Northfield 25th Annual Research Conference

Creating Dynamic Pre-Trade Models: Beyond the Black Box

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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

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

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

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

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

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

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

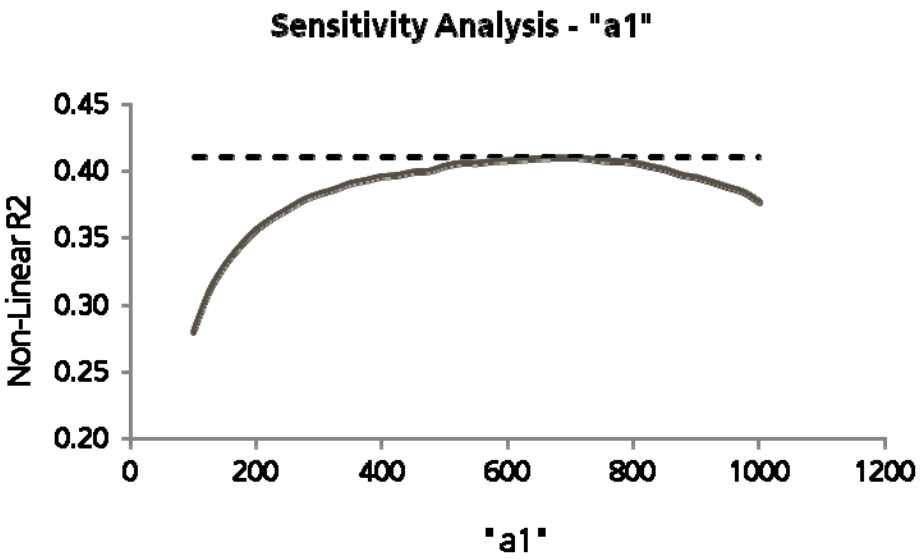
$$MI = Side \cdot \left(\frac{VWAP}{P_0} - 1\right) \cdot 10^4\, bp$$

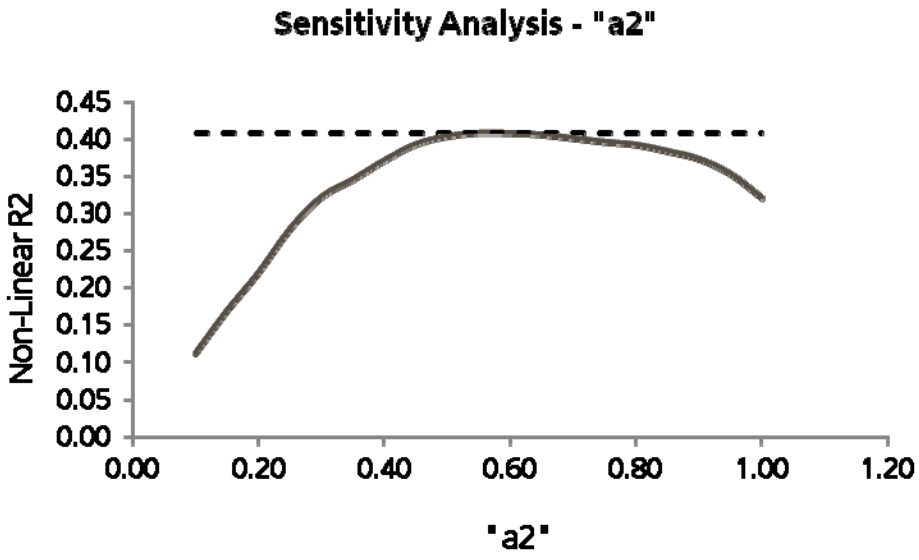
UBS Source: Optimal Trading Strategies, Science of Algorithmic Trading

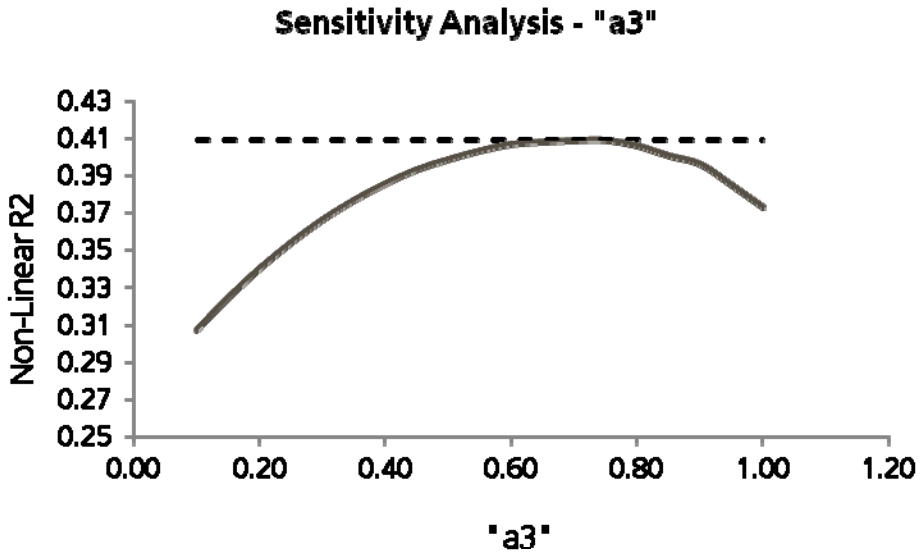
Sensitivity Analysis - Model Parameters

- 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

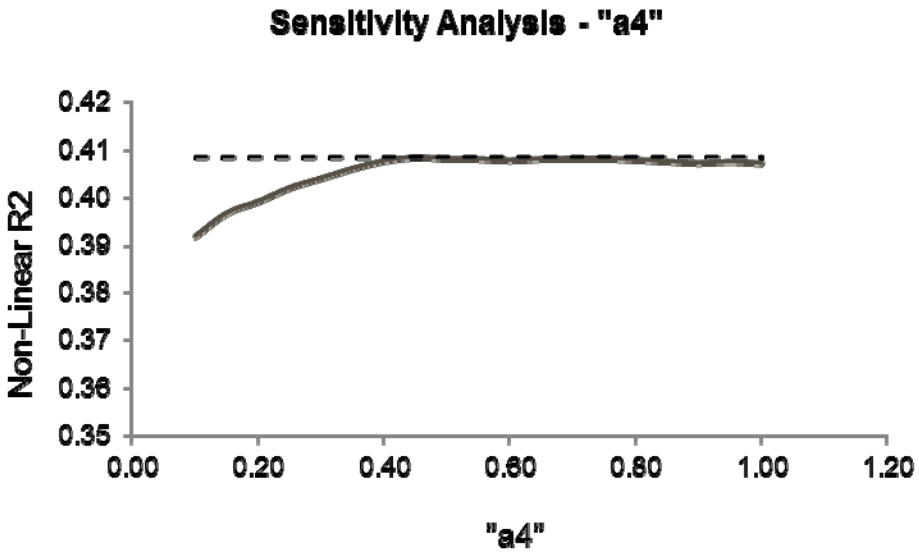


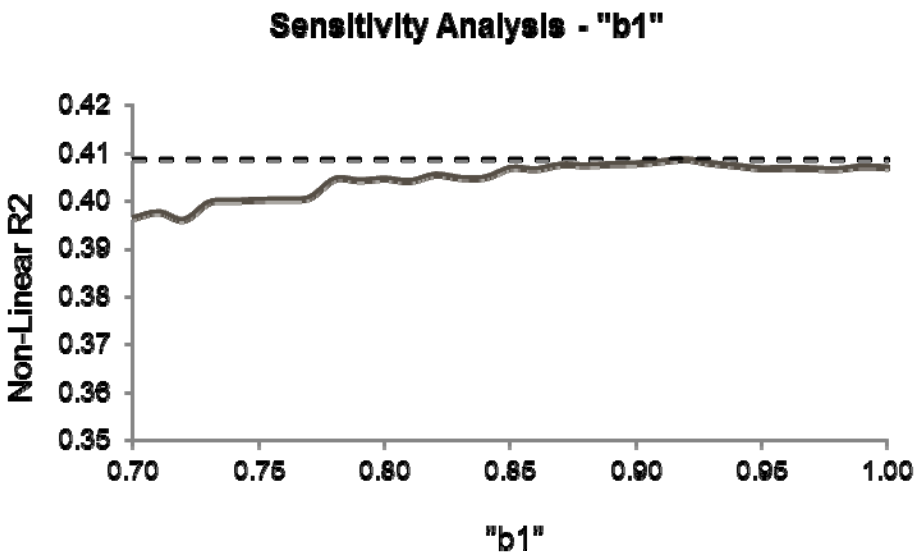




$$I^*_{bp} = \hat{a}_1 \cdot Size^{\hat{a}_2} \cdot \sigma^{\hat{a}_3}$$

Estimating Parameters: Non-Linear R2



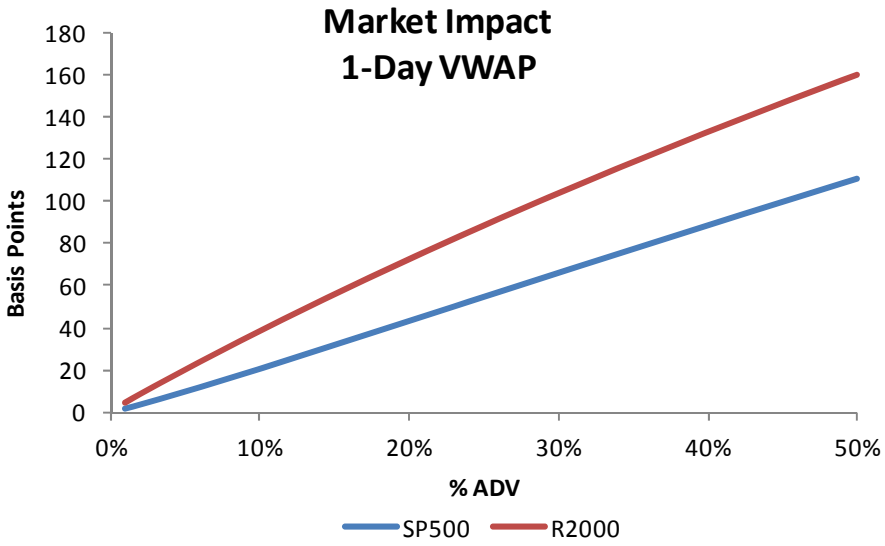


$$MI_{bp} = \hat{b}_1 \cdot I^* \cdot POV^{\hat{a}_4} + \left(1 - \hat{b}_1\right) \cdot I^*$$

Estimated Parameters

Estimated Market Impact Parameters						
Scenario	a1	a2	a3	a4	b1	non-R2
All Data	708	0.55	0.71	0.50	0.98	0.404
SP500	687	0.70	0.72	0.45	0.98	0.422
R2000	702	0.47	0.69	0.55	0.97	0.402

* Estimation Period: 1H2011
* Results are dependent upon the robustness of the dataset.



Source: Science of Algorithmic Trading

Cost Curves

SP500 Index

Order Size	Trading Strategy								
	1-day	Percentage of Volume (POV Rate)							
%ADV	VWAP	5%	10%	15%	20%	25%	30%	35%	40%
1%	2	3	4	5	6	6	7	7	8
5%	10	10	13	16	18	19	21	22	24
10%	20	16	21	25	29	32	34	36	39
15%	32	21	28	34	38	42	45	48	51
20%	43	26	35	41	47	51	55	59	63
25%	54	30	40	48	54	60	65	69	73
30%	66	34	46	55	62	68	74	79	83
35%	77	38	51	61	69	76	82	88	93
40%	88	42	56	67	76	83	90	96	102
45%	99	46	61	72	82	90	98	105	111
50%	110	49	66	78	88	97	105	113	119

R2000 Index

Order Size	Trading Strategy								
	1-day	Percentage of Volume (POV Rate)							
%ADV	VWAP	5%	10%	15%	20%	25%	30%	35%	40%
1%	5	10	14	17	19	22	24	26	28
5%	20	21	29	36	41	46	51	55	59
10%	39	29	40	49	57	64	71	76	82
15%	56	35	49	60	69	78	85	93	99
20%	72	40	56	69	79	89	98	106	114
25%	88	44	62	76	88	99	109	118	126
30%	104	48	68	83	96	108	119	129	138
35%	118	52	73	89	104	116	128	138	148
40%	133	56	78	95	110	124	136	147	158
45%	146	59	82	101	117	131	144	156	167
50%	160	62	86	106	123	137	151	164	176

- Cost curves provide the expected market impact cost for the order size (%Adv) in the left hand column traded via the corresponding strategy shown as the column headings.
- Cost curves are used by traders to select algorithm, appropriate trading time, and in post trade analysis for benchmark comparison.
- Cost curves are used by PMs as part of stock selection and portfolio construction. These estimated values are often integrated into portfolio analysis systems (screens, optimization, etc.).

Source: Science of Algorithmic Trading

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

Deciphering black box models

Table 1. Estimated Market Impact Cost from Vendor I									
Stock	Est Cost	Size	Stdev	POV		LnCost	LnSize	Stdev	LnPOV
RLK	9.2	1%	0.20	20%		2.22	-4.61	-1.61	-1.61
RLK	7.5	1%	0.20	10%		2.01	-4.61	-1.61	-2.30
RLK	5.0	1%	0.20	5%		1.61	-4.61	-1.61	-3.00
RLK	28.1	5%	0.20	20%		3.34	-3.00	-1.61	-1.61
RLK	12.1	5%	0.20	10%		2.49	-3.00	-1.61	-2.30
RLK	6.4	5%	0.20	5%		1.86	-3.00	-1.61	-3.00
RLK	38.4	10%	0.20	20%		3.65	-2.30	-1.61	-1.61
RLK	17.2	10%	0.20	10%		2.84	-2.30	-1.61	-2.30
RLK	11.4	10%	0.20	5%		2.43	-2.30	-1.61	-3.00
RLK	39.5	20%	0.20	20%		3.68	-1.61	-1.61	-1.61
RLK	18.1	20%	0.20	10%		2.90	-1.61	-1.61	-2.30
RLK	6.7	20%	0.20	5%		1.90	-1.61	-1.61	-3.00
ABC	17.4	1%	0.30	20%		2.86	-4.61	-1.20	-1.61
ABC	7.2	1%	0.30	10%		1.97	-4.61	-1.20	-2.30
ABC	6.9	1%	0.30	5%		1.93	-4.61	-1.20	-3.00
ABC	35.0	5%	0.30	20%		3.56	-3.00	-1.20	-1.61
ABC	22.0	5%	0.30	10%		3.09	-3.00	-1.20	-2.30
ABC	11.0	5%	0.30	5%		2.40	-3.00	-1.20	-3.00
ABC	46.0	10%	0.30	20%		3.83	-2.30	-1.20	-1.61
ABC	24.4	10%	0.30	10%		3.19	-2.30	-1.20	-2.30
ABC	18.8	10%	0.30	5%		2.93	-2.30	-1.20	-3.00
ABC	57.5	20%	0.30	20%		4.05	-1.61	-1.20	-1.61
ABC	31.4	20%	0.30	10%		3.45	-1.61	-1.20	-2.30
ABC	22.1	20%	0.30	5%		3.10	-1.61	-1.20	-3.00

Regression Results - Vendor I				
	Ln_a1	a2	a3	a4
Est.	7.34	0.38	1.12	0.81
SE	0.39	0.04	0.23	0.08
t-stat	18.85	9.28	4.94	10.04
R2:	0.91			
SeY:	0.22			
F-Stat.	70.43			

- Fit the Model using the Vendor Cost Estimates
- Vendor Model is a Black Box Model
- We know the main drivers of cost
  - Size, Volatility, & POV
- High $R^2 = 0.91$!!!

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

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

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

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

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

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

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

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

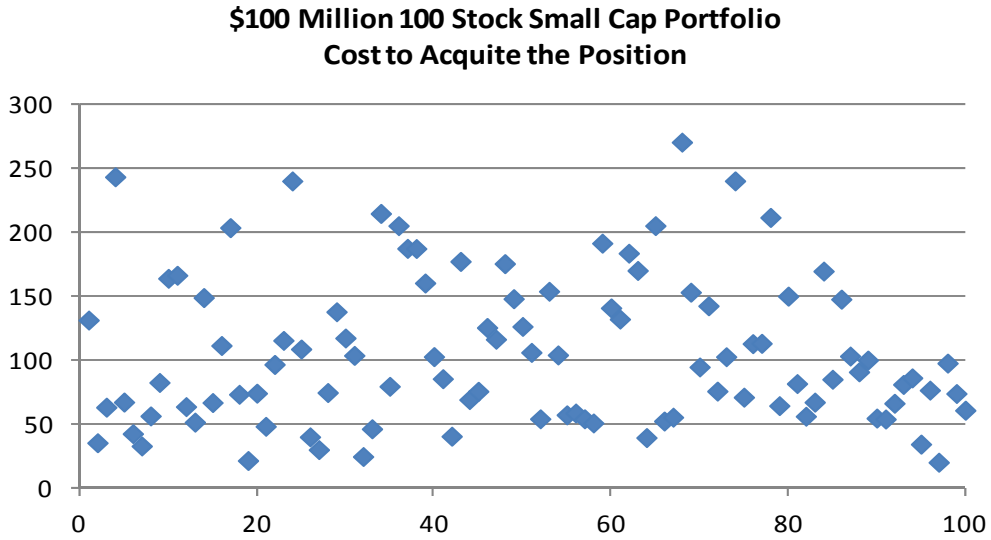
$$MI = 957 \cdot Size^{0.36} \cdot \sigma^{0.89} \cdot POV^{0.69}$$

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

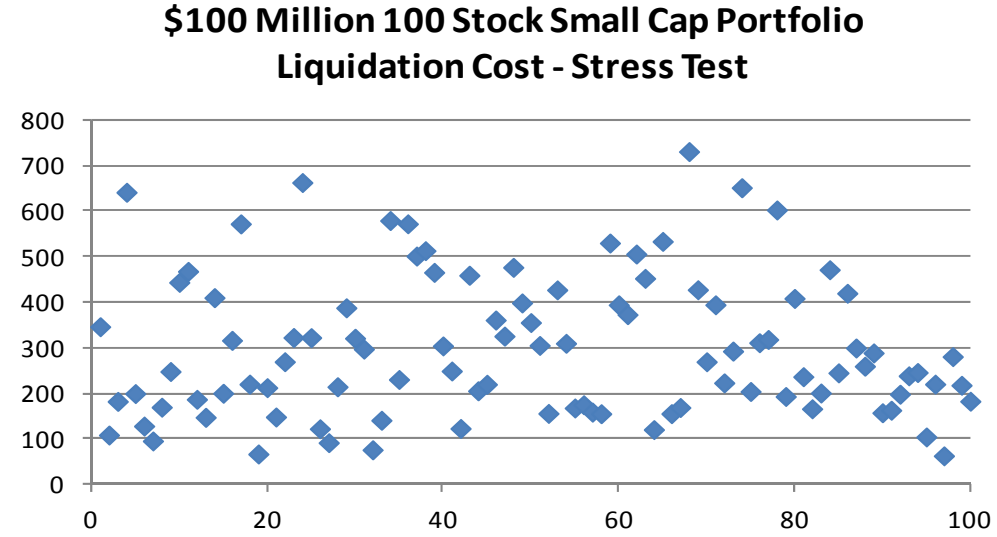
Transparent Market Impact Model

- 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!)

UBS Source: UBS Portfolio Trading, Science of Algorithmic Trading, Bloomberg.

SECTION 3

Portfolio Analysis

Comparison of Indexes

Comparison of Trading Characteristics: June 2012

Index	Avg Dollar Turnover*	Avg Daily Volume*	Avg Price	Avg Volatility	Avg Rho	Median Spread (cps)	Median Spread (bp)
SP500	202,511,240	5,666,180	$54.28	30%	0.57	1.80	3.316
R2000	6,674,599	503,553	$20.34	43%	0.39	10.01	49.159
Net Diff	195,836,641	5,162,627	$33.93	-13%	0.18	-8.21	-45.84
Ratio	30.34	11.25	2.67	0.70	1.45	0.18	0.07

* = stocks level averages, e.g., the average ADV for an SP500 stock was 5,666,180 in June 2012

Estimated MI Parameters *

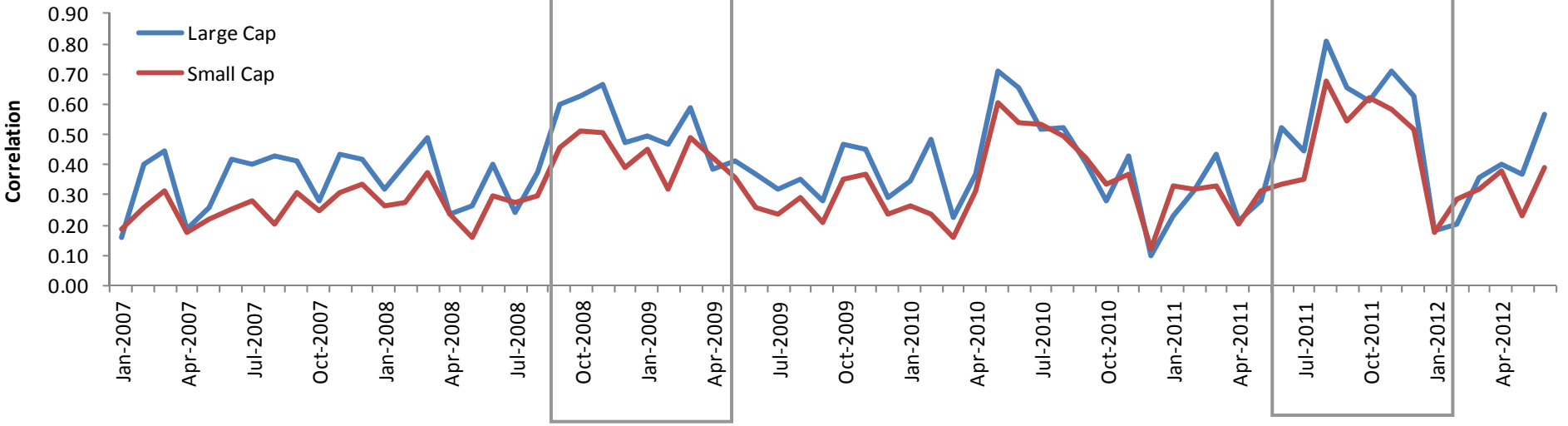
Scenario	a1	a2	a3	a4	b1	R2
All Data	708	0.55	0.71	0.50	0.98	0.404
SP500	687	0.70	0.72	0.45	0.98	0.422
R2000	702	0.47	0.69	0.55	0.97	0.402

* = Estimation Period: 1H2011

Volatility & Correlation – Monthly Trends

Figure: Avg Stock Volatility

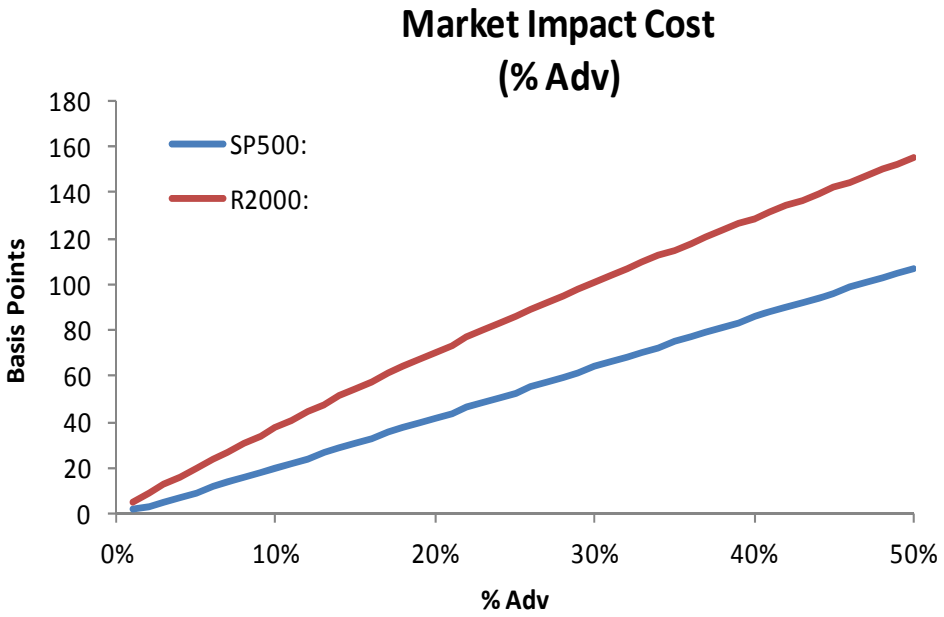
Figure: Avg Pairwise Correlation

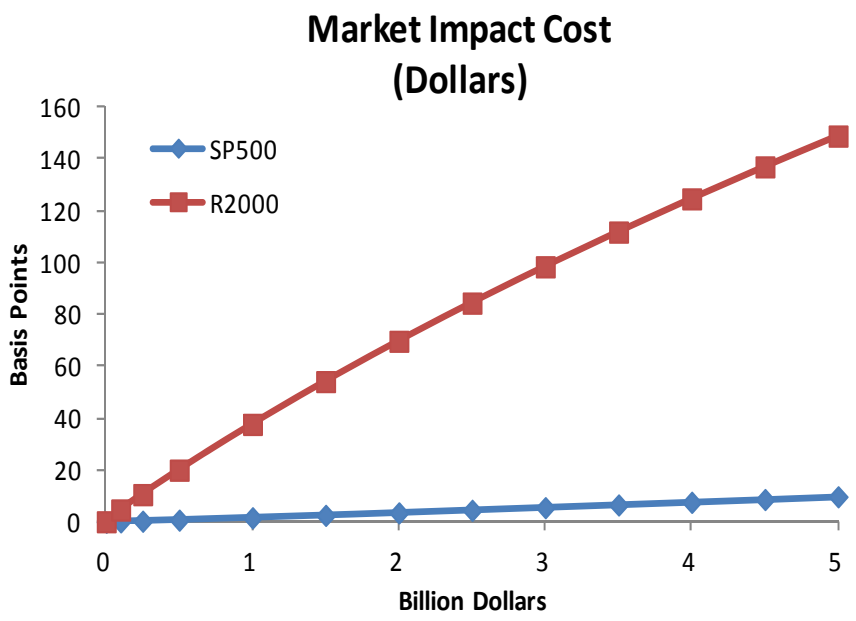


UBS

Source: UBS Portfolio Trading, Bloomberg

Comparison of Market Impact by Index





- Market Impact Cost for specified order size
- R2000 costs are higher for equivalent size
- This is due primarily to spread, volatility, and slighter sensitivity to order flow for the small cap stocks.

- Market Impact Cost for specified investment dollars. Dollar amount is allocated across all stocks in the index based on weight in index.
- R2000 costs are "considerable!" higher than S&P500 cost for equivalent dollars invested
- This is due primarily liquidity and volatility.

UBS

Source: Science of Algorithmic Trading

SECTION 3a

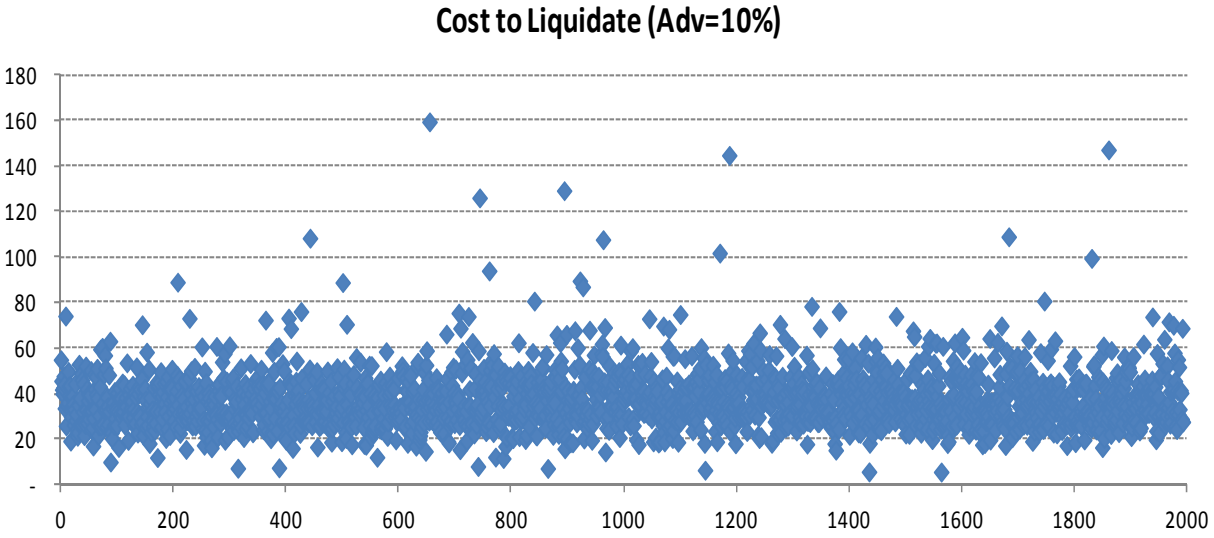
Quant MI Factor Scorecard

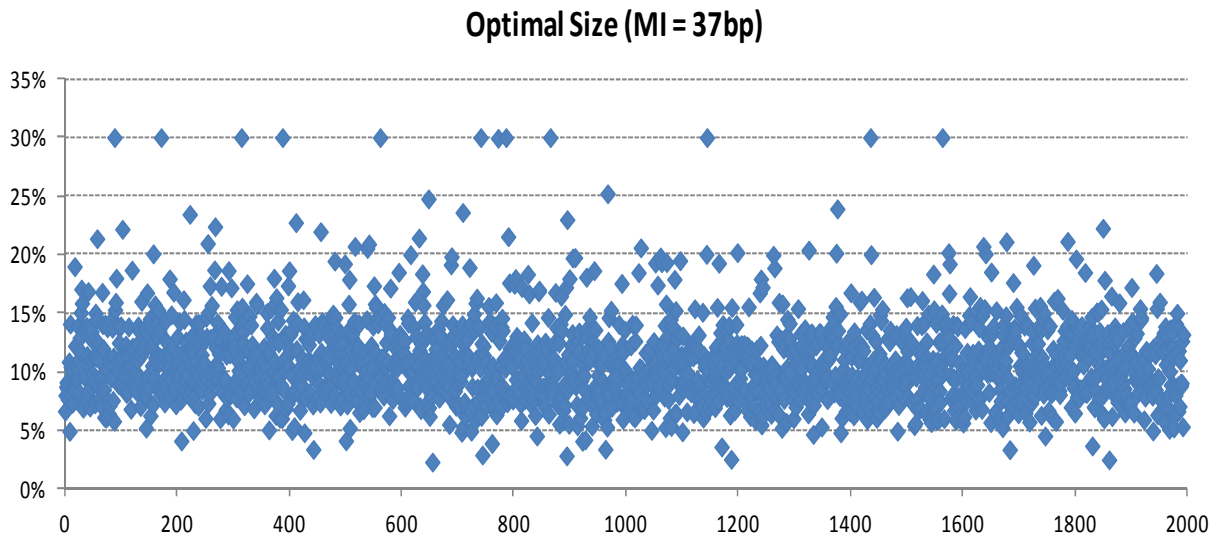
MI Factor Score

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.

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.

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Source: UBS Portfolio Trading, Science of Algorithmic Trading, Bloomberg.

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:

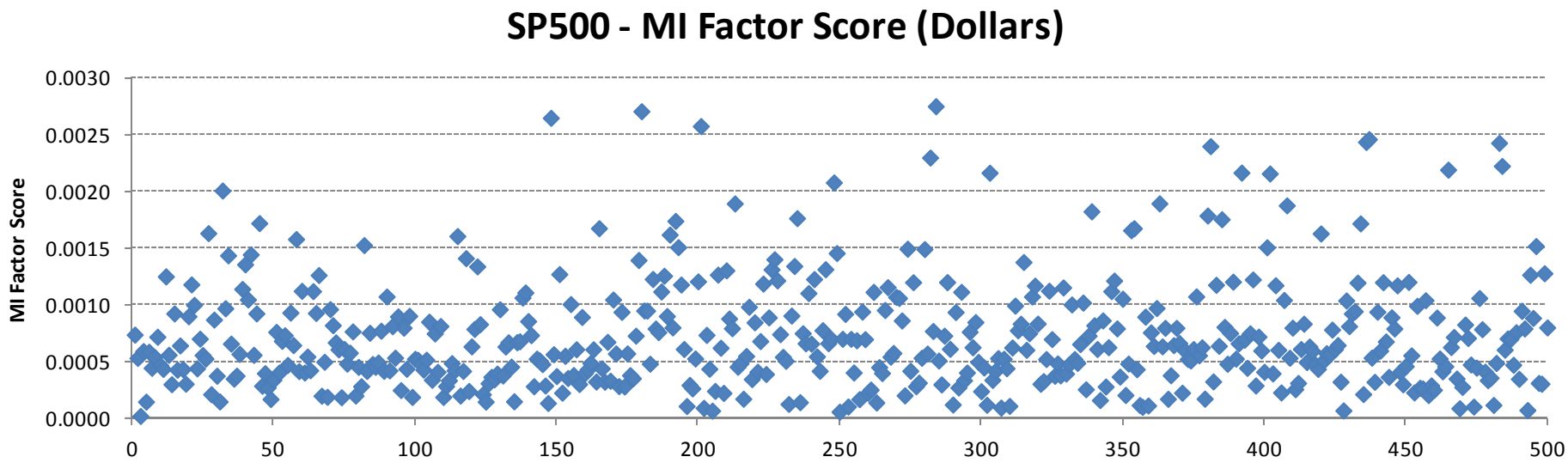
$$\alpha^*(Shares) = \hat{a}_1 \cdot \sigma^{\hat{a}3} \cdot \left(\frac{1}{ADV}\right)^{\hat{a}2}$$

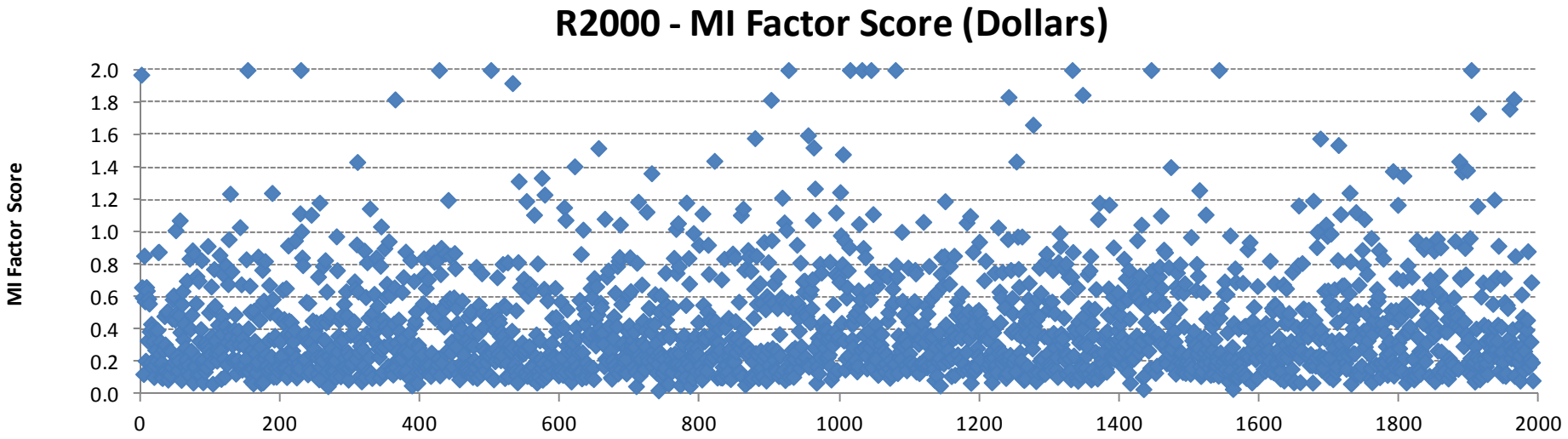
$$\alpha^*(Dollars\$) = \hat{a}_1 \cdot \sigma^{\hat{a}3} \cdot \left(\frac{1}{ADV}\right)^{\hat{a}2} \cdot \left(\frac{1}{P}\right)^{\hat{a}2}$$

UBS

Source: Algorithmic Trading Strategies, Kissell (2006)

Comparison of MI Factor Scores (Dollars)





Source: UBS Portfolio Trading, Science of Algorithmic Trading, Bloomberg.

SECTION 3b

Alpha Capture Curves

Alpha Capture Curves

Alpha Capture Curves:

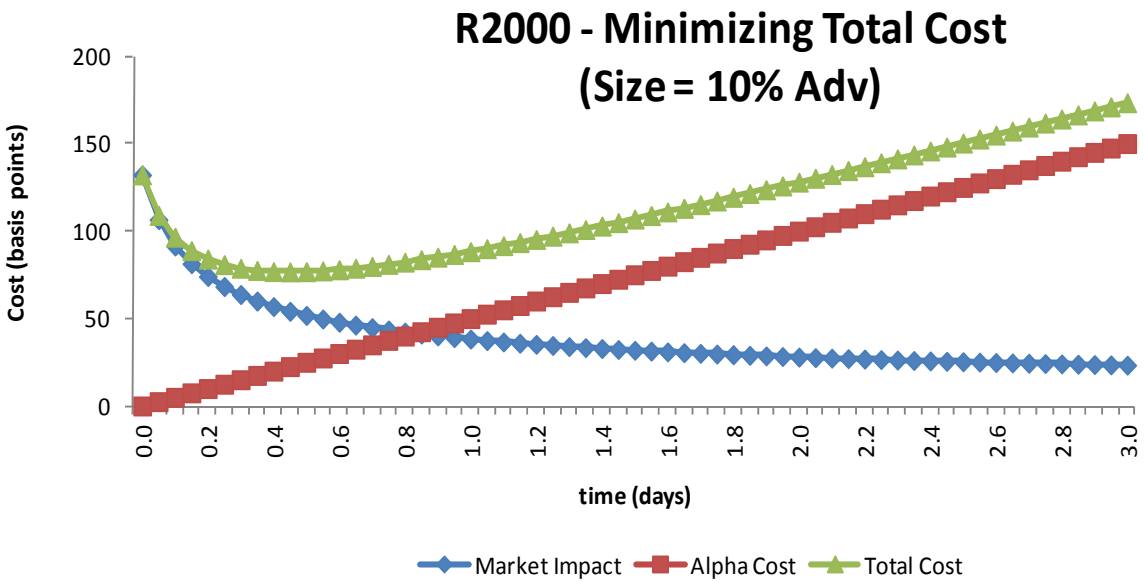
The portfolio manager's answer to trader Cost Curves

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.

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Source: UBS Portfolio Trading, Science of Algorithmic Trading, Bloomberg.

Alpha Capture Curves

Portfolio Manager Profit Curves Maximum Trading Profit				
	Alpha over 3 days			
%Adv	1%	2%	3%	4%
1%	87	184	282	380
5%	65	156	250	346
10%	45	132	223	317
15%	29	112	201	293
20%	15	95	182	272
25%	2	79	164	253
30%	-10	64	148	236
35%	-22	51	133	219
40%	-32	38	118	204
45%	-43	25	105	190
50%	-52	14	92	176

Portfolio Manager "Alpha Capture Curves"

- Provide information pertaining to the expected alpha capture for various position sizes (%adv) for a specified alpha signal.
- PM's could use these curves to additionally determine the appropriate size of the investment based on their economic opportunity cost. That is, the optimal or maximum "alpha capture."
- PM's version of Cost Curves

Example,

- The PM has a 3% alpha signal over the next 3 days. The next most attractive signal is 2% over the next three days.
- The PM could transact an order size of 15% ADV and earn a profit of 201bp. A larger size trade would decrease alpha below the opportunity cost of the trade.
- Of course we would also need to consider the cost of trading the next most attractive vehicle which could change the optimal investment size. But this is a reasonable and appropriate starting point.

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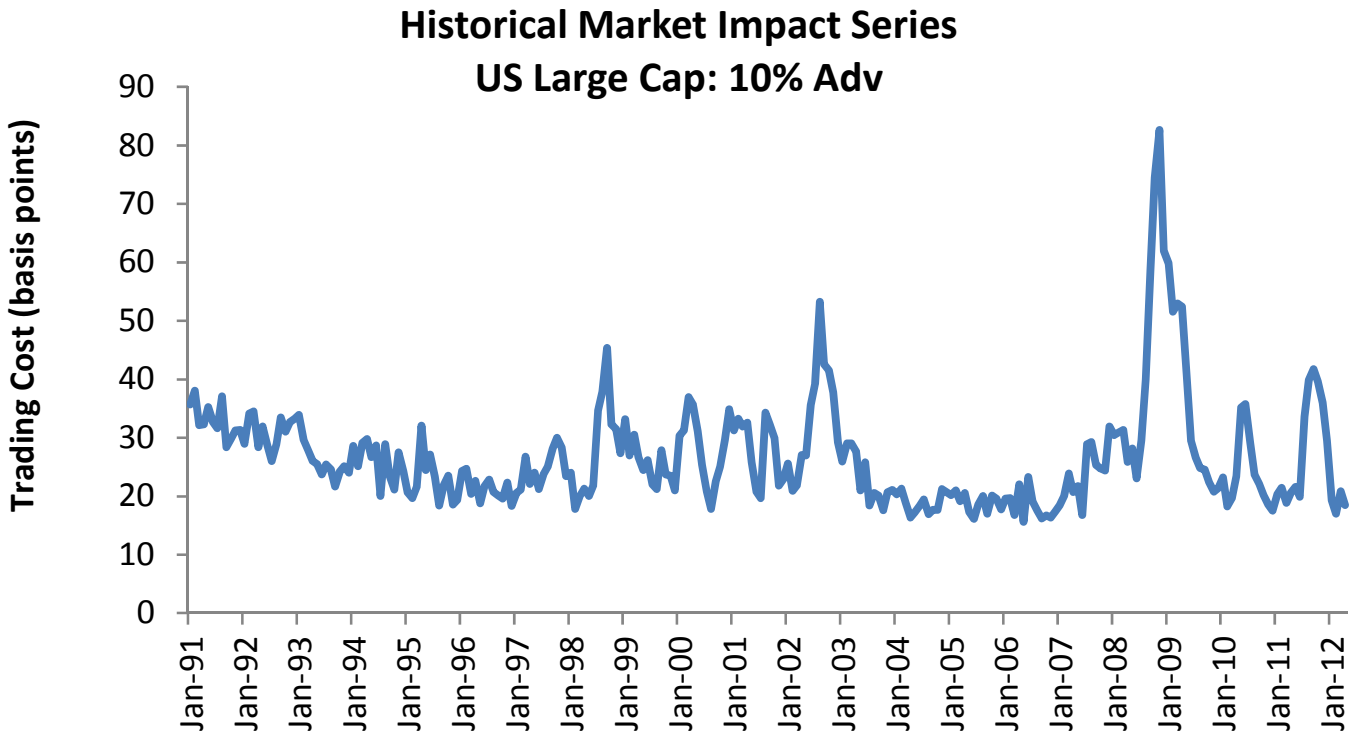
Source: UBS Portfolio Trading, Science of Algorithmic Trading, Bloomberg.

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."

UBS Source: Science of Algorithmic Trading

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

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