<td>-35.76</td>
<td>80.82</td>
<td>45.07</td>
<td>-75.94</td>
<td>High</td>
</tr>
<tr>
<td>ACAT</td>
<td>$48.53</td>
<td>Sell</td>
<td>-55,600</td>
<td>-32.9%</td>
<td>-72.57</td>
<td>-135.60</td>
<td>-208.17</td>
<td>-12.55</td>
<td>Low</td>
</tr>
<tr>
<td>ACC</td>
<td>$37.69</td>
<td>Buy</td>
<td>604,270</td>
<td>77.8%</td>
<td>-127.80</td>
<td>57.72</td>
<td>-70.09</td>
<td>-107.49</td>
<td>High</td>
</tr>
<tr>
<td>ACE</td>
<td>$98.84</td>
<td>Buy</td>
<td>360,468</td>
<td>24.6%</td>
<td>-34.18</td>
<td>81.14</td>
<td>46.96</td>
<td>-93.28</td>
<td>High</td>
</tr>
</tbody>
</table>
KRG Cost Index with HFT Activity Indicator
AAPL - Historical End of Day (2014)
KRG Cost Index with HFT Activity Indicator
AAPL – Intraday Index (4/4/2014)
Back-Testing – Portfolio Construction

- Historical trading cost indexes: regions, countries, and indexes (1990 – present)
- Back-test investment ideas via portfolio optimization (US, Europe, Asia, Developed, Emerging, Latam, Frontier)
- Expected cost that investors would have incurred historically based on today’s market environment, e.g., decimalization, electronic algorithms, dark pools, internal crossing, ATS, etc.
- Series can be generated for a constant order size (% Adv), share quantity, or dollar value.
- Customized by market, investment style, stock specific, or any investment objective.

HOW TO USE THE HFT COST INDEX?
Example

- A trader is buying 100,000 shares of stock XYZ.
  - Trading Cost is typically $0.10/share.
  - By 12:00pm the cost is already $0.50/share.
  - Trader only executed 50,000 shares.
  - What is the reason for the higher price?

- Is the reason...
  - The effect of all other buyers and sellers
  - Market conditions (market movement, volumes, volatility)
  - High Frequency Traders (The Flash Boys)
  - The Broker just under-performing
Example #1

- A trader is buying 100,000 shares of stock XYZ.
  - Trading Cost is typically $0.10/share.
  - By 12:00pm the cost is already $0.50/share.
  - Trader only executed 50,000 shares.
  - What is the reason for the higher price?

- KRG Real-Time Cost Index with HFT Activity Indicator:
  - Aggregated Imbalance = +750,000 shares.
  - KRG TCA = $0.50/share.
  - HFT Activity = +1,000 shares.
  - HFT Cost = $0.001/share (less than 1 cent/share).

- Conclusion:
  - Higher Cost is due to increased buying pressure in the stock (e.g., +750,000 shares).
  - The cost of $0.50/share is reasonable.
Example #2

• A trader is buying 100,000 shares of stock XYZ.
  • Trading Cost is typically $0.10/share.
  • By 12:00 the cost is already $0.50/share.
  • Trader only executed 50,000 shares.
  • What is the reason for the higher price?

• KRG Real-Time Cost Index with HFT Activity Indicator:
  • Aggregated Imbalance = +50,000 shares.
  • KRG TCA = $0.10/share.
  • HFT Activity = +200,000 shares.
  • HFT Cost = $0.40/share.

• Conclusion:
  • Higher cost is due to HFT Activity.
  • HFT = +200,000
  • HFT caused the investor to incur total cost of $0.50/share.
Example #3

• A trader is buying 100,000 shares of stock XYZ.
  • Trading Cost is typically $0.10/share.
  • By 12:00 the cost is already $0.50/share.
  • Trader only executed 50,000 shares.
  • What is the reason for the higher price?

• KRG Real-Time Cost Index with HFT Activity Indicator:
  • Aggregated Imbalance = +50,000 shares.
  • KRG TCA = $0.10/share.
  • HFT Activity = +1,000 shares.
  • HFT Cost = $0.001/share (less than 1 cent/share).

• Conclusion:
  • Higher cost is due to Broker/Algorithm under-performing.
  • It is not due to HFT or Market Conditions!
  • Investor can discuss revising the algorithm/strategy and realize improvement on the last 50,000 shares.
  • It is not too late to do better!
SECTION 5
Portfolio Management
**Transparent Market Impact Model**

- Once a PM has the MI Model they can incorporate their own views regarding liquidity and volatility (as well as alpha) into the cost estimate.

- This allows proper “stress-testing” of positions to determine the cost to liquidate a position.

- Most often, positions are liquidated in a worse-case scenario, e.g., the stock has fallen out of favor, liquidity has dried up, and volatility has spiked.

- Vendor models incorporate the current point in time variables such as current volatility, current liquidity conditions, and cost estimates for stocks that are well behaved, e.g., we want to own them in our portfolio.

- But the cost to get out is much higher than the cost to get in.

- A transparent model allows:
  - “Stress-testing,” “what-if,” and “sensitivity” analysis
Comparison of Costs in “Normal” and “Stressed Environment”

- $100 million investment in a 100 stock small cap portfolio (market cap weighted)
- MI models provide cost estimates under current market conditions.
- These are usually the most appealing market conditions since the stock is being considered for inclusion in the investment portfolio.
- Average Cost = 106bp

- Stress Test of the same $100 million 100 stock small cap portfolio.
- But here we perform a stress test of costs.
- We consider the impact cost to liquidate the position in a market environment where volatility doubles and liquidity halves.
- A more realistic representation of trading cost when we liquidate because a stock has fallen out of favor
- Average Cost = 298bp (almost 3x as higher!)

Source: MATLAB, Science of Algorithmic Trading and Portfolio Management
R2000: What is the cost to liquidate an order?

- Portfolio Managers often limit holdings in any specific stock based on a percentage of ADV to limit transaction cost.
- These position sizes are often limited in size in case the fund needs to liquidate the position quickly (for example, if the stock falls out of favor or if there is unfavorable news).
- The graph on the top left shows the liquidation cost for sizes of 10% ADV for each stock in the R2000 Index using a full day VWAP strategy. The average liquidation cost across names is about 37bp with majority of costs in the 20bp to 55bp range.
- The graph on the bottom left shows the position size (%adv) that could be held in each stock such that the expected liquidation cost in each name will be about 37bp. Many of these stocks could be held in much larger sizes without adversely affecting its liquidation cost and some of the stocks have to be held in position sizes much lower than 10% Adv.
- This graph (bottom left) was also truncated at a size of 35% Adv to better show the range of sizes.

Conclusions

• High Frequency Trading (HFT) is here to stay!
  • 35% - 60% of total volumes

• HFT is only going to increase!
  • HFT Firms, Brokers (Full Service & Research), Hedge Funds, Institutions, Money Managers

• KRG HFT Index
  • Is HFT helping or hurting?
  • Real-Time (web access, API’s)
  • End of Day (All Stocks)
  • Historical (1990 – Present)
  • HFT Hot List – signs of price trend reversion
References

• Multi-Asset Trading Costs, Journal of Trading, Fall 2013, Vol. 8 No. 4
• Smart Technology for Big Data, Michael Blake, Journal of Trading, Winter 2014, Vol. 9, No. 1
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