NORTHFIELD 18TH SUMMER SEMINAR - 2013
ALPHA CAPTURE & DYNAMIC MODELS
"BEYOND THE BLACK BOX"

Robert Kissell, PhD

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Kissell Research Group, LLC
1010 Northern Blvd., Suite 208
Great Neck, NY 11021
www.kissellresearch.com

Outline

- **I-Star Impact Model**
  - Estimating Parameters
  - Nonlinear Least Squares, Non-Linear R2
- **Dynamic Model***
  - Deciphering Black Box / Pre-Trade of Pre-Trades
  - Proprietary Estimates and Alpha
- **Portfolio Analysis**
  - MI Quant Factors
  - Alpha Capture
  - Back-Testing
  - Acquiring Factor Exposure & Shadow Liquidity

"Dynamic Pre-Trade Models: Beyond the Black Box," was published in Journal of Trading, Fall 2011, Vol. 6, No. 4.

SECTION 1

I-Star Market Impact Model

M.I. Model – Current State

- Non-Transparent
- Black-Box
- 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

I-Star Market Impact Model - Transparency

$$I^*_{bp} = \hat{a}_1 \cdot Size^{\hat{a}_2} \cdot \sigma^{\hat{a}_3}$$

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

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: $a_k > 0$; $0 \leq b_1 \leq 1$

Source: Optimal Trading Strategies, Science of Algorithmic Trading and Portfolio Management

Estimating Model Parameters

- Tic Data
  - Inferred Buy/Sell Imbalance
- End of Day
  - Log Price Change
  - Volume, Buy Volume, Sell Volume
  - Average Daily Volume
  - Volatility
- Non-Linear Regression
  - Convergence Algorithm
  - Non-R2

Variables

$$Side = sign\left(Buy\ Volume - Sell\ Volume\right)$$

$$X = Side \cdot \left(Buy\ Volume - SellV\ olume\right)$$

$$POV = \frac{X}{Volume}$$

$$Size = \frac{X}{ADV}$$

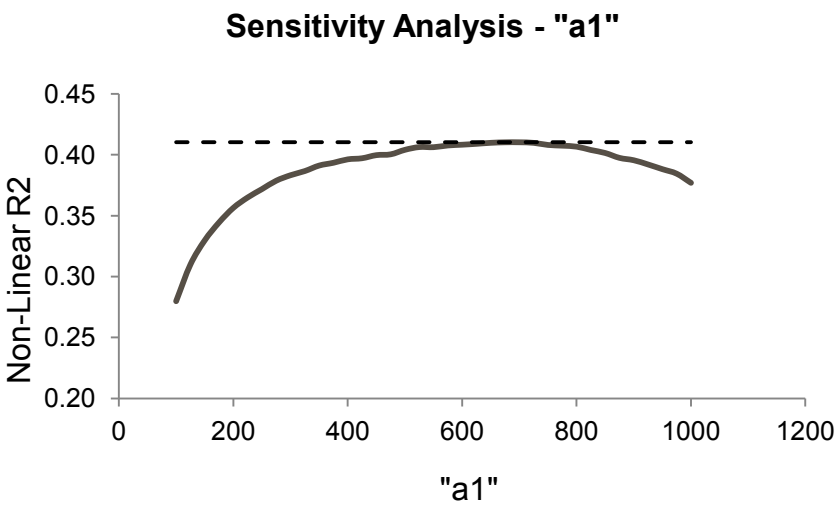
$$MI = Side \cdot \ln\left(\frac{VWAP}{P_0}\right) \cdot 10^4\, bp$$

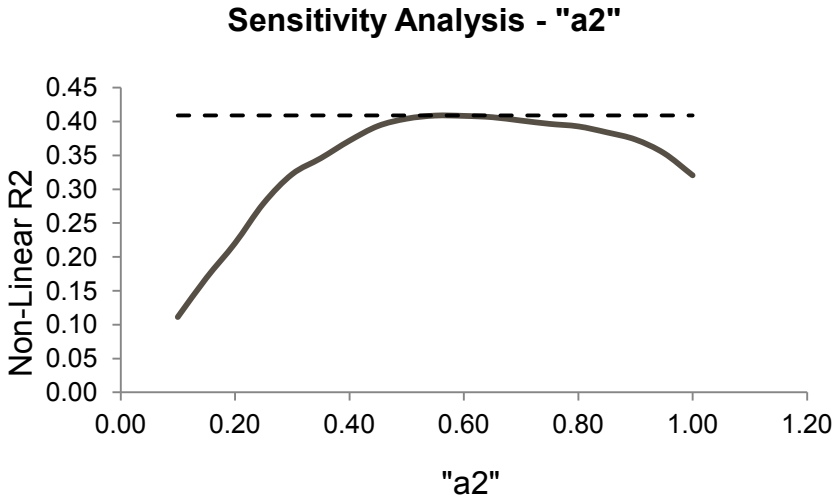
Source: Optimal Trading Strategies, Science of Algorithmic Trading and Portfolio Management

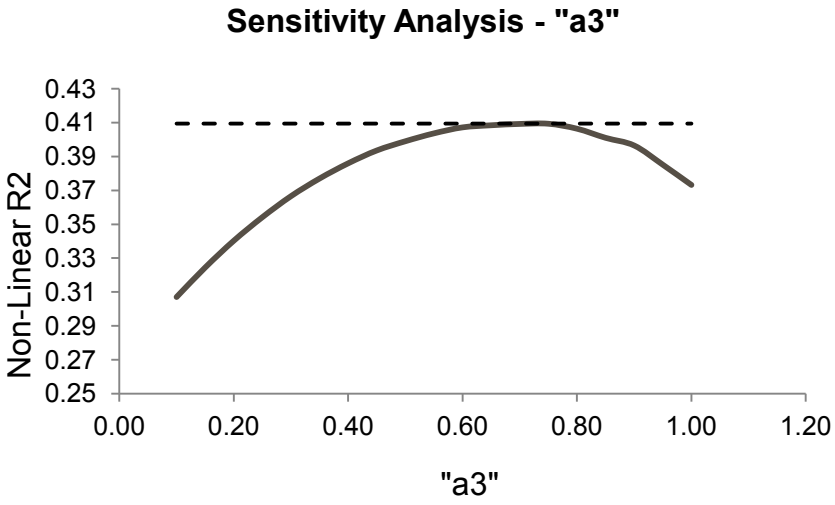
Sensitivity Analysis - Model Parameters

- We ran an iterative optimization process to determine the models 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 a1, 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



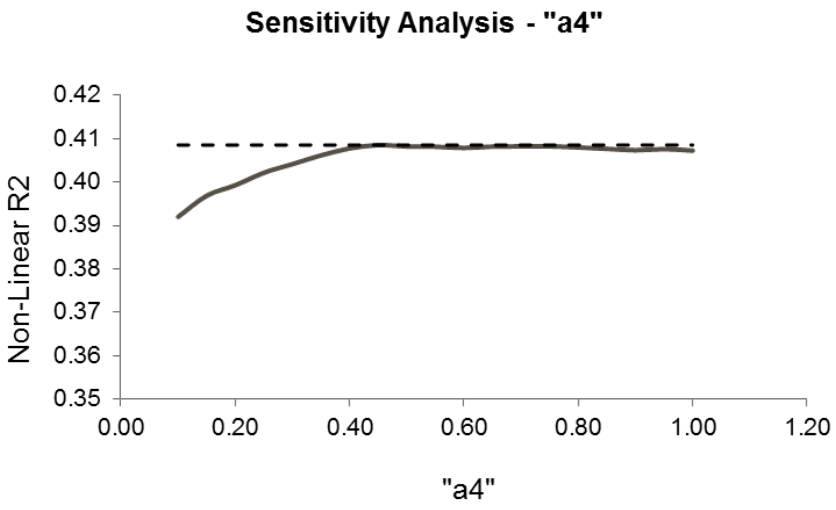


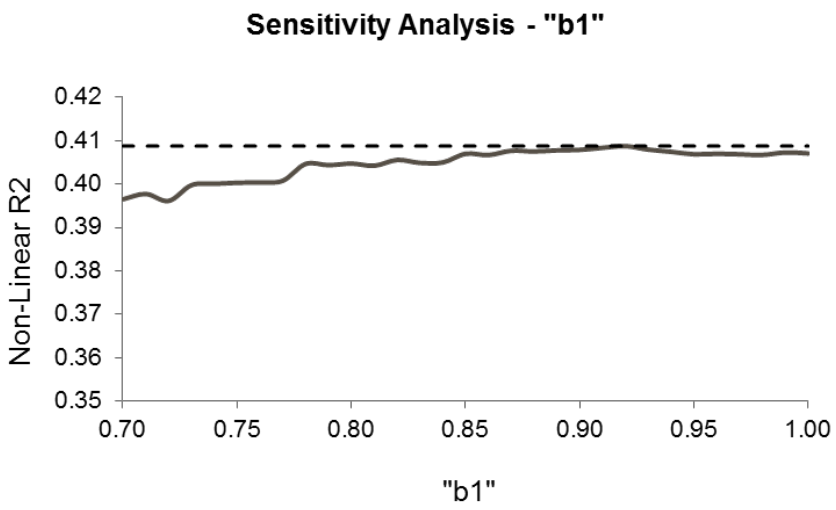


$$I^*_{bp} = \hat{a}_1 \cdot Size^{\hat{a}_2} \cdot \sigma^{\hat{a}_3}$$

Source: Science of Algorithmic Trading and Portfolio Management, Elsevier 2013

Estimating Parameters: Non-Linear R2





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

Source: Science of Algorithmic Trading and Portfolio Management, Elsevier (2013)

Estimating I-Star Parameters

Market Impact Parameters: 2012										
Parameter	US Large	US Small	Canada Large	Canada Small	Europe Developed	Europe Emerging	Asia Developed	Asia Emerging	Latam	Frontier
a1:	687.44	701.63	862.00	862.00	768.95	761.93	980.63	1225.76	1384.20	1584.20
a2:	0.70	0.47	0.65	0.65	0.75	0.73	0.70	0.75	0.75	0.65
a3:	0.72	0.69	0.83	0.83	0.60	0.59	0.72	0.70	0.83	1.00
a4:	0.45	0.60	0.52	0.52	0.50	0.50	0.58	0.50	0.50	0.40
b1:	0.98	0.97	0.97	0.95	0.90	0.88	0.92	0.86	0.86	0.82

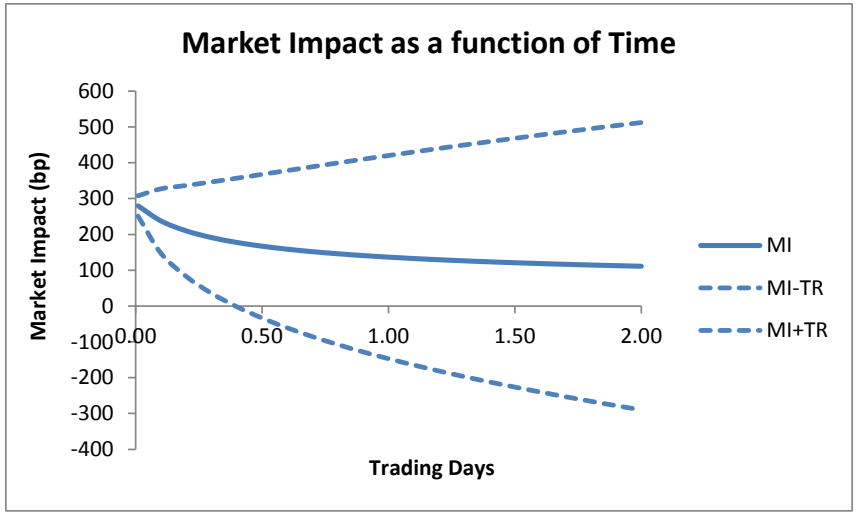
* updated on a weekly basis

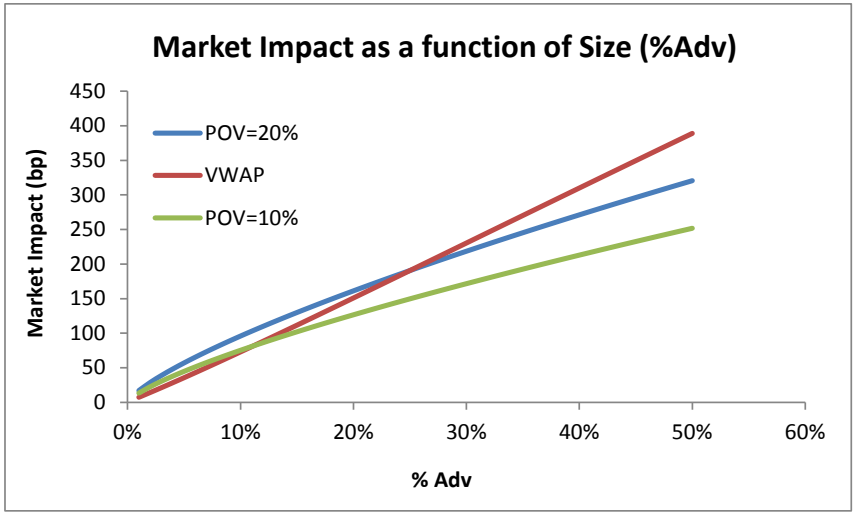
$$I_{bp}^{*} = \hat{a}_1 \cdot Size^{\hat{a}_2} \cdot \sigma^{\hat{a}_3}$$

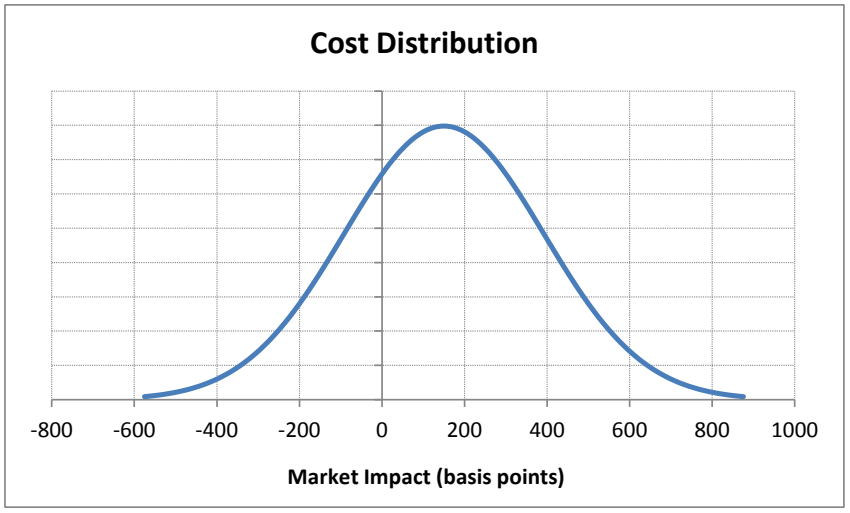
$$MI_{bp} = \hat{b}_1 \cdot I^{*} \cdot POV^{\hat{a}_4} + \left(1 - \hat{b}_1\right) \cdot I^{*}$$

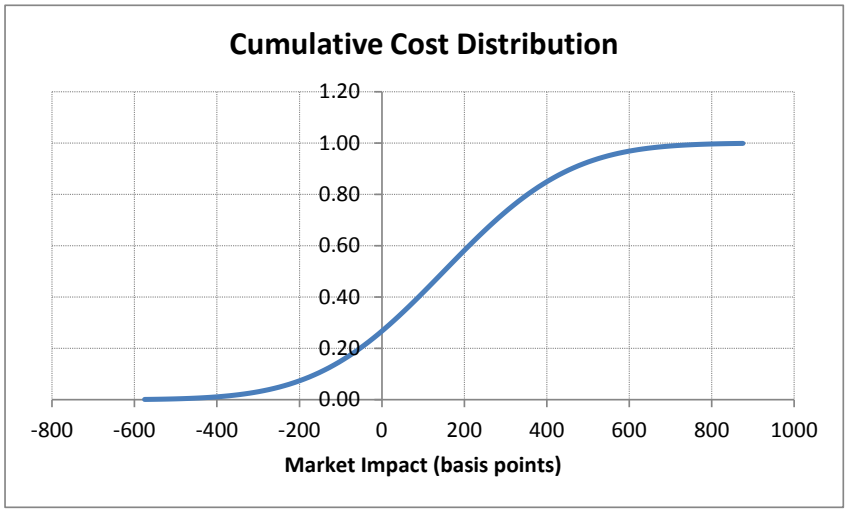
Source: Optimal Trading Strategies, Science of Algorithmic Trading and Portfolio Management

Cost Analysis – Single Stock & Baskets









Source: Science of Algorithmic Trading and Portfolio Management, Elsevier (2013)

Cost Curves – Global Stocks & ETFs

1Q-2013: US Large Cap Stocks

Order Size	Trading Strategy								
	1-day	Percentage of Volume (POV Rate)							
%ADV	VWAP	5%	10%	15%	20%	25%	30%	35%	40%
1%	1.7	3.2	4.3	5.1	5.8	6.4	6.9	7.4	7.9
5%	8.7	8.9	11.9	14.2	16.1	17.7	19.1	20.5	21.7
10%	17.7	13.8	18.5	22.0	24.9	27.4	29.6	31.7	33.6
15%	26.7	17.8	23.8	28.3	32.1	35.3	38.2	40.9	43.4
20%	35.6	21.3	28.6	34.0	38.5	42.4	45.8	49.0	52.0
25%	44.3	24.6	32.9	39.1	44.3	48.8	52.8	56.4	59.8
30%	52.8	27.5	36.9	43.9	49.7	54.7	59.2	63.3	67.1
35%	61.2	30.3	40.6	48.3	54.7	60.3	65.2	69.8	73.9
40%	69.5	33.0	44.2	52.6	59.5	65.6	71.0	75.9	80.4
45%	77.6	35.6	47.6	56.6	64.1	70.6	76.4	81.7	86.6
50%	85.5	38.0	50.9	60.5	68.5	75.4	81.7	87.3	92.6

1Q-2013: US Small Cap Stocks

Order Size	Trading Strategy								
	1-day	Percentage of Volume (POV Rate)							
%ADV	VWAP	5%	10%	15%	20%	25%	30%	35%	40%
1%	2.5	5.3	7.6	9.5	11.1	12.6	13.9	15.2	16.4
5%	11.1	11.3	16.3	20.3	23.7	26.9	29.8	32.5	35.1
10%	21.5	15.7	22.6	28.1	33.0	37.3	41.3	45.1	48.7
15%	31.6	19.1	27.4	34.1	39.9	45.2	50.1	54.7	59.0
20%	41.4	21.8	31.3	39.0	45.7	51.8	57.4	62.6	67.6
25%	50.8	24.3	34.8	43.4	50.8	57.6	63.8	69.6	75.1
30%	60.0	26.5	38.0	47.3	55.4	62.7	69.5	75.9	81.8
35%	68.9	28.5	40.8	50.9	59.6	67.5	74.8	81.6	88.0
40%	77.5	30.3	43.5	54.2	63.5	71.9	79.7	86.9	93.8
45%	85.8	32.1	46.0	57.3	67.1	76.0	84.2	91.9	99.1
50%	93.9	33.7	48.3	60.2	70.5	79.9	88.5	96.6	104.2

1Q-2013: Canada Large Cap Stocks

Order Size	Trading Strategy								
	1-day	Percentage of Volume (POV Rate)							
%ADV	VWAP	5%	10%	15%	20%	25%	30%	35%	40%
1%	1.6	3.6	5.1	6.2	7.2	8.1	8.9	9.6	10.3
5%	8.9	9.1	12.9	15.8	18.3	20.5	22.5	24.4	26.1
10%	18.4	13.6	19.3	23.7	27.4	30.7	33.7	36.4	39.0
15%	27.9	17.3	24.4	29.9	34.6	38.8	42.6	46.1	49.3
20%	37.3	20.4	28.8	35.4	40.9	45.9	50.3	54.4	58.3
25%	46.6	23.2	32.8	40.3	46.6	52.2	57.3	62.0	66.3
30%	55.7	25.8	36.5	44.8	51.8	58.0	63.7	68.9	73.7
35%	64.6	28.2	39.9	48.9	56.6	63.4	69.6	75.3	80.6
40%	73.4	30.5	43.1	52.9	61.2	68.5	75.2	81.4	87.1
45%	82.0	32.6	46.1	56.6	65.5	73.4	80.5	87.1	93.3
50%	90.4	34.7	49.1	60.2	69.6	78.0	85.6	92.6	99.2

1Q-2013: Canada Small Cap Stocks

Order Size	Trading Strategy								
	1-day	Percentage of Volume (POV Rate)							
%ADV	VWAP	5%	10%	15%	20%	25%	30%	35%	40%
1%	1.6	3.2	4.4	5.3	6.1	6.8	7.4	8.0	8.6
5%	8.8	9.0	12.4	15.1	17.3	19.3	21.1	22.8	24.3
10%	18.7	14.2	19.5	23.7	27.2	30.3	33.1	35.8	38.2
15%	28.8	18.4	25.4	30.8	35.4	39.5	43.1	46.5	49.7
20%	39.1	22.2	30.6	37.1	42.7	47.6	52.0	56.1	59.9
25%	49.3	25.7	35.4	42.9	49.3	55.0	60.1	64.9	69.3
30%	59.5	28.9	39.8	48.3	55.5	61.9	67.7	73.0	78.0
35%	69.7	32.0	44.0	53.4	61.4	68.4	74.8	80.7	86.2
40%	79.7	34.9	48.0	58.3	67.0	74.6	81.6	88.1	94.1
45%	89.6	37.6	51.9	62.9	72.3	80.6	88.1	95.1	101.6
50%	99.4	40.3	55.5	67.4	77.4	86.3	94.4	101.8	108.8

I-Star Cost Curves are available across all Regions and across All Global Equities & ETFs

Source: Science of Algorithmic Trading and Portfolio Management, Elsevier (2013)

SECTION 2

Deciphering Black Box Models: Pre-Trade of Pre-Trades

How do we decipher black box models

Simplified I-Star model

$$MI_{bp} = \hat{a}_1 \cdot Size^{\hat{a}2} \cdot \sigma^{\hat{a}3} \cdot POV^{\hat{a}4}$$

$$\ln(MI) = \ln(\hat{a}_1) + \hat{a}_2 \cdot \ln(Size) + \hat{a}_3 \cdot \ln(\sigma) + \hat{a}_4 \cdot \ln(POV)$$

Solution:

- Largest explanatory factors of trading cost are: Size, Volatility, and Trading Rate
- Use vendor pre-trade cost estimates as model input (LHS)
- Vendor estimates are always positive
- Log transformation, OLS regression

Source: Science of Algorithmic Trading and Portfolio Management

Pre-Trade of Pre-Trades

- Obtain cost estimates from multiple vendors
- Request costs for same stocks, sizes, and pov rates
- Use various sizes and strategies
    - from VWAP to aggressive POV rates
- Combine all vendor cost estimates as model input (LHS)
- Use simplified I-Star model
    - Solve using OLS Regression

Source: Creating Dynamic Pre-Trade Models: Beyond the Black Box, Journal of Trading, Fall 2011

Pre-Trade of Pre-Trades

I-Star: Pre-Trade of Pre-Trades - Example						
Stock	Size	Volt.	POV	Vendor I	Vendor II	Vendor III
RLK	1%	20%	20%	9.2	17.9	15.3
RLK	1%	20%	10%	7.5	9.2	9.3
RLK	1%	20%	5%	5.0	6.8	6.6
RLK	5%	20%	20%	28.1	35.4	26.8
RLK	5%	20%	10%	12.1	16.4	17.8
RLK	5%	20%	5%	6.4	6.4	9.1
RLK	10%	20%	20%	38.4	33.6	32.4
RLK	10%	20%	10%	17.2	21.0	17.2
RLK	10%	20%	5%	11.4	15.7	16.0
RLK	20%	20%	20%	39.5	43.1	41.1
RLK	20%	20%	10%	18.1	22.1	37.5
RLK	20%	20%	5%	6.7	20.1	16.4
ABC	1%	30%	20%	17.4	19.4	16.3
ABC	1%	30%	10%	7.2	14.3	12.8
ABC	1%	30%	5%	6.9	9.7	8.4
ABC	5%	30%	20%	35.0	39.6	34.4
ABC	5%	30%	10%	22.0	31.4	24.1
ABC	5%	30%	5%	11.0	12.4	15.1
ABC	10%	30%	20%	46.0	44.5	42.0
ABC	10%	30%	10%	24.4	34.6	29.1
ABC	10%	30%	5%	18.8	21.5	19.4
ABC	20%	30%	20%	57.5	55.4	51.4
ABC	20%	30%	10%	31.4	39.4	33.4
ABC	20%	30%	5%	22.1	23.4	26.5

Combined Cost Estimates - All Vendors - RLK					
		Log Transformation			
		LHS	RHS		
Stock	Vendor	LnCost	LnSize	LnVolt.	LnPOV
RLK	I	2.22	-4.61	-1.61	-1.61
RLK	I	2.01	-4.61	-1.61	-2.30
RLK	I	1.61	-4.61	-1.61	-3.00
RLK	I	3.34	-3.00	-1.61	-1.61
RLK	I	2.49	-3.00	-1.61	-2.30
RLK	I	1.86	-3.00	-1.61	-3.00
RLK	I	3.65	-2.30	-1.61	-1.61
RLK	I	2.84	-2.30	-1.61	-2.30
RLK	I	2.43	-2.30	-1.61	-3.00
RLK	I	3.68	-1.61	-1.61	-1.61
RLK	I	2.90	-1.61	-1.61	-2.30
RLK	I	1.90	-1.61	-1.61	-3.00
RLK	II	2.88	-4.61	-1.61	-1.61
RLK	II	2.22	-4.61	-1.61	-2.30
RLK	II	1.92	-4.61	-1.61	-3.00
RLK	II	3.57	-3.00	-1.61	-1.61
RLK	II	2.80	-3.00	-1.61	-2.30
RLK	II	1.86	-3.00	-1.61	-3.00
RLK	II	3.51	-2.30	-1.61	-1.61
RLK	II	3.04	-2.30	-1.61	-2.30
RLK	II	2.75	-2.30	-1.61	-3.00
RLK	II	3.76	-1.61	-1.61	-1.61
RLK	II	3.10	-1.61	-1.61	-2.30
RLK	II	3.00	-1.61	-1.61	-3.00
RLK	III	2.73	-4.61	-1.61	-1.61
RLK	III	2.23	-4.61	-1.61	-2.30
RLK	III	1.89	-4.61	-1.61	-3.00
RLK	III	3.29	-3.00	-1.61	-1.61
RLK	III	2.88	-3.00	-1.61	-2.30
RLK	III	2.21	-3.00	-1.61	-3.00
RLK	III	3.48	-2.30	-1.61	-1.61
RLK	III	2.84	-2.30	-1.61	-2.30
RLK	III	2.77	-2.30	-1.61	-3.00
RLK	III	3.72	-1.61	-1.61	-1.61
RLK	III	3.62	-1.61	-1.61	-2.30
RLK	III	2.80	-1.61	-1.61	-3.00

Source: Creating Dynamic Pre-Trade Models: Beyond the Black Box, Journal of Trading, Fall 2011

Pre-Trade of Pre-Trades

Pre-Trade of Pre-Trades - Regression Results				
	Ln_a1	a2	a3	a4
Est.	6.84	0.36	0.89	0.69
se	0.21	0.02	0.12	0.04
t-stat	31.95	15.79	7.21	15.63
seY	0.21			
R2	0.89			
F-Stat	181.91			

Remember

$$x \sim \ln \mathrm{N}\left(\mu, \sigma^2\right)$$

$$E\left(x\right) = e^{\mu + 0.5\sigma^2}$$

$$\ln\left(MI\right) = 6.84 + 0.36 \cdot \ln\left(Size\right) + 0.89 \cdot \ln\left(\sigma\right) + 0.64 \cdot \ln\left(POV\right)$$

$$MI = 957 \cdot Size^{0.36} \cdot \sigma^{0.89} \cdot POV^{0.69}$$

Source: Creating Dynamic Pre-Trade Models: Beyond the Black Box, Journal of Trading, Fall 2011

Dynamic Models

- Investors can infer essential information from black box models
- Simplified I-Star provides vehicle to decipher relationships
- Investors can utilize data provided by multiple vendors to construct their own model
- Allows incorporation of own market views corresponding to volatility & liquidity, as well as proprietary alpha signals.
- All analyses are independent of B/D or vendor
- Allows “what-if” and “sensitivity” analysis

$$MI = 957 \cdot Size^{0.36} \cdot \sigma^{0.89} \cdot POV^{0.69}$$

Source: Optimal Trading Strategies, Science of Algorithmic Trading, Journal of Trading (Fall 2011)

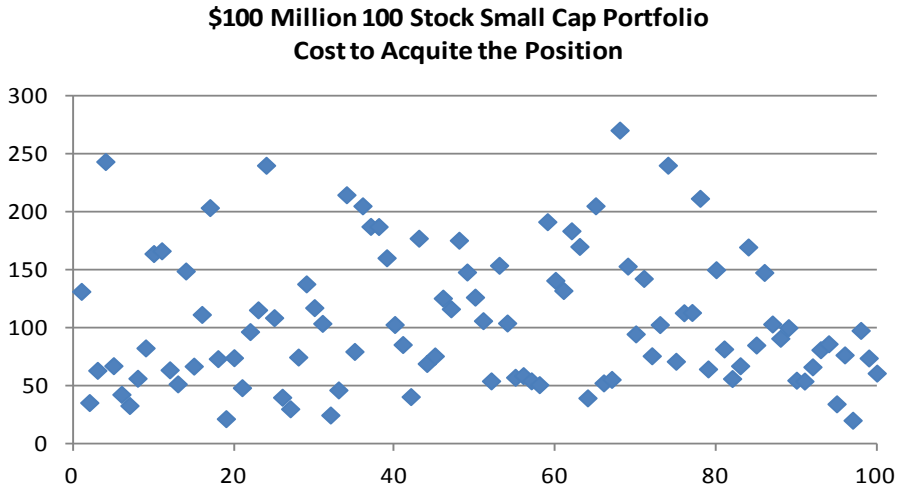
SECTION 3

Portfolio Analysis

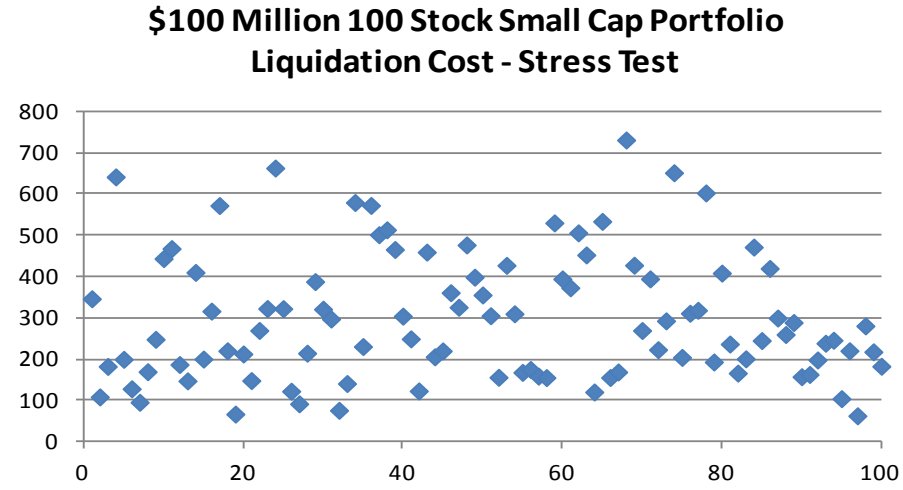
Transparent Market Impact Model

- 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"



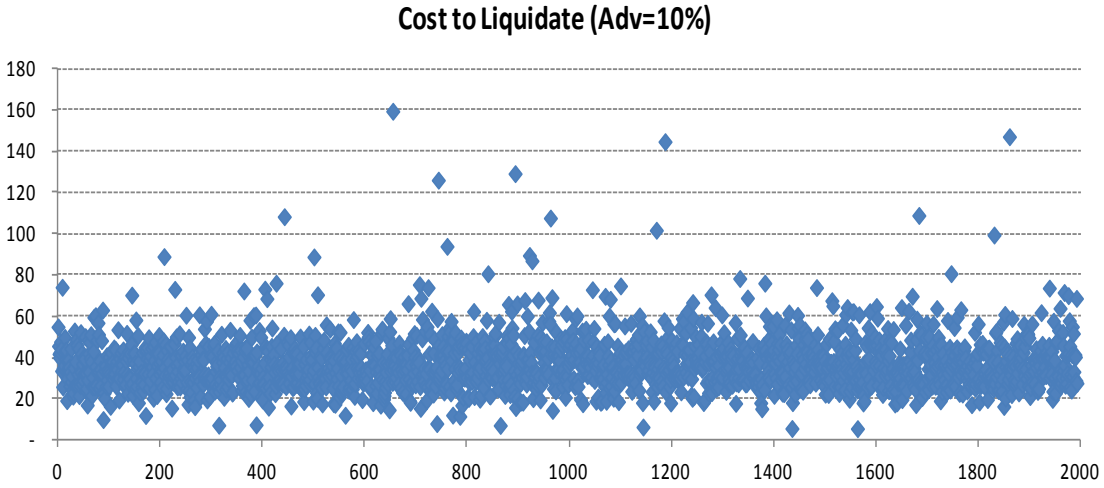
- $100 million investment in a 100 stock small cap portfolio (market cap weighted)
- MI models provide cost estimates under current market conditions.
- These are usually the most appealing market conditions since the stock is being considered for inclusion in the investment portfolio.
- Average Cost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

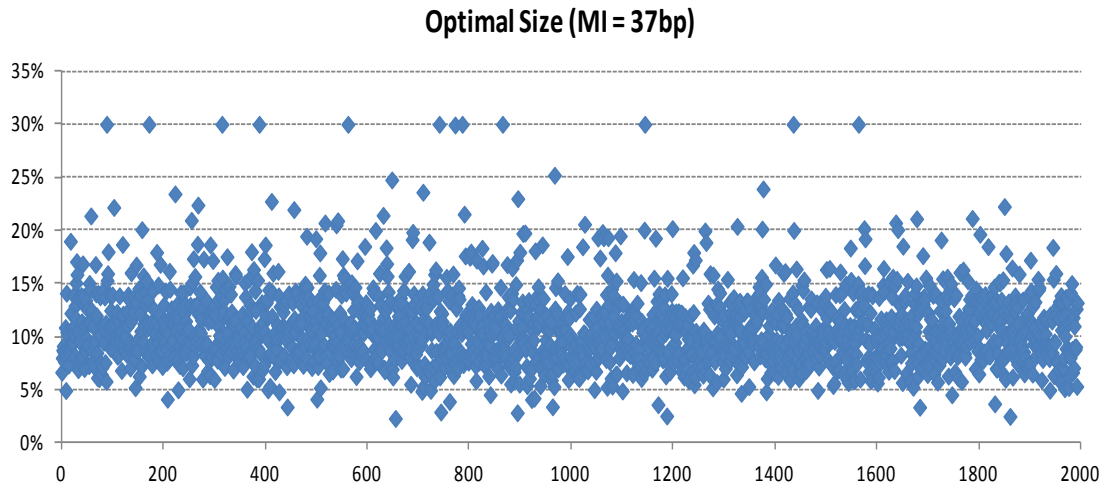


- Stress Test of the same $100 million 100 stock small cap portfolio.
- But here we perform a stress test of costs.
- We consider the impact cost to liquidate the position in a market environment where volatility doubles and liquidity halves.
- A more realistic representation of trading cost when we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

Source: Science of Algorithmic Trading and Portfolio Management, Bloomberg, Yahoo Finance

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.

Source: Science of Algorithmic Trading and Portfolio Management, Bloomberg, Yahoo Finance.

SECTION 3A

Quant MI Factor Scorecard

MI Factor Score

MI Factor Score:

- Provides a “score” across stocks to estimate the market impact cost for “equivalent” share quantities or dollar value to invest.
- Incorporates the market impact model, and stock specific trading characteristics such as liquidity, volatility, and market price.
- Allows PMs to screen stocks and specific indexes to determine the more expensive and difficult names to trade.
- Improvement over screening methodologies that only consider liquidity (e.g., hold 10% Adv max) and/or volatility.

Developing a MI Factor Score

Starting with I-Star Model:

$$I^* = \hat{a}_1 \cdot \left(\frac{S}{ADV}\right)^{\hat{a}2} \cdot \sigma^{\hat{a}3}$$

Rearrange the equation:

$$I^*(Share) = \left\{\hat{a}_1 \cdot \sigma^{\hat{a}3} \cdot \left(\frac{1}{ADV}\right)^{\hat{a}2}\right\} \cdot S^{\hat{a}2}$$

$$I^*(Dollar\$) = \left\{\hat{a}_1 \cdot \sigma^{\hat{a}3} \cdot \left(\frac{1}{ADV}\right)^{\hat{a}2}\right\} \cdot \left(\frac{Dollars\$}{P}\right)^{\hat{a}2}$$

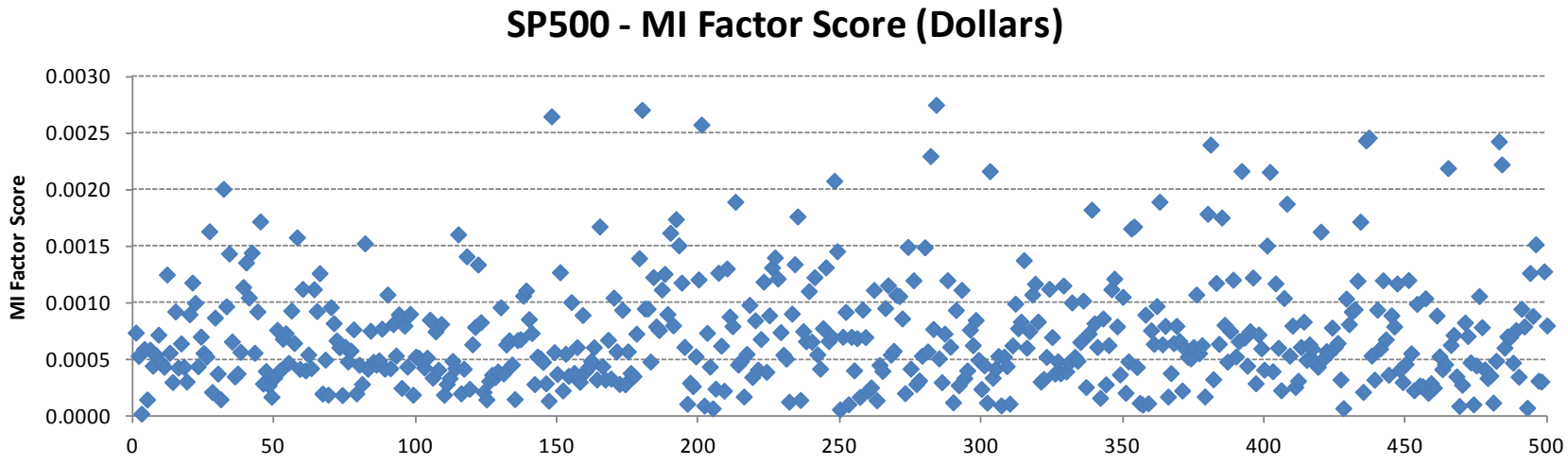
We have our MI Factor score:

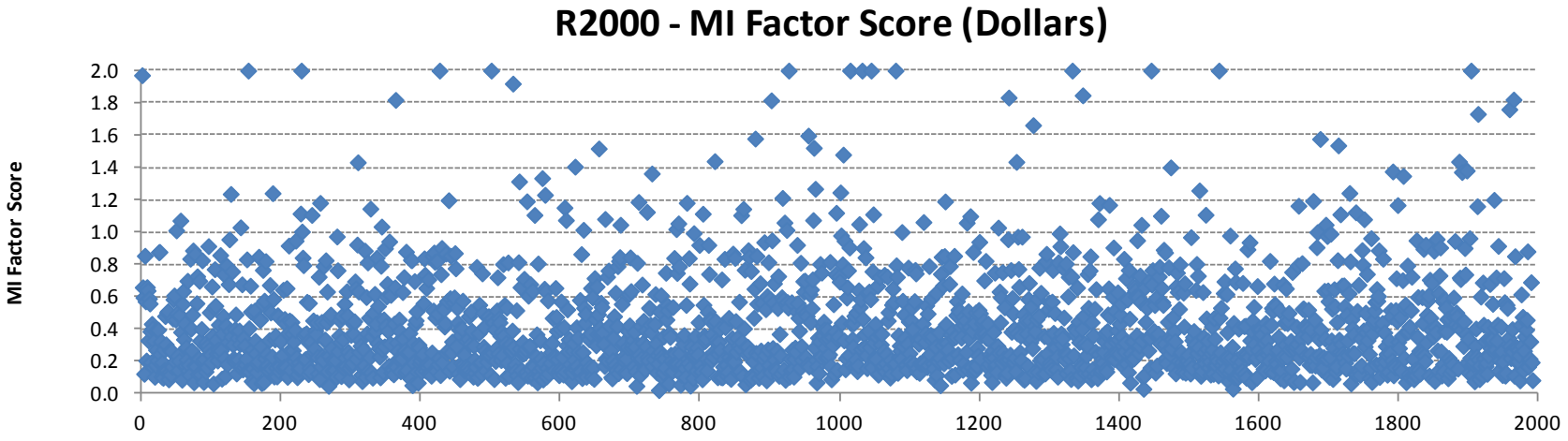
$$\alpha^*(Shares) = \hat{a}_1 \cdot \sigma^{\hat{a}3} \cdot \left(\frac{1}{ADV}\right)^{\hat{a}2}$$

$$\alpha^*(Dollars\$) = \hat{a}_1 \cdot \sigma^{\hat{a}3} \cdot \left(\frac{1}{ADV}\right)^{\hat{a}2} \cdot \left(\frac{1}{P}\right)^{\hat{a}2}$$

Source: Algorithmic Trading Strategies, Kissell (2006)

Comparison of MI Factor Scores (Dollars)





Source: Science of Algorithmic Trading, Bloomberg, Yahoo Finance

SECTION 3B

Alpha Capture Curves

Alpha Capture Curves

Alpha Capture Curves:

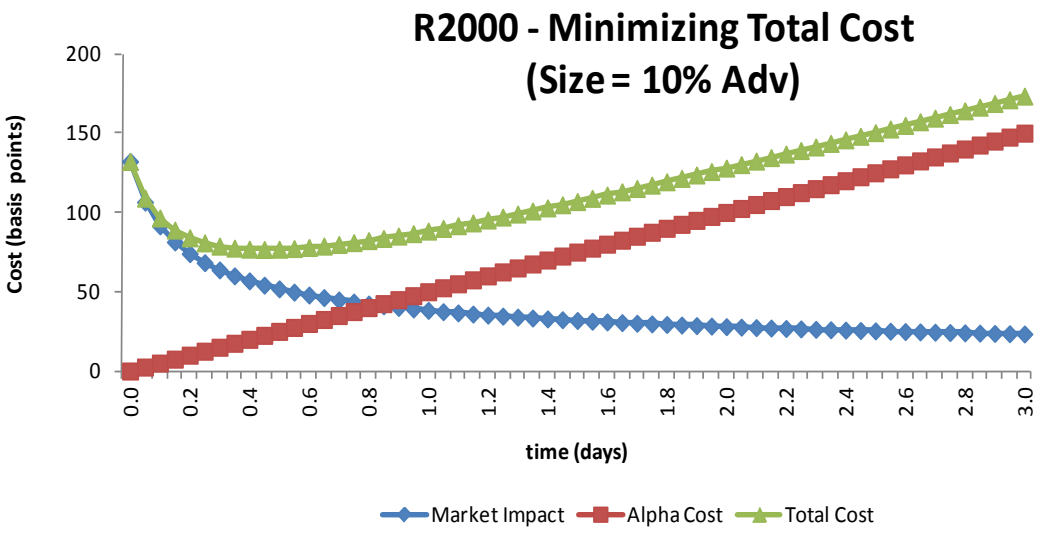
The portfolio manager's answer to trader Cost Curves

Question?

- Stock is expected to increase 3% in next 3 days (linear trend)
- Next most attractive investment will increase 2% in next 3 days
- Economic Opportunity Cost = 2%

- How much alpha can I capture?
- How much should I invest?
- How can we use TCA to help answer these questions?

Alpha Capture Curves



Trade Characteristics			Analysis Results (basis points)			Profit Analysis (bp)	
Size:	10%		Size:	10%		Size	Net Profit
Volatility:	43%		Volatility:	28%		1%	282
Alpha/day (bp):	100					5%	250
Alpha/total (bp):	300		Min Total Cost:	77		**10%**	**223**
			market impact:	54		15%	201
			alpha cost:	23		**20%**	**182**
			time:	0.45		25%	164
						30%	148
			Alpha 3 days (bp):	300			
			Net Profit (bp)	223			

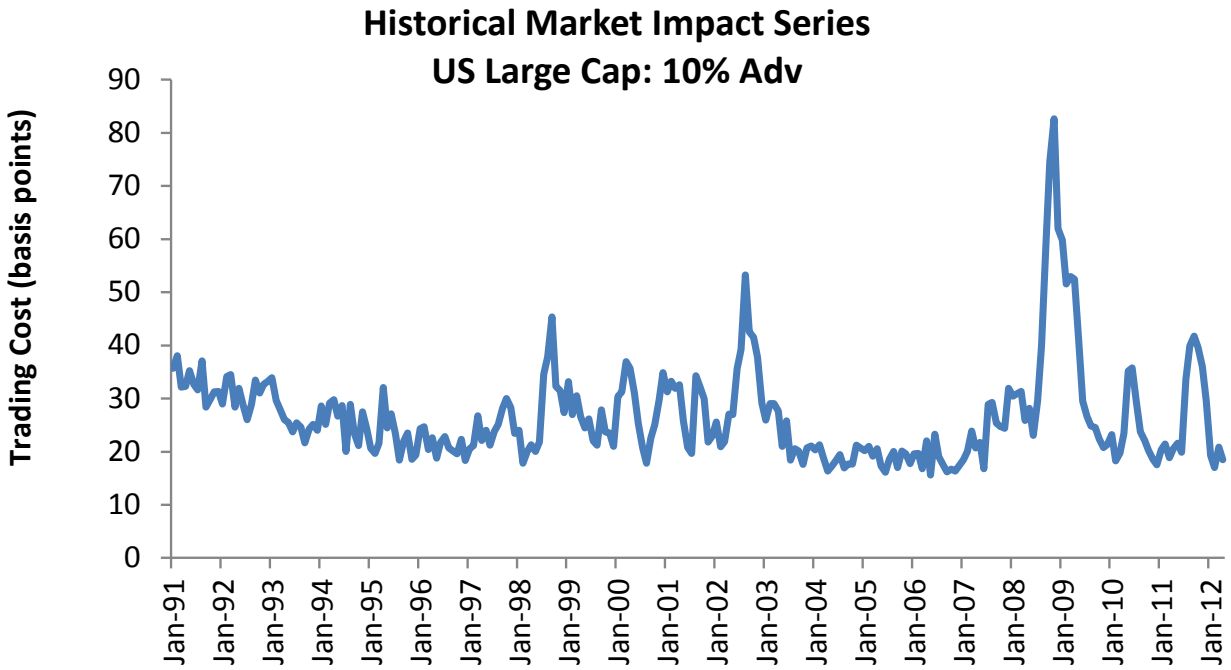
- The graph to the left shows how both market impact and alpha evolve over time.
- Maximum "alpha capture" occurs at the point where the sum of market impact cost and alpha trend are minimized (our Total Cost curve).
- To maximize total revenue, the goal of the portfolio manager is to determine the maximum number of shares that could be purchased such that the "alpha capture" will be equal to the true investment "economic" opportunity cost.
- In this example, the goal is to determine the number of shares that can be purchased such that the net profit will be equal to the profit opportunity of the next most attractive investment option (in this example 200bp).
- An order size of 20% Adv meets this criteria and is the optimal "capacity" size.
- An "alpha capture" analysis provides expected cost and profit, as well as means to determine if the proposed position size should be reduced or increased. That is, the "capacity" of the investment idea.

Source: Science of Algorithmic Trading, Bloomberg, Yahoo Finance

SECTION 3C

Back-Testing

Back-Testing – Portfolio Construction

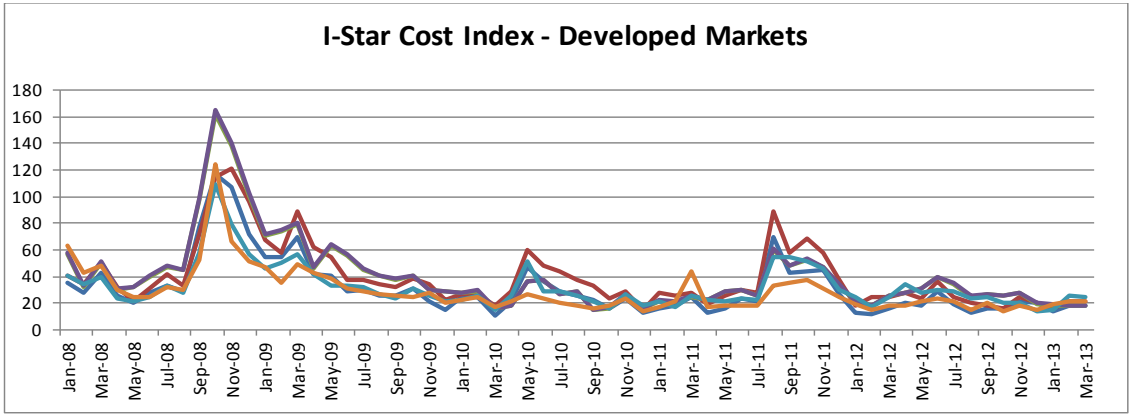


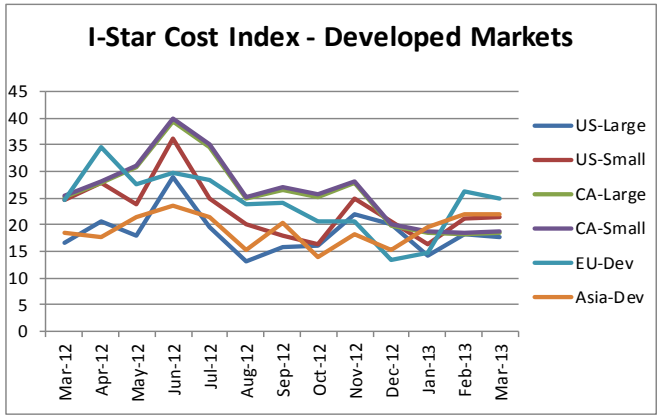
- Historical trading cost indexes: regions, countries, and indexes (1991 – present)
- Back-test investment ideas via portfolio optimization
- Expected cost that investors would have incurred historically based on today's market environment, e.g., decimalization, electronic, algorithms, dark pools, internal 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.

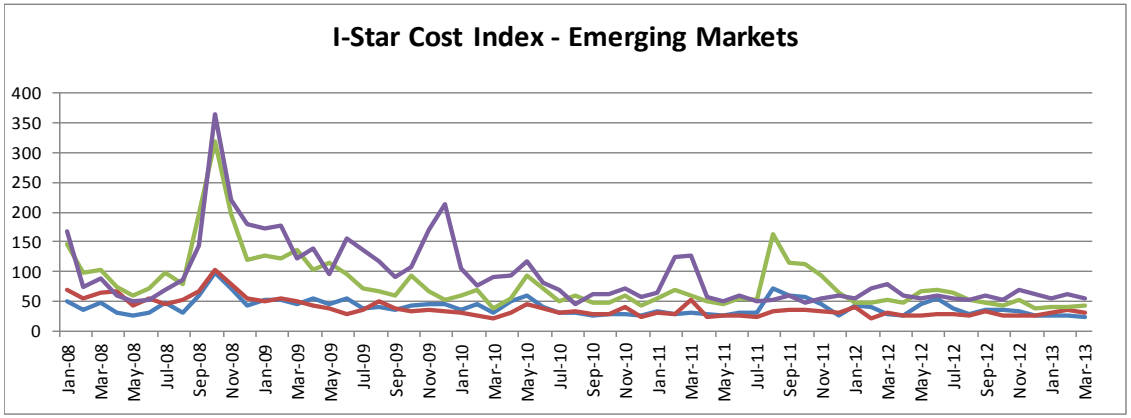
"The above has been derived from back tested data. Past performance is not indicative of future performance. Please refer to the Back Tested disclaimer at the end of this presentation for important additional information."

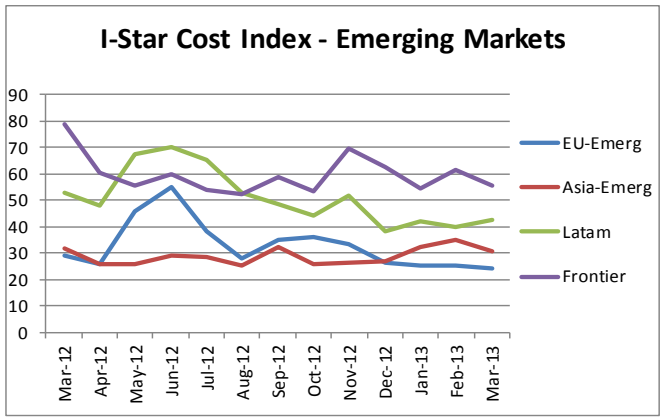
Source: Science of Algorithmic Trading and Portfolio Management

Historical Cost Curves – Global Regions



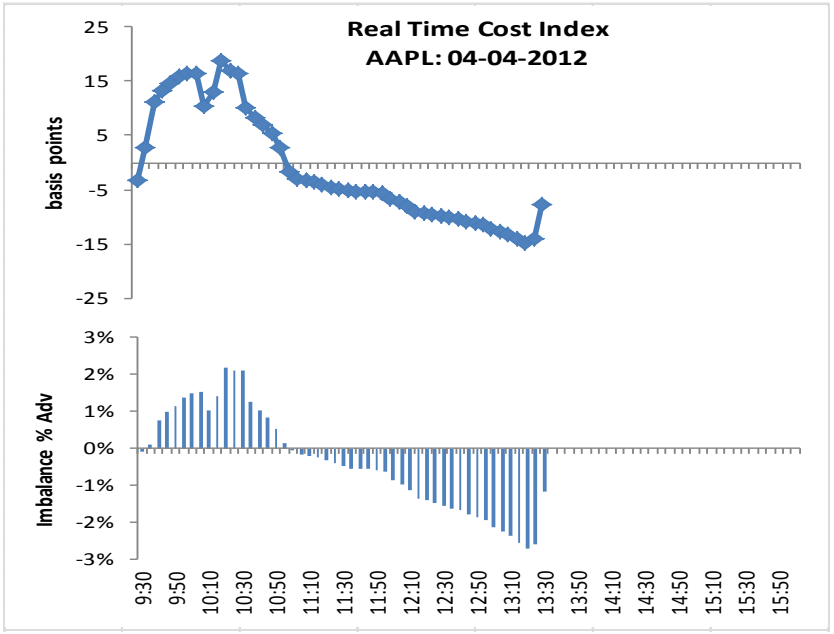


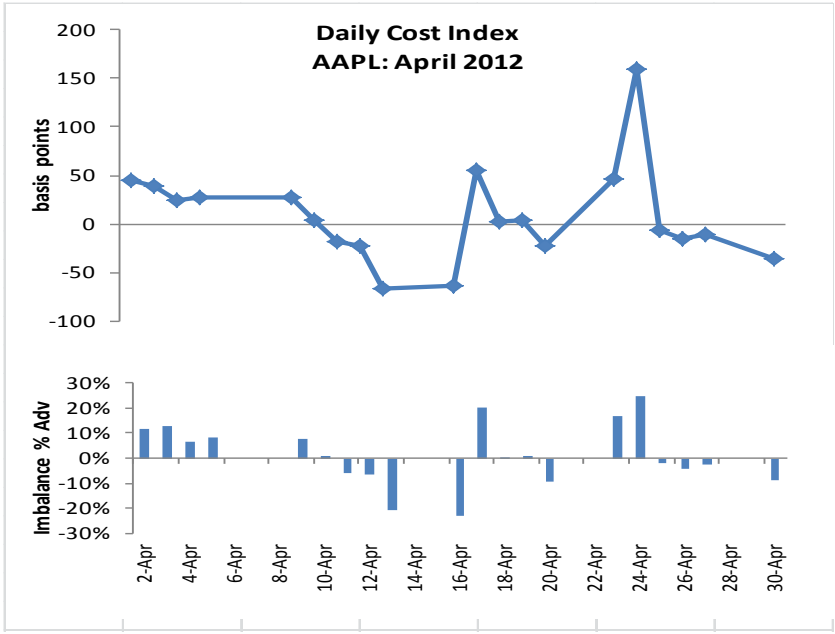




Source: Science of Algorithmic Trading and Portfolio Management

Real-Time Cost Index





Real-Time Cost Index

- Provides real-time "Cost of Trading"
- Based on current market conditions and trading activity
- Intraday Buy-Sell Imbalance and corresponding Market Impact cost.
- Allows Traders and evaluate trading performance and critique brokers and algorithms during the trading day.
- Determine the "cost of trading" over a specified trading interval such as 10:30am to 1:00pm.

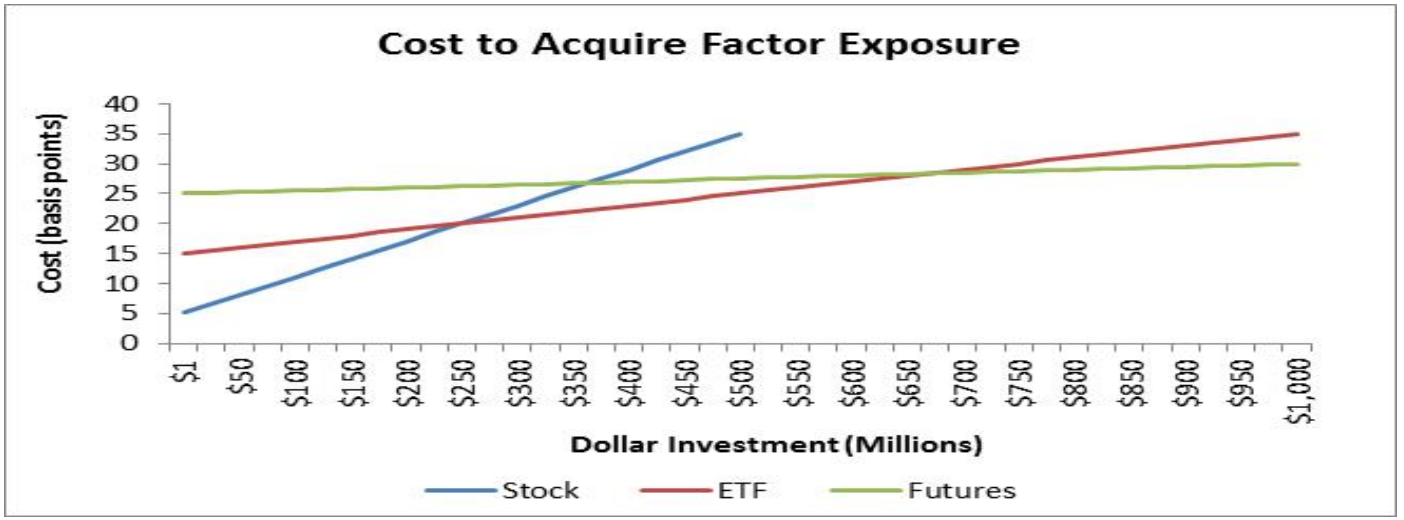
Historical Trading Cost Index

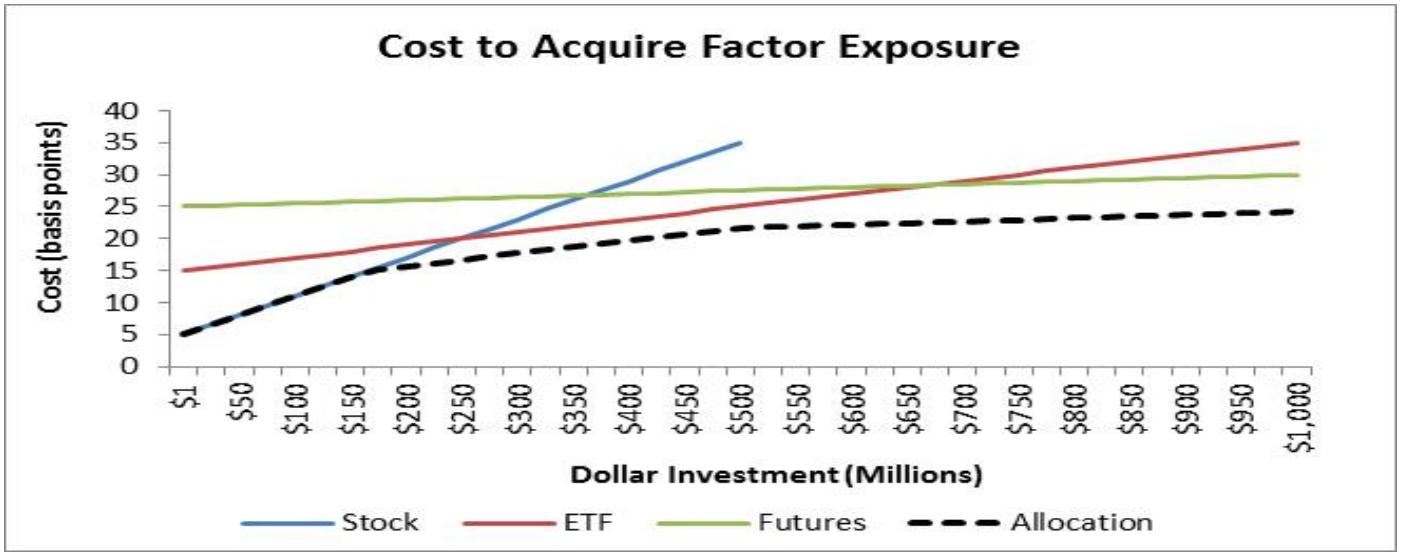
- Provides historical "Cost of Trading"
- Based on actual market conditions on the day
- Daily Buy-Sell Imbalance and corresponding Market Impact cost.
- Allows Portfolio Managers to Uncover buying-selling trends in the market
- Determine the "cost of trading" for a particular day or date range.

SECTION 3D

Factor Exposure & Shadow Liquidity

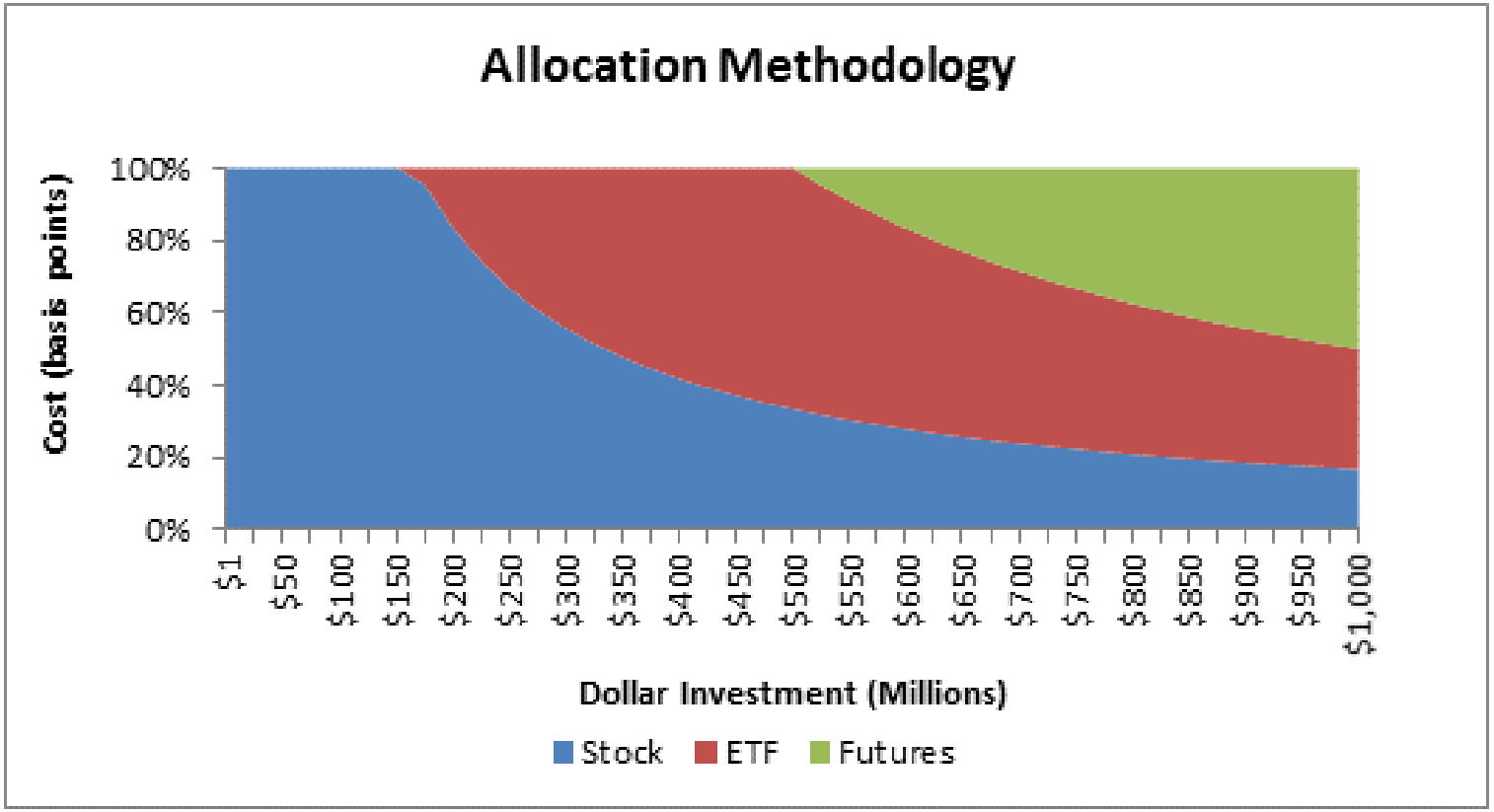
Acquiring Factor Exposure





Source: Science of Algorithmic Trading and Portfolio Management, Elsevier (2013)

Allocation Methodology



Source: Science of Algorithmic Trading and Portfolio Management, Elsevier (2013)

Factor Exposure - 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

Code	Financial Instrument	Avg. Notional
SPY	SPDR S&P 500 ETF Trust	$20,276,415,644
SPYG	SPDR S&P 500 Growth ETF	$723,381
SPYV	SPDR S&P 500 Value ETF	$976,523
IVV	iShares S&P 500 Index Fund/US	$694,854,709
IVW	iShares S&P 500 Growth Index Fund	$57,783,397
IVE	iShares S&P 500 Value Index Fund	$61,200,933
VOO	Vanguard S&P 500 ETF	$120,489,588
VOOG	Vanguard S&P 500 Growth ETF	$628,670
VOOV	Vanguard S&P 500 Value ETF	$616,676
RSP	Guggenheim S&P 500 Equal Weight ETF	$32,145,818
RPG	Guggenheim S&P 500 Pure Growth ETF	$2,615,697
RPV	Guggenheim S&P 500 Pure Value ETF	$1,734,476
	Subtotal	$21,250,185,513
SP500	SP500 Stocks	$138,405,600,000
	Subtotal	$138,405,600,000
ESA	Emini	$3,902,500,000
SP1	SP500 Futures	$3,233,061,433
	Subtotal	$7,135,561,433
Total		$166,791,346,946

Trade Cost Analysis

Param	SPY Analysis	Factor Analysis
a1	1507.5	1507.5
a2	0.38	0.38
a3	0.94	0.94
a4	1.05	1.05
b1	0.97	0.97
Size	99%	12%
Volatility	12%	12%
POV	50%	11%
I-Star	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

Conclusions

- Transparent Market Impact Model - on client's own desktop. Cost analysis, portfolio construction, optimization, back-testing.
- Independent Cost Analysis – own views of market variables, no information leakage
- Pre-Trade of Pre-Trades - a potential means to estimate parameters
- MI Factor Scores –comparison across stocks & indexes, provides an additional quant screening tool
- Alpha Capture – incorporate own proprietary alpha estimates into model
- Back-Testing – optimization w/ TCA
- Factor Exposure – evaluate the best means to acquire the exposure.

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