Factor Alignment Effects in Portfolio Construction

Jyh-Huei Lee

Jose Menchero

Outline

- Capturing Factor Premia
  - Simple, pure, and minimum-volatility factor portfolios
  - Alpha factors, risk factors, and portfolio optimization
- Should Alpha Factors be Included in Risk Model?
  - Alpha/risk factor “misalignment”
  - Simulation framework
- Effect of Sample Size (length of estimation window)
- Impact of Long-Only Constraint
- Empirical Results
- Technical Appendix
- Summary

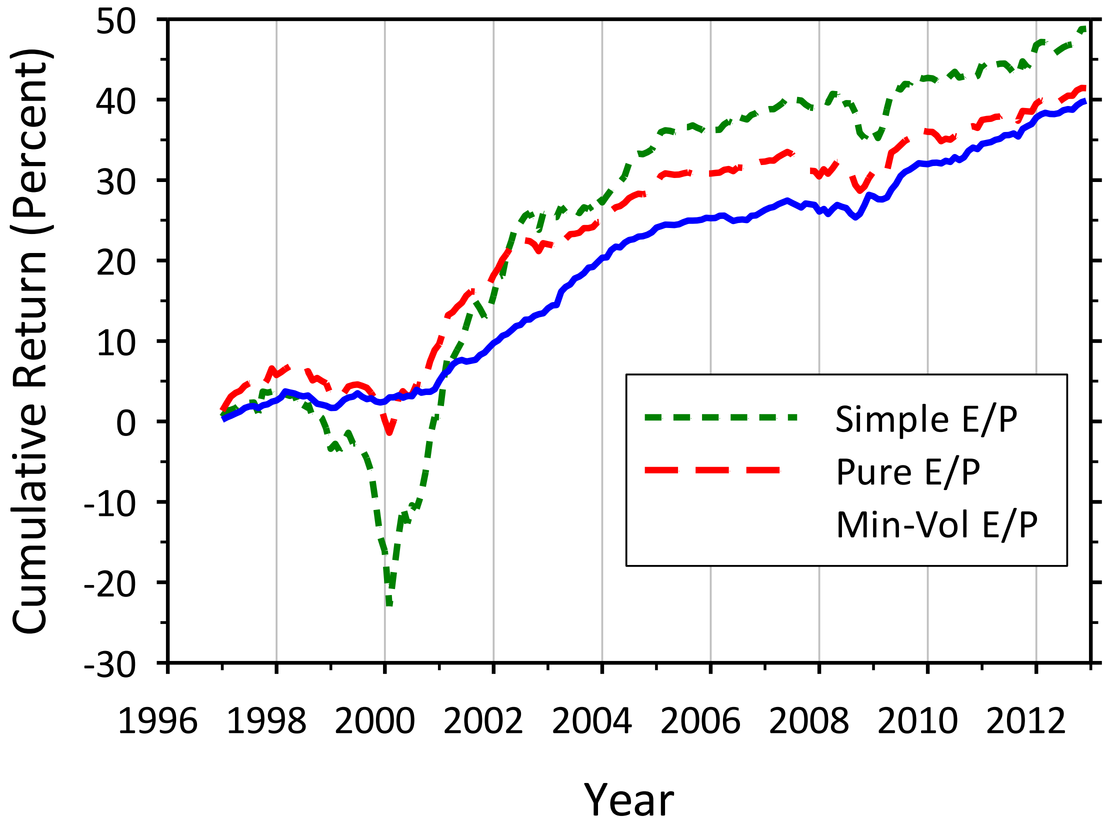
Capturing Factor Premia

Different Ways of Capturing Risk Premia

- Simple Factor Portfolios
  - Provide unit exposure to particular style
  - Portfolio has non-zero exposures to all other risk factors
  - Portfolios weights are obtained by univariate regression
- Pure Factor Portfolios
  - Provide unit exposure to particular style
  - Portfolio has zero exposures to all other risk factors
  - Portfolios weights are obtained by multivariate regression
- Minimum-Volatility Factor Portfolios
  - Provide unit exposure to particular style
  - Portfolio has non-zero exposures to all other risk factors
  - Portfolio weights are obtained via mean-variance optimization

Example: Global Equity Model (GEM3) Earnings Yield Factor

- Simple Earnings Yield Factor was dominated by industry effects during Internet Bubble period and its aftermath



E/P	Simple	Pure	M-Vol
Return	3.05	2.59	2.49
Risk	4.63	2.24	1.28
IR	0.67	1.25	2.11

- Minimum-volatility factor portfolio was unperturbed by Internet Bubble
- Simple and pure portfolios use root-cap regression weights

Using Optimization to Reduce Portfolio Risk

- Portfolio optimization is designed to produce portfolios with the highest possible risk-adjusted performance (subject to investment constraints)
- Optimized portfolios will have the lowest predicted risk of all portfolios for a given level of expected return (alpha)
- Optimization employs risk models to reduce risk in two ways:
  1) By using risk factors to hedge alpha factor risk
  2) By diversifying the specific risk of the portfolio

Notes:

- Alpha risk can only be hedged with risk factors if the alpha signal contains true systematic risk (i.e., the alpha factor must be a valid risk factor)
- Even if the alpha factor contains systematic risk, correlations must be reliably estimated to avoid spurious hedges

Alpha Factors versus Risk Factors

- Customarily, risk models do not explicitly distinguish between "alpha" factors and "risk" factors
- Such distinction is important for portfolio construction purposes

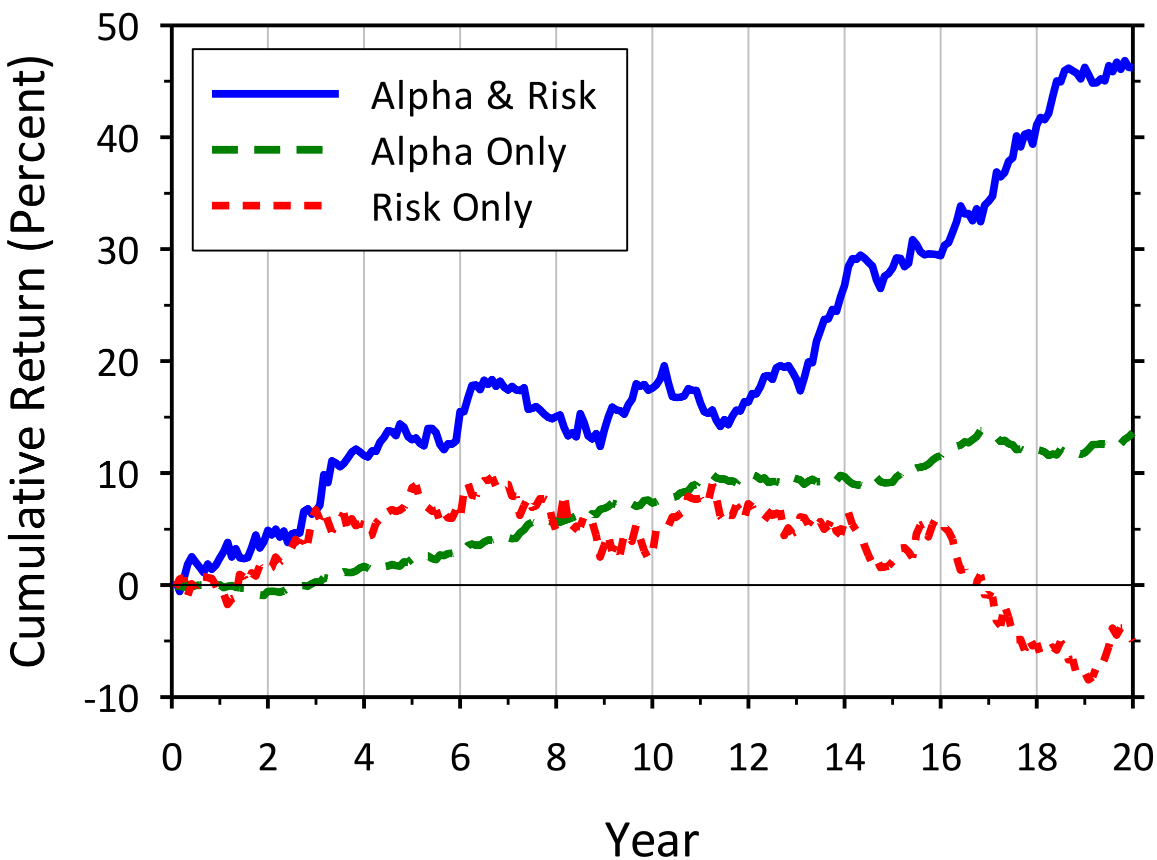
Definitions:

- Risk factors represent systematic drivers of equity return co-movement
- Alpha factors represent sources of directional "drift"
- Categories are not mutually exclusive:

Alpha Factor? \ *Risk Factor?*	*Yes*	*No*
Yes	Momentum	Unique PM Signal
No	Industry/Country	Random Signal

Illustrating the Factor Types

Simulated Returns



Summary Table

Measure	Alpha & Risk	Alpha Factor	Risk Factor
Risk (*ex ante*)	2.86	0.76	2.86
Risk (*ex post*)	2.74	0.75	3.04
IR (*ex ante*)	0.96	1.00	0.00
IR (*ex post*)	0.84	0.91	-0.08

- Even over 20-year period, the standard error in IR is quite large (0.22)
- The volatility of the alpha factor is purely specific
- Managers with skill may underperform for years

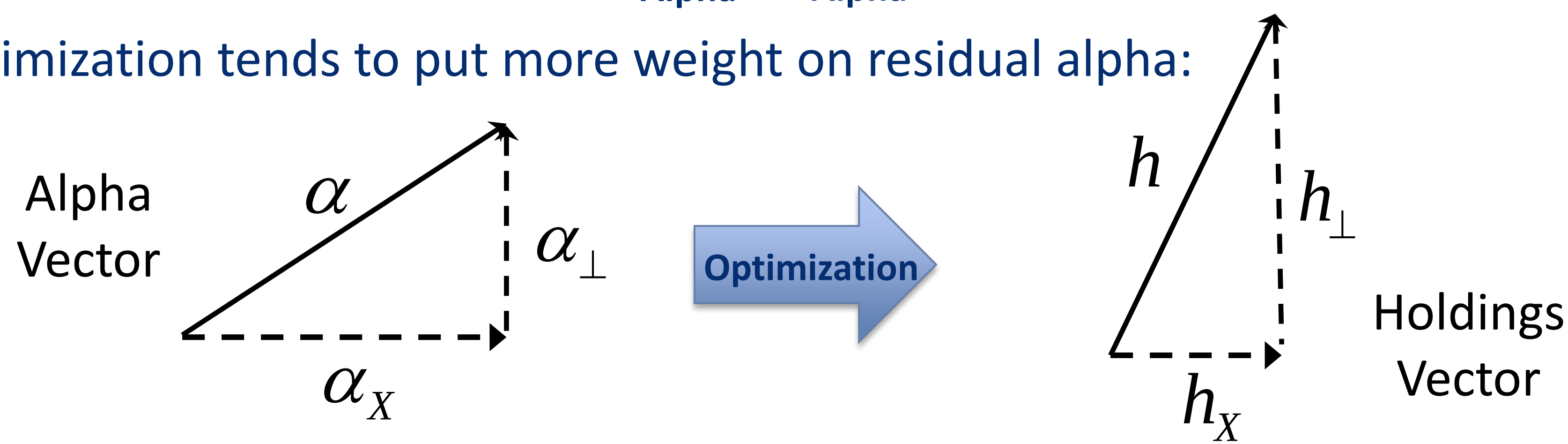
Should Alpha Factors be Included in Risk Model?

Interplay of Alpha Factors and Risk Factors in Optimization

- Alpha signal contains a component within the factor space (spanned alpha) and a component orthogonal to the factors (residual alpha):

$$\alpha = X\beta + \alpha_{\perp} = \underbrace{\alpha_X}_{\text{Spanned Alpha}} + \underbrace{\alpha_{\perp}}_{\text{Residual Alpha}} \qquad \text{Alpha Signal}$$

- Optimization tends to put more weight on residual alpha:



- If residual alpha contains true factor risk, the optimization may allocate the risk budget inefficiently, leading to a potential drop in portfolio IR

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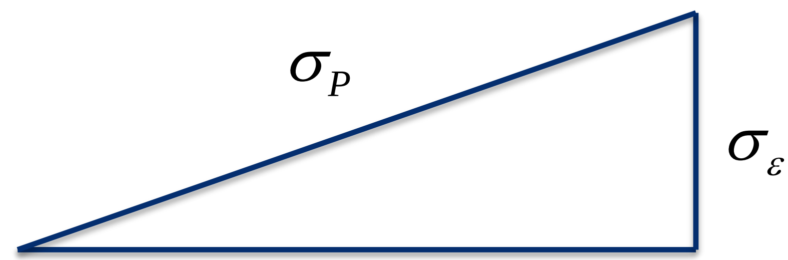
Transfer Coefficient

- Investment constraints force the *actual* portfolio *P* to deviate from the *ideal* portfolio *Q*

$$R_P = \beta_P R_Q + R_\varepsilon$$

Portfolio you own — Portfolio you want — Residual Portfolio



$$\beta_P \sigma_Q = \rho \sigma_P$$

- Residual portfolio contributes to risk, but *not* to expected return
- Compute betas and correlations relative to ideal portfolio *Q*
- TC measures loss in efficiency

$$IR_P = \rho \cdot IR_Q$$

Transfer Coefficient

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Simulation Framework

- Assume the true risk model (T) is based off Barra US Equity Model (USE4)
- Assume one of the USE4 style factors represents the true alpha signal
- Construct the true optimal portfolio $\left(P_T\right)$
- Unfortunately, investors do not have luxury of knowing true risk model; they must estimate it from available data
- Generate time series of simulated stock returns for USE4 universe
- Estimate two risk models from the simulated stock returns:
  - Model A uses the full factor set from USE4
  - Model B uses USE4 factors but omits one of the style factors (alpha)
- Construct optimal portfolios using models A and B $\left(P_A \text{ and } P_B\right)$
- Compute the true TC of the portfolios using Model T:

$$TC_A = \rho_T\left(P_A, P_T\right) \qquad TC_B = \rho_T\left(P_B, P_T\right)$$

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Two Important Cases to Consider

Case 1: Alpha factor is a valid risk factor

- Model A now uses the true factor structure
- Model B factor structure is now misspecified:
  - It has omitted a true risk factor
- Simulate stock returns using Model T (full USE4 model)

Case 2: Alpha factor is a spurious risk factor

- Model A factor structure is now misspecified
  - It has included a spurious risk factor
- Model B now uses the true factor structure
- Simulate stock returns using Model T (USE4 omitting alpha)

	Case 1	Case 2
Model A	**Alpha Valid** **Alpha Included**	**Alpha Spurious** **Alpha Included**
Model B	**Alpha Valid** **Alpha Omitted**	**Alpha Spurious** **Alpha Omitted**

Case 1 Results (Alpha is a Valid Risk Factor)

- For each date, simulate 200 periods of stock returns from USE4
- Estimate risk models A and B using simulated data (200 observations)
- Repeat exercise 10,000 times and compute the average TC
- Beta factor is an anomaly:
  - Country factor provides near perfect hedge

On average, we found a 3 percent gain in IR by including the valid alpha factor in the risk model

Sample period: Dec-1998 to Dec-2013

Alpha Factor	December 2013 TC(A)	December 2013 TC(B)	Sample Average TC(A)	Sample Average TC(B)
Growth	0.86	0.94	0.85	0.88
Size	0.86	0.83	0.86	0.81
Non-linear Size	0.86	0.86	0.87	0.84
Dividend Yield	0.87	0.91	0.86	0.87
Book-to-Price	0.85	0.88	0.85	0.87
Earnings Yield	0.87	0.91	0.86	0.85
Beta	0.83	0.46	0.84	0.53
Residual Volatility	0.86	0.75	0.85	0.71
Non-linear Beta	0.86	0.91	0.86	0.85
Momentum	0.87	0.89	0.87	0.86
Leverage	0.85	0.83	0.86	0.84
Liquidity	0.85	0.84	0.84	0.80
Average (ex Beta)	0.86	0.87	0.86	0.83

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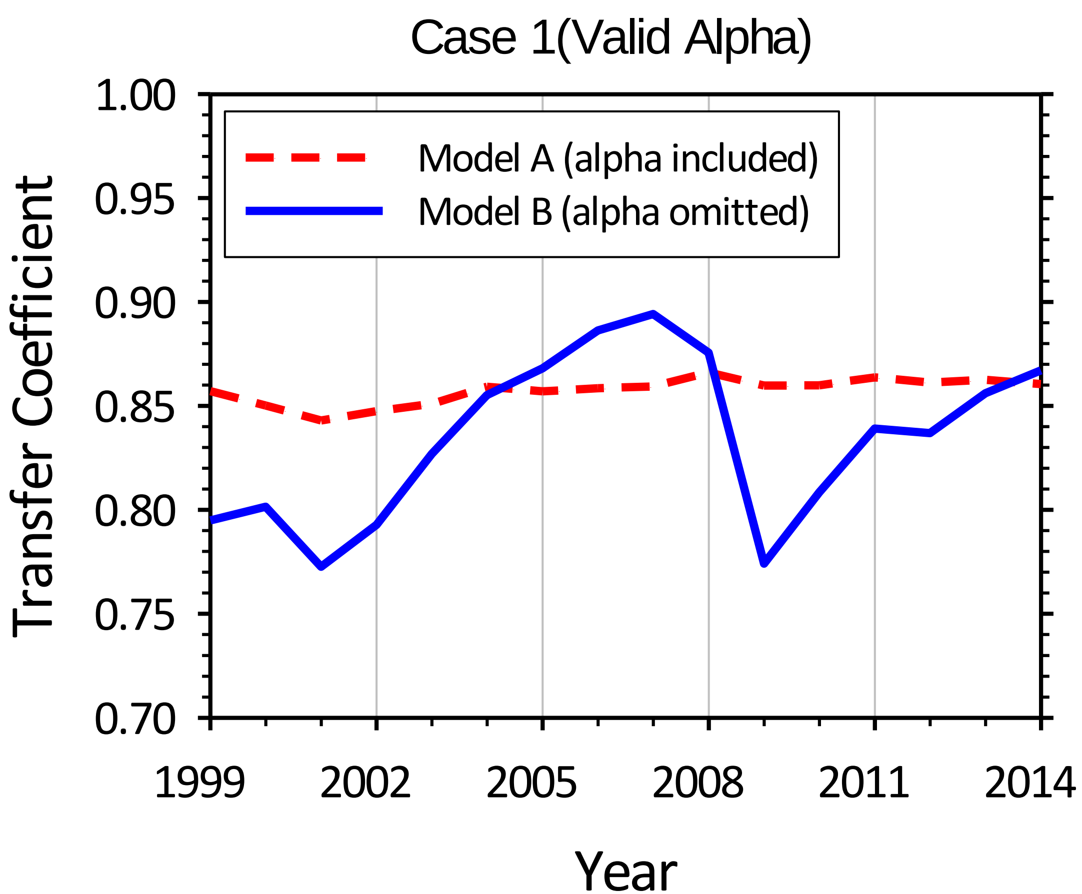
Transfer Coefficient over Time (Case 1)

- The average difference in TC was small (about 3 percent)
- Differences were slightly larger during crisis periods
- Model B outperformed slightly during calm periods

- Note that USE4 factors were selected for their strength
- Thus, Model B omits an important risk factor



Case 2 Results (Alpha is a Spurious Risk Factor)

- For each date, simulate 200 periods of stock returns using Model T (i.e., USE4 but with the alpha factor deleted)
- Estimate risk models A and B using simulated data (200 observations)
- Repeat exercise 10,000 times and compute the average TC
- Adding a spurious factor to risk model harmed portfolio

On average, we found a 20 percent drop in IR by including a spurious alpha factor in the risk model

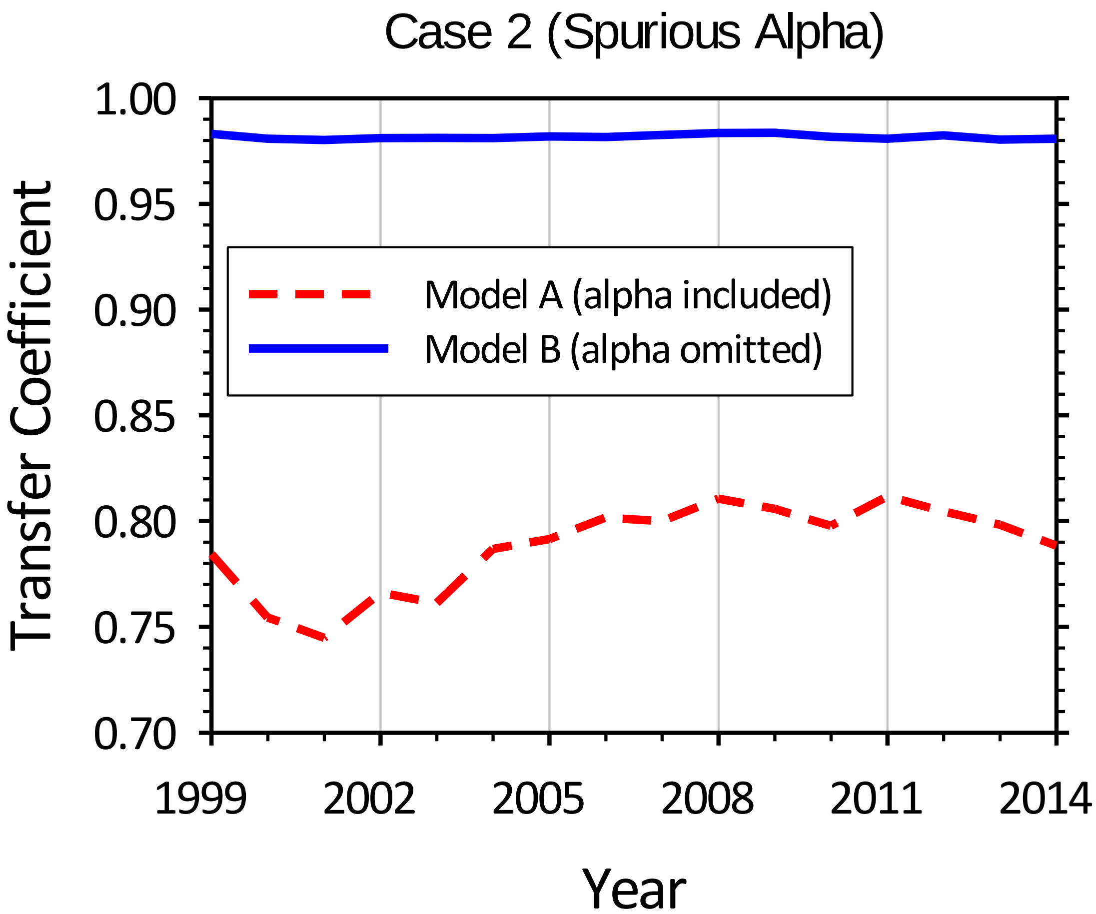
Sample period: Dec-1998 to Dec-2013

Alpha Factor	December 2013 TC(A)	December 2013 TC(B)	Sample Average TC(A)	Sample Average TC(B)
Growth	0.80	0.99	0.79	0.99
Size	0.77	0.98	0.78	0.98
Non-linear Size	0.78	0.98	0.79	0.98
Dividend Yield	0.79	0.98	0.78	0.98
Book-to-Price	0.80	0.98	0.79	0.98
Earnings Yield	0.79	0.98	0.80	0.98
Beta	0.78	0.97	0.78	0.97
Residual Volatility	0.76	0.97	0.77	0.98
Non-linear Beta	0.80	0.99	0.81	0.99
Momentum	0.80	0.98	0.80	0.98
Leverage	0.80	0.98	0.79	0.98
Liquidity	0.77	0.98	0.78	0.98
Average (all factors)	0.79	0.98	0.79	0.98

Transfer Coefficient over Time (Case 2)

- Model B had a very high and stable TC (about 0.98)
- Ability to minimize specific risk appeared stable

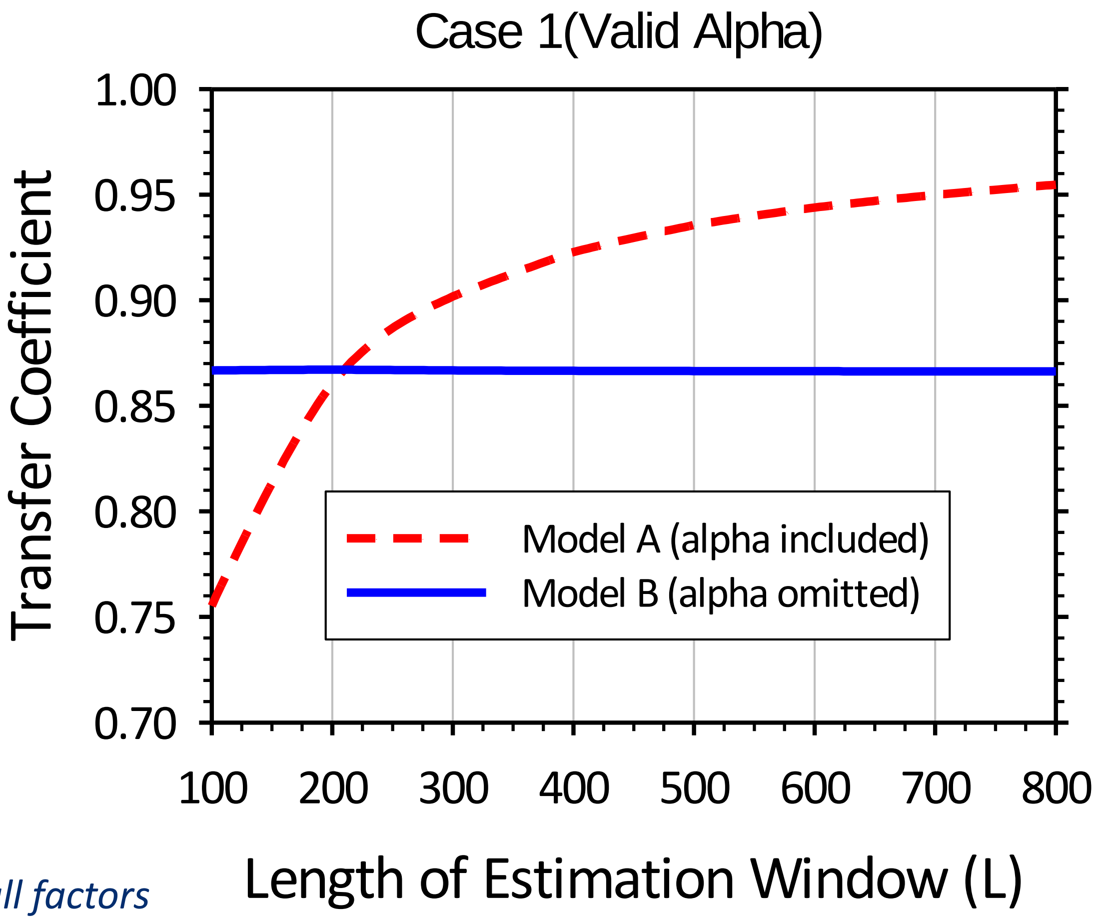
- The TC of Model A varied from 0.75 to 0.80
- Spurious hedges increased the portfolio risk



Effect of Sample Size

Effect of Window Length (Case 1)

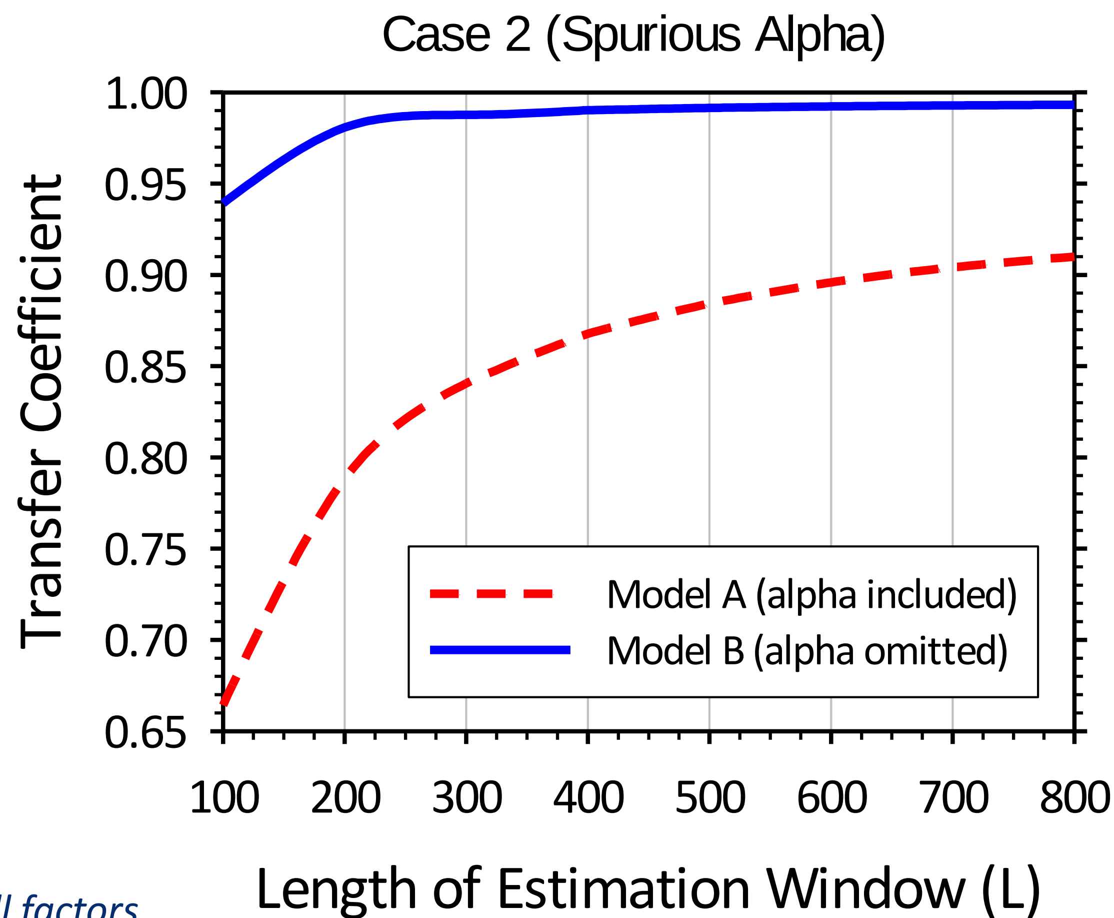
- For Model A, short windows harmed the portfolio IR due to spurious hedging
- Model A benefited from optimization when the correlations were reliably estimated
- Model B was not sensitive to the window length since factor correlations played little role in this case



Average over all factors (exclude Beta) Dec-2013

Effect of Window Length (Case 2)

- Adding a spurious alpha factor to the risk model hurt the portfolio IR
- The inflicted damage decreased as the window length expanded
- Factor correlations were much less important for Model B



Average over all factors (exclude Beta) Dec-2013

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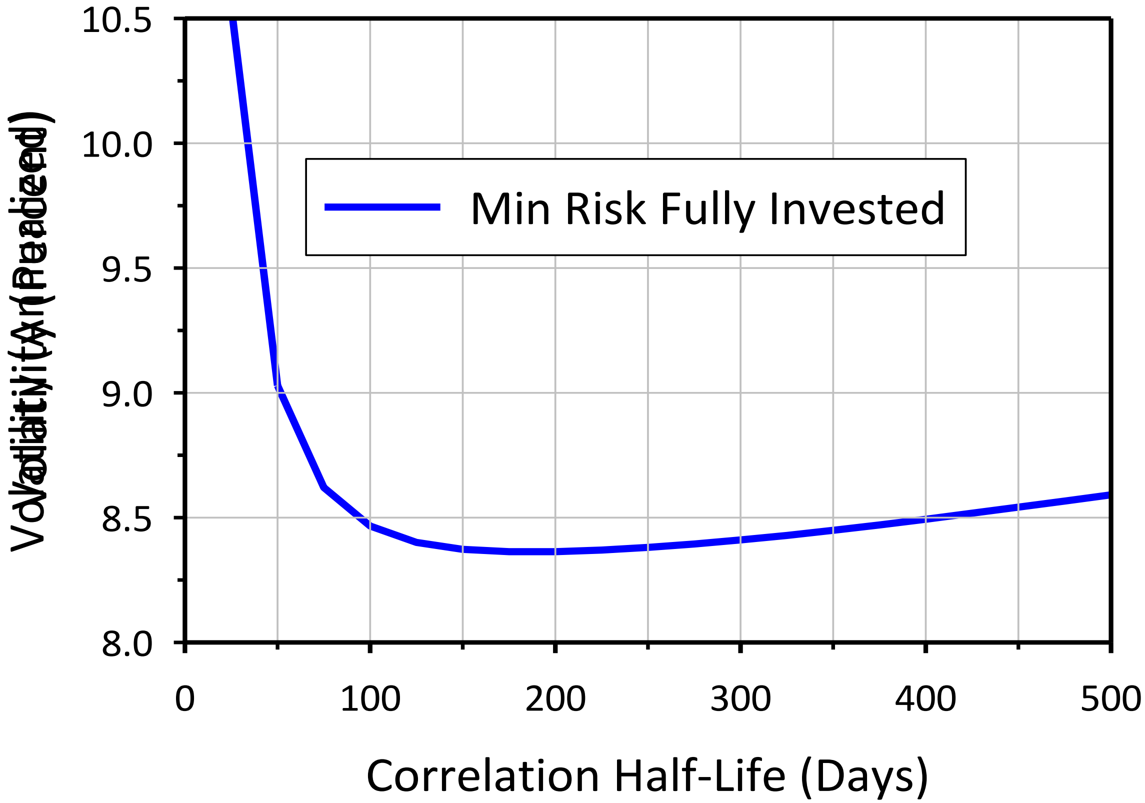
Optimal Window Length

- Construct the minimum-volatility fully invested portfolio (USE4D)
- Observe out-of-sample volatility over 17 years (Jan-1997 to Dec-2013)



- The optimal half-life was less than 200 days
- Short window lengths contain most relevant data, but have large sampling error
- Long window lengths have smaller sampling error, but include more stale data

Impact of Long-Only Constraint

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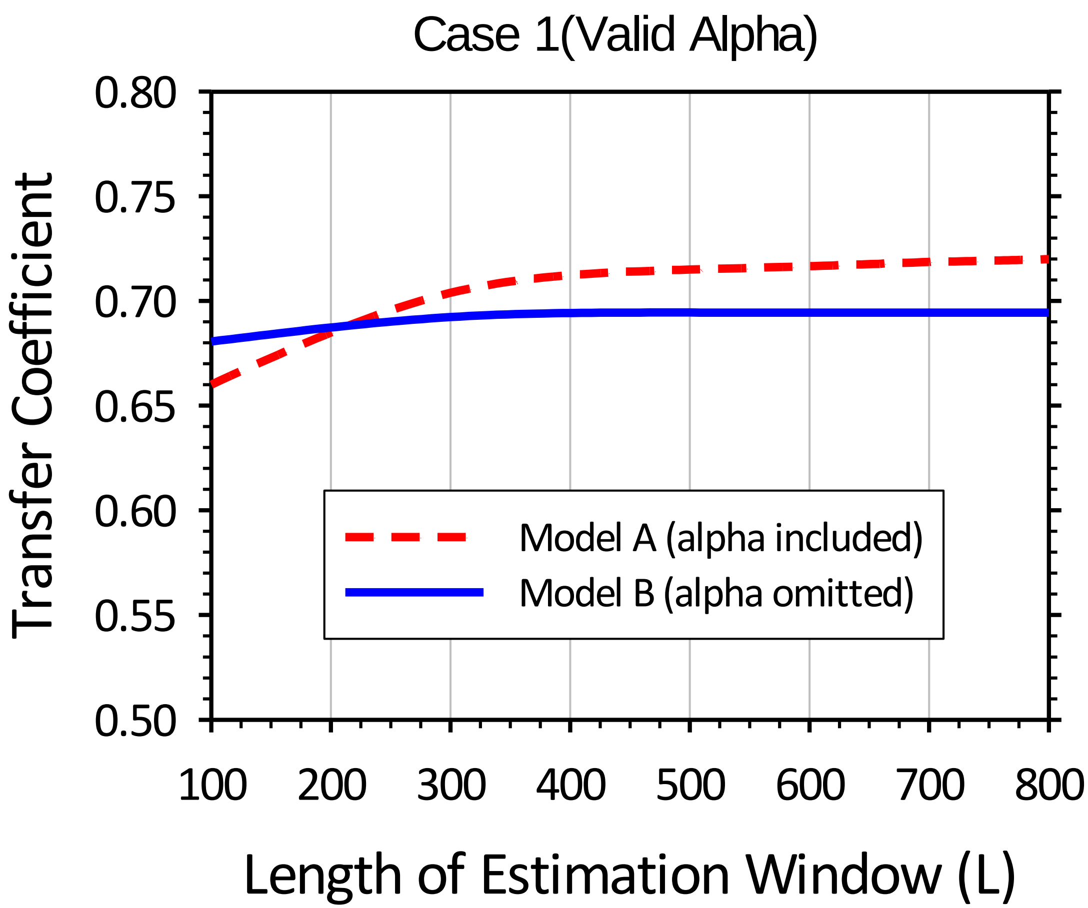
Long-Only Constraint (Case 1)

- Imposing the long-only constraint reduced TC of both Models A and B
- Differences between Models A and B were strongly compressed
- Even at 800 periods, the increase in IR was only 3% when valid alpha signal was properly included in the risk model



Average over all factors (exclude Beta) Dec-2013

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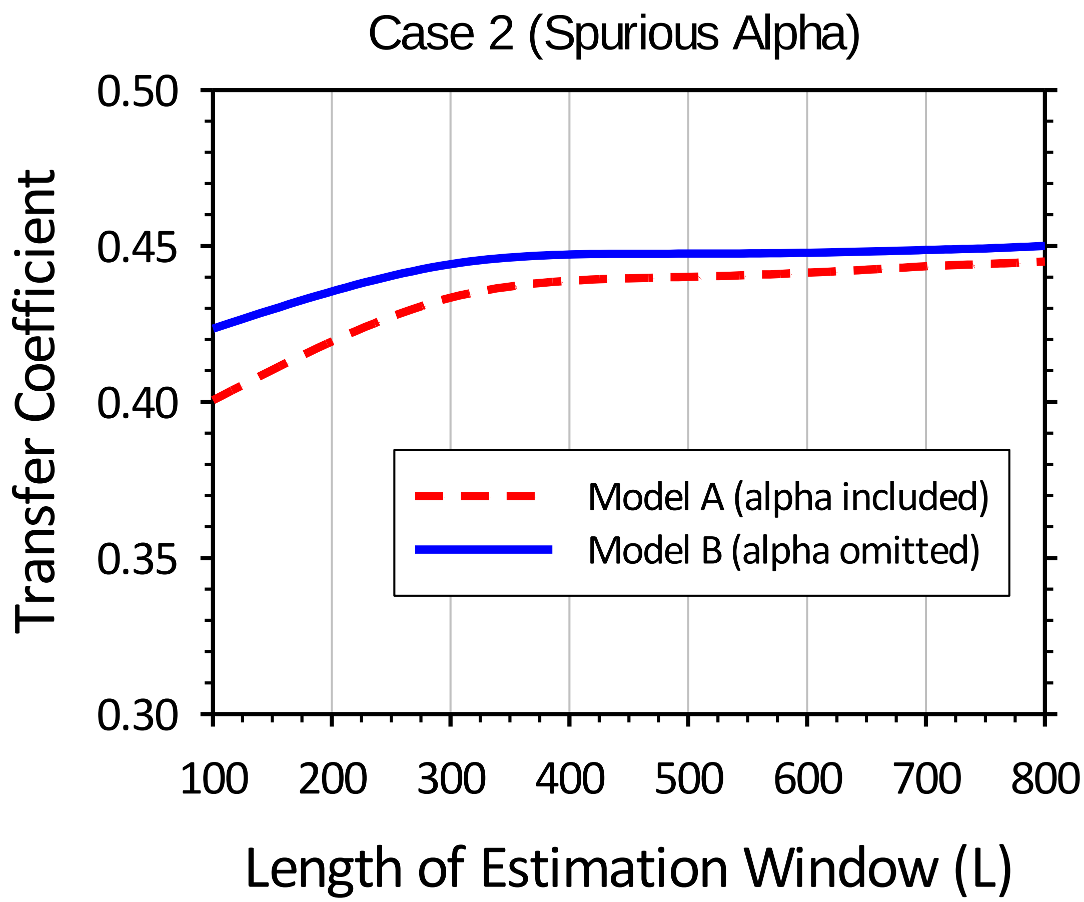
Long-Only Constraint (Case 2)

- The long-only constraint sharply reduced the TC for both Models A and B
- Differences between Models A and B were strongly compressed
- Even at 100 periods, the increase in IR was only 5% when alpha was properly omitted from risk model



Average over all factors (exclude Beta) Dec-2013

Empirical Results

Empirical Study

- Start with USE4S risk model
- Only consider Case 1 (all USE4 style factors are valid risk factors)
- At start of each month, create two optimized portfolios:
  - Using USE4 with complete factor set (Model A)
  - Using USE4 with style factor omitted (Model B)
- Compute the out-of-sample volatilities of both portfolios
- The lower the volatility, the higher the IR for a fixed expected return
- The volatility ratio gives the empirical estimate of the TC ratio

$$\frac{TC_A}{TC_B} = \frac{\sigma(P_B)}{\sigma(P_A)}$$

Volatility Ratio

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Empirical Study: Unconstrained Case

- USE4S model uses two Newey-West lags (l=2)
- The correlation half-life is 504 trading days
- The effective number of observations is about 500-700
- Simulation results suggest a volatility ratio of 1.09
- The empirical volatility ratio (1.11) is in excellent agreement with the simulation results

Alpha Factor	Realized Risk (%) (Model A)	(Model B)	Volatility Ratio
Growth	1.56	1.74	1.11
Size	2.57	2.82	1.10
Non-linear Size	2.76	2.59	0.94
Dividend Yield	1.76	1.79	1.02
Book-to-Price	1.82	1.90	1.04
Earnings Yield	2.79	3.05	1.09
Beta	3.09	5.90	1.91
Residual Volatility	2.66	3.44	1.30
Non-linear Beta	1.36	1.71	1.26
Momentum	6.26	6.43	1.03
Leverage	1.64	2.16	1.32
Liquidity	1.76	1.96	1.11
Average (ex Beta)	2.45	2.69	1.11

$$L \approx \frac{3 \cdot HL}{(l+1)\ln(2)}$$

Effective Number of Observations

Empirical Study: Long-Only Constraint

- Simulation results for long-only constraint suggest a volatility ratio of 1.04
- Simulations were in perfect agreement with the empirical volatility ratio (1.04)
- Again, the effect of constraints is to compress differences between the two models

Alpha Factor	Realized Risk (%) (Model A)	Realized Risk (%) (Model B)	Volatility Ratio
Growth	2.94	3.21	1.09
Size	5.15	5.15	1.00
Non-linear Size	8.98	8.93	0.99
Dividend Yield	2.65	2.75	1.04
Book-to-Price	3.06	3.09	1.01
Earnings Yield	4.69	4.64	0.99
Beta	6.42	6.78	1.06
Residual Volatility	4.49	5.16	1.15
Non-linear Beta	3.42	3.54	1.04
Momentum	6.73	6.79	1.01
Leverage	2.24	2.38	1.06
Liquidity	4.57	4.79	1.05
Average (all factors)	4.45	4.58	1.04

Summary

- Factor premia can be captured using simple, pure, or minimum-volatility factor portfolios
- Minimum-volatility factor portfolios are the most efficient (*ex ante*)
- Risk models reduce risk in two ways:
  - By hedging the alpha factor with risk factors
  - By diversifying away the specific risk
- Transfer coefficient is ideally suited to measure portfolio efficiency
- Adding a valid alpha factor to the risk model may help improve IR only if the factor correlations can be reliably estimated
- Adding a spurious alpha factor to the risk model resulted in a significant drop in portfolio IR

Technical Appendix

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Simple Factor Portfolios

- Provide unit exposure to particular style
- No consideration given to other factors
- Simple factor portfolios are constructed by univariate regression:

$$r_n = f_w + X_{nk} f_k^S + e_n$$

$$\sum_n w_n X_{nk} = 0$$ Mean-zero exposures (regression weighted)

$$\sum_n w_n X_{nk}^2 = 1$$ Unit standard deviation exposures

$$\boxed{f_k^S = \sum_n \left(w_n X_{nk} \right) r_n}$$ Return of simple factor portfolio k

- Portfolio has non-zero exposures to other risk factors

Pure Factor Portfolios

- Provide unit exposure to particular style
- Portfolio has zero exposure to other factors
- Pure factor portfolios are constructed by multivariate regression:

$$r_n = f_w + \sum_k X_{nk} f_k^P + u_n \qquad \left(r = Xf + u\right)$$

$$f = \left[\left(X'WX\right)^{-1} X'W\right] r$$

Weighted Least Squares Solution

$$f_k^P = \sum_n \Omega_{nk}^P r_n$$

Return of pure factor portfolio *k*

- Ω_{nk}^P gives the weight of stock *n* in pure factor portfolio *k*

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Minimum-Volatility Factor Portfolios

- Provide unit exposure to particular style
- Portfolio has minimum risk
- Minimum-volatility factor portfolios are constructed by optimization:

$$\Omega_k^{MV} = \frac{V^{-1} X_k}{X_k' V^{-1} X_k}$$

$$f_k^{MV} = \sum_n \Omega_{nk}^{MV} r_n$$

Return of minimum-volatility factor portfolio k

- Ω_{nk}^{MV} gives the weight of stock n in minimum-volatility factor portfolio k
- Minimum-volatility portfolios form building blocks for combining alpha

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Information Ratio Attribution (Ex Ante)

$$IR = \frac{R}{\sigma(R)}; \quad R = \sum_m x_m g_m ; \quad \sigma(R) = \sum_m x_m \sigma(g_m)\, \rho(g_m, R)$$

$$IR = \sum_m \underbrace{\left(\frac{x_m \sigma(g_m)\, \rho(g_m, R)}{\sigma(R)} \right)}_{\text{“Risk Weight”}} \underbrace{\left(\frac{x_m g_m}{x_m \sigma(g_m)\, \rho(g_m, R)} \right)}_{\text{“Component IR”}}$$

- Portfolio *IR* is the risk-weighted average of component *IR*
- Component *IR* is the stand-alone *IR* of return source, but magnified by ρ^{-1}. This represents a diversification benefit.

IR Analysis (Case 1)

- Alpha is a valid risk factor
  - Model A has true factor structure
  - Model B is missing true factor
- In Model A, the total portfolio is identical to spanned portfolio
- Model B contains both spanned and residual portfolios
- In Model B, most of the risk weight is assigned to the residual portfolio, which has a high (true) information ratio

USE4 Leverage factor (Dec-2013)

Total Portfolio	Model A	Truth	Model B	Truth
Information Ratio	1.06	0.85	2.34	0.83
Return (bps)	112.4	112.4	112.4	112.4
Risk (bps)	106.5	131.7	48.1	135.4
Risk Weight (%)	100.0	100.0	100.0	100.0
Component IR	1.06	0.85	2.34	0.83
Correlation	1.00	1.00	1.00	1.00
Absolute Weights (%)	122.1	122.1	101.6	101.6
Spanned Portfolio	**Model A**	**Truth**	**Model B**	**Truth**
Information Ratio	1.06	0.85	0.46	0.38
Return (bps)	112.4	112.4	4.3	4.3
Risk (bps)	106.5	131.7	9.4	11.4
Risk Weight (%)	100.0	100.0	3.8	3.0
Component IR	1.06	0.85	2.34	1.06
Correlation	1.00	1.00	0.20	0.36
Absolute Weights (%)	122.1	122.1	9.1	9.1
Residual Portfolio	**Model A**	**Truth**	**Model B**	**Truth**
Information Ratio	0.0	0.0	2.29	0.82
Return (bps)	0.0	0.0	108.1	108.1
Risk (bps)	0.0	0.0	47.1	131.8
Risk Weight (%)	0.0	0.0	96.2	97.0
Component IR	0.0	0.0	2.34	0.82
Correlation	0.0	0.0	0.98	1.00
Absolute Weights (%)	0.0	0.0	100.7	100.7

IR Analysis (Case 2)

- Alpha is a spurious risk factor
  - Model A has included spurious factor
  - Model B has true factor structure
- In Model A, the total portfolio is identical to spanned portfolio
- Model B contains both spanned and residual portfolios
- In Model B, most of the risk weight is assigned to the residual portfolio, which has a high (true) information ratio

Total Portfolio	Model A	Truth	Model B	Truth
Information Ratio	0.73	0.80	1.03	0.98
Return (bps)	48.7	48.7	48.7	48.7
Risk (bps)	66.6	60.9	47.3	49.8
Risk Weight (%)	100.0	100.0	100.0	100.0
Component IR	0.73	0.80	1.03	0.98
Correlation	1.00	1.00	1.00	1.00
Absolute Weights (%)	101.6	101.6	100.3	100.3
Spanned Portfolio	**Model A**	**Truth**	**Model B**	**Truth**
Information Ratio	0.73	0.80	0.22	0.17
Return (bps)	48.7	48.7	2.2	2.2
Risk (bps)	66.6	60.9	10.0	12.6
Risk Weight (%)	100.0	100.0	4.5	6.7
Component IR	0.73	0.80	1.03	0.66
Correlation	1.00	1.00	0.21	0.26
Absolute Weights (%)	101.6	101.6	10.4	10.4
Residual Portfolio	**Model A**	**Truth**	**Model B**	**Truth**
Information Ratio	0.0	0.0	1.01	0.97
Return (bps)	0.0	0.0	46.5	46.5
Risk (bps)	0.0	0.0	46.2	48.0
Risk Weight (%)	0.0	0.0	95.5	93.3
Component IR	0.0	0.0	1.03	1.00
Correlation	0.0	0.0	0.98	0.97
Absolute Weights (%)	0.0	0.0	99.1	99.1

USE4 Leverage factor (Dec-2013)

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