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Efficiently Combining Multiple Sources of Alpha

Zoltan Nagy

Outline

- Factor portfolios (Simple, Pure, Minimum Volatility)
- Alpha factors versus risk factors
- Empirical Comparison
  - Performance of simple, pure, and min-vol factors
- Combining Multiple Alpha Signals
  - Pure factors
  - Min-Vol factors

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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
- Min-Vol 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

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Risk Attribution for Min-Vol Factor Portfolios

- Pure factor portfolios are uncorrelated with min-vol factor portfolios
- Pure factors contribute zero to risk of min-vol factor portfolios
- Example: Momentum factor (31-Dec-2012)

Factor	Exposure	Volatility	Correlation	Risk Contrib
World	0.04	11.25	0.00	0.00
Banks	0.06	3.66	0.00	0.00
Momentum	1.00	2.91	0.80	2.34
Beta	0.02	4.40	0.00	0.00
Size	0.04	1.11	0.00	0.00
USA	-0.02	3.64	0.00	0.00

- Positive exposure to World factor helps hedge risk of Momentum factor
- Pure Momentum not perfectly correlated with min-vol Momentum

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Alpha Factors versus Risk Factors

- Customarily, risk models make no explicit distinction between "alpha" factors and "risk" factors
- For portfolio construction purposes, it is useful to distinguish the two:
- Alpha factors have directional "drift"
  - Expected value of pure alpha factor return is non-zero
- Risk factors have no directional drift:
  - Expected value of pure factor return is zero

Risk factors can hedge alpha factors without impacting expected returns

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Reporting Convention for Return, Risk, and Information Ratio

- Portfolio Returns:
  - Compute average monthly return of portfolio
  - Annualize returns via multiplication by 12
- Portfolio Risk
  - Compute volatility as the standard deviation of monthly returns
  - Annualize volatility via multiplication by sqrt(12)
- Information Ratio
  - Compute z-score of portfolio return each month using predicted volatility
  - Compute mean and standard deviation of monthly z-score returns
  - Take return/risk ratio and annualize it via multiplication by sqrt(12)
- Approach prevents *IR* from being dominated by periods of high volatility
- In practice, PM controls predicted volatility

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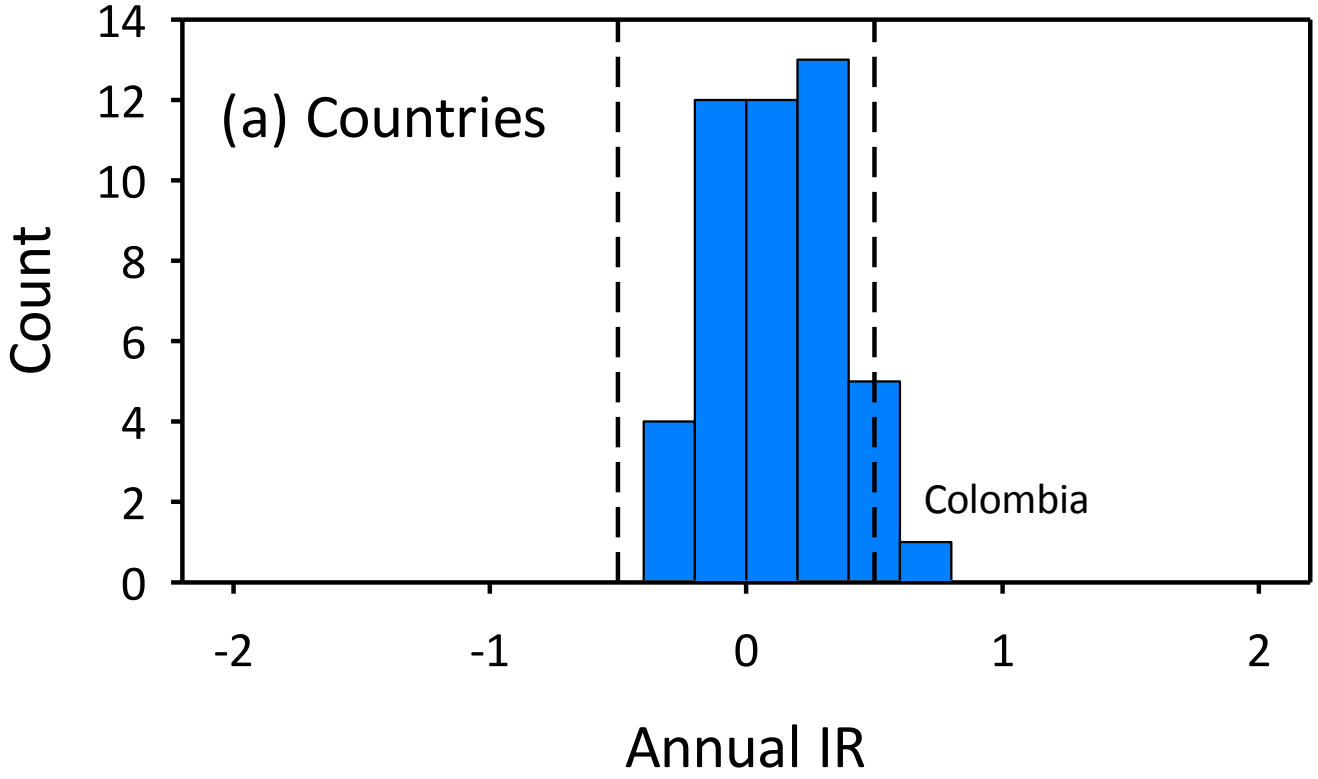
Realized *IR* for GEM3 Pure Country Factors

- Only one country (Colombia) out of 48 had a statistically significant IR



Sample Period:
Jan-97 to Dec-12

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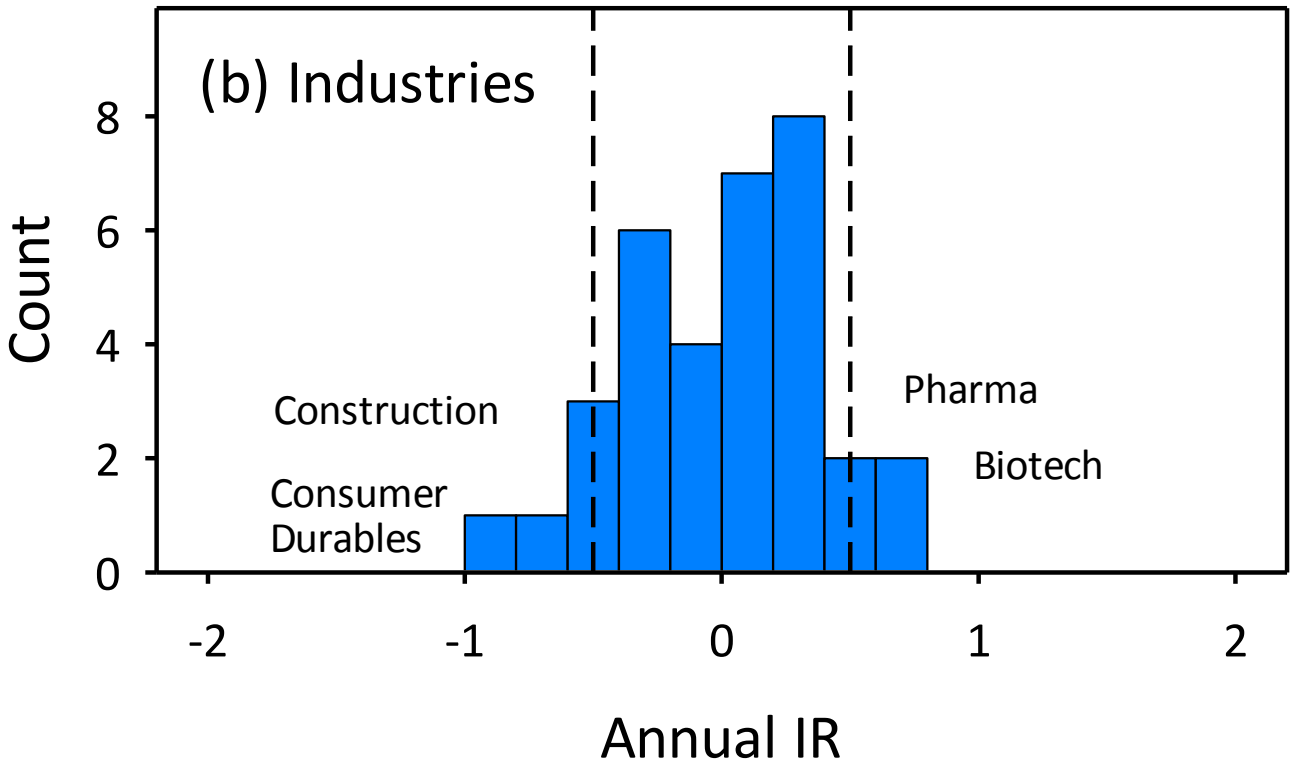
Realized *IR* for GEM3 Pure Industry Factors

- Only a few industries (out of 34) had a statistically significant IR
- Results may be due to one-time events (i.e., not *persistent*)



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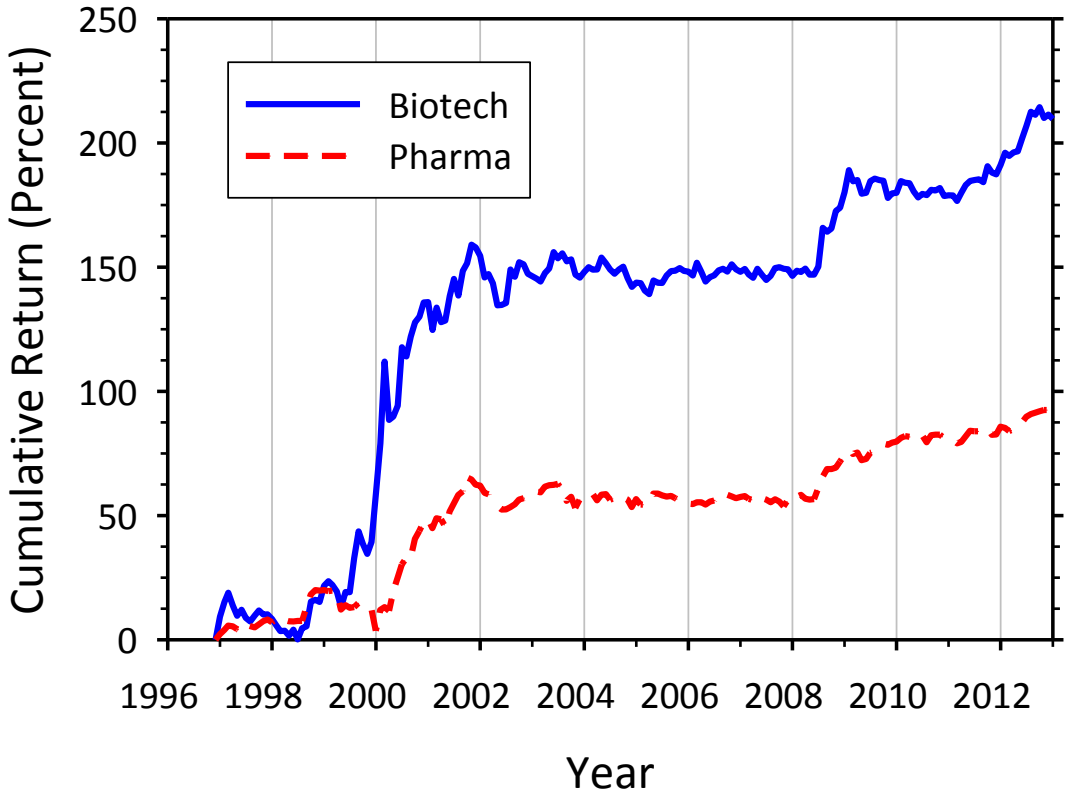
Do Industry Factors Exhibit Persistent Drift?

- Example: Biotechnology and Pharmaceuticals
- Performance for these factors was dominated by brief window



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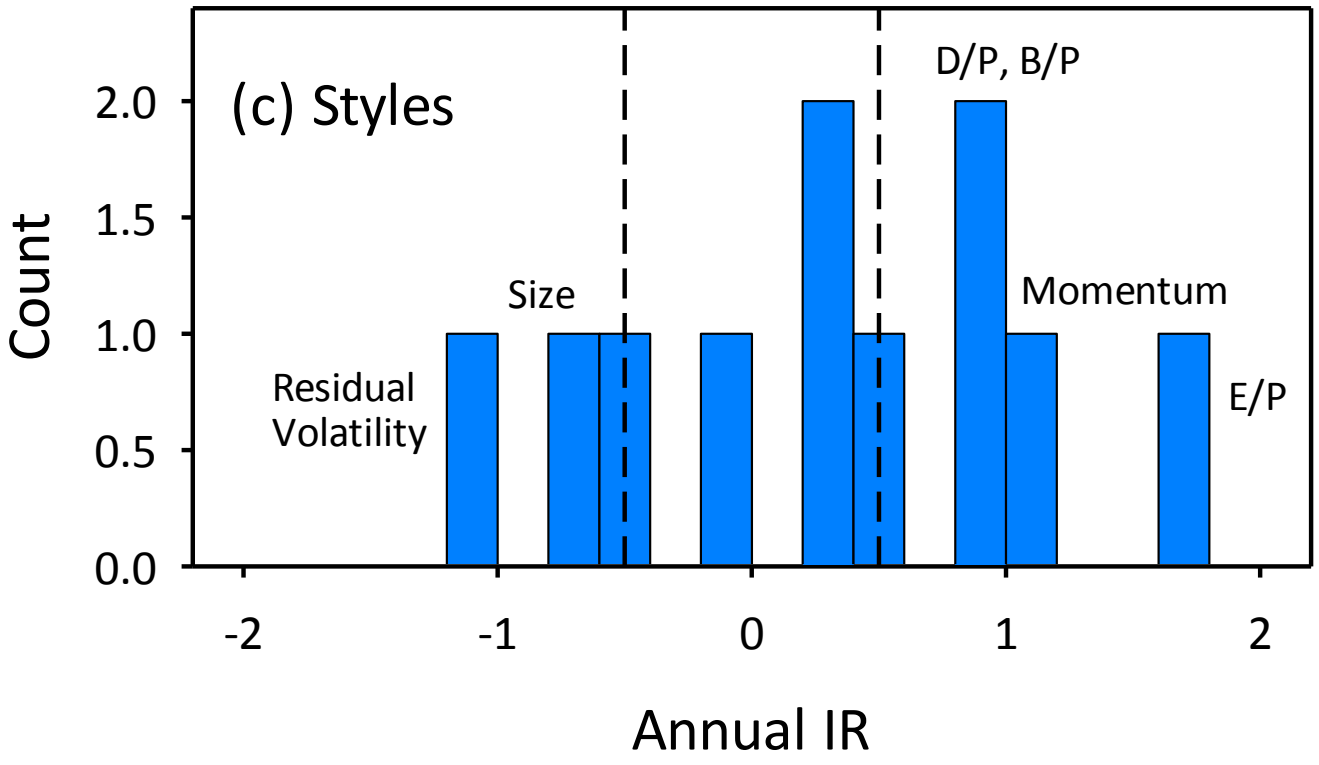
Realized *IR* for GEM3 Pure Style Factors

- Style *IR* were generally larger than for industries/countries
- Most style factors (6 of 11) had a statistically significant *IR*



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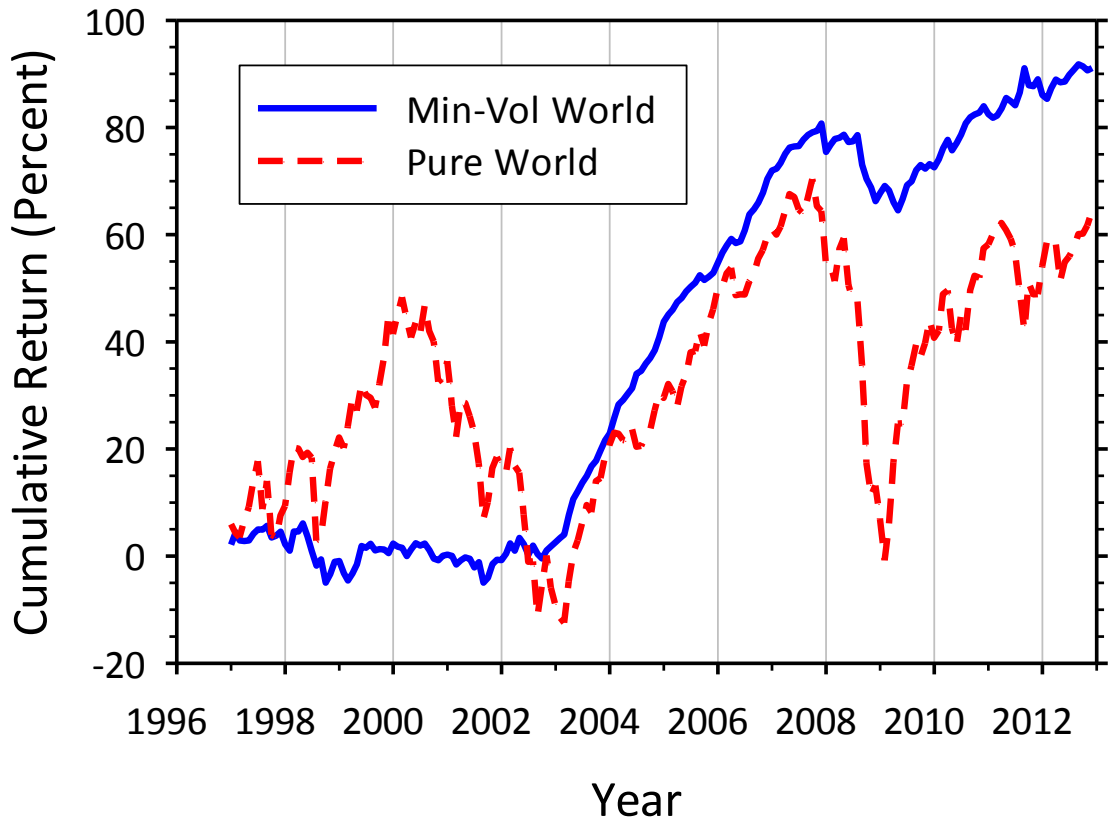
World Factor

- Min-Vol Factor (minimum volatility fully invested portfolio)
- Pure Factor: cap-weighted world portfolio



World	Pure	M-Vol
Return	4.03	5.69
Risk	16.06	5.61
IR	0.31	1.33

- Minimum Volatility portfolio avoided big swings during Internet Bubble and Financial crisis

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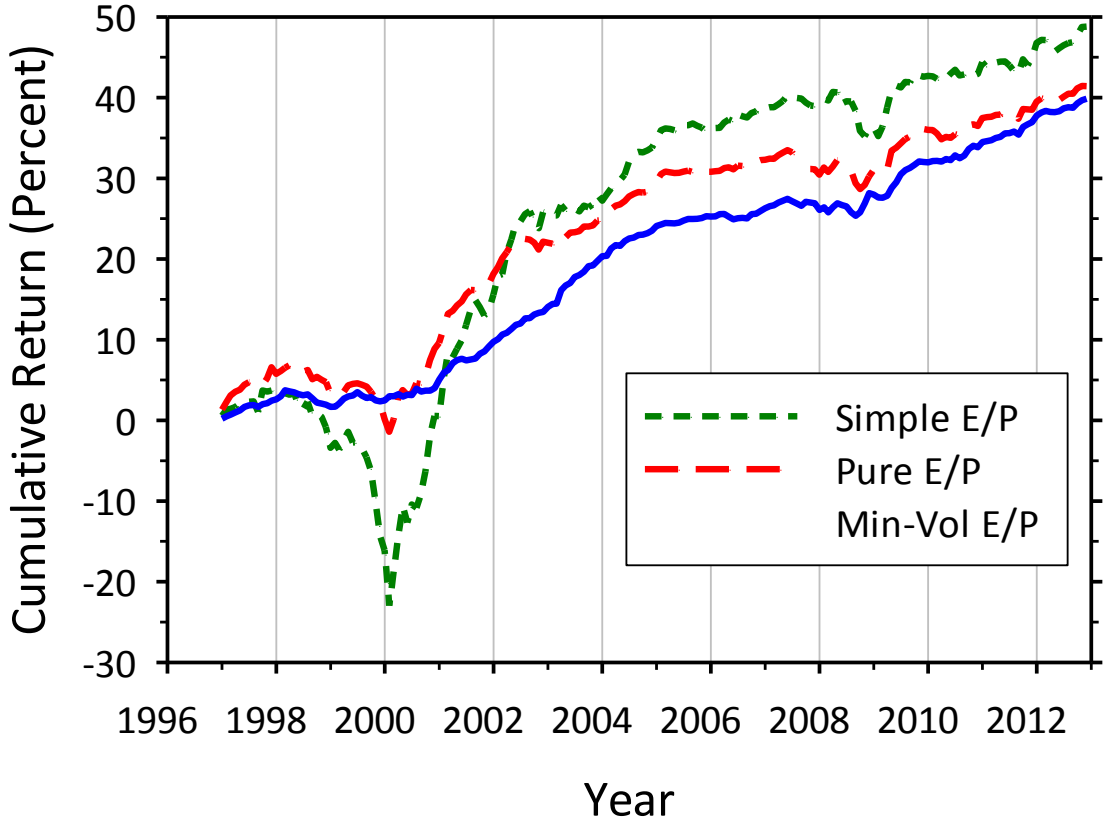
Earnings Yield

- 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
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- Min-Vol factor portfolio was largely unaffected by Internet Bubble

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Earnings Yield Factor Portfolios (April 2000)

- Simple factor portfolio was long "old economy" and short "new economy"

Factor	Simple Exposure	Pure Exposure	Min-Vol Exposure
Beta	-0.347	0.000	0.089
Momentum	-0.554	0.000	0.014
Earnings Yield	1.000	1.000	1.000
Dividend Yield	0.565	0.000	0.327
Book-to-Price	0.579	0.000	0.183
Food & Beverage	0.018	0.000	-0.011
Diversified Financials	0.019	0.000	-0.011
Construction	0.018	0.000	-0.026
Telecommunications	-0.054	0.000	0.024
Internet	-0.031	0.000	0.016
Software	-0.041	0.000	0.018

Old Economy

New Economy

- Min-Vol factor portfolio took offsetting positions to hedge risk

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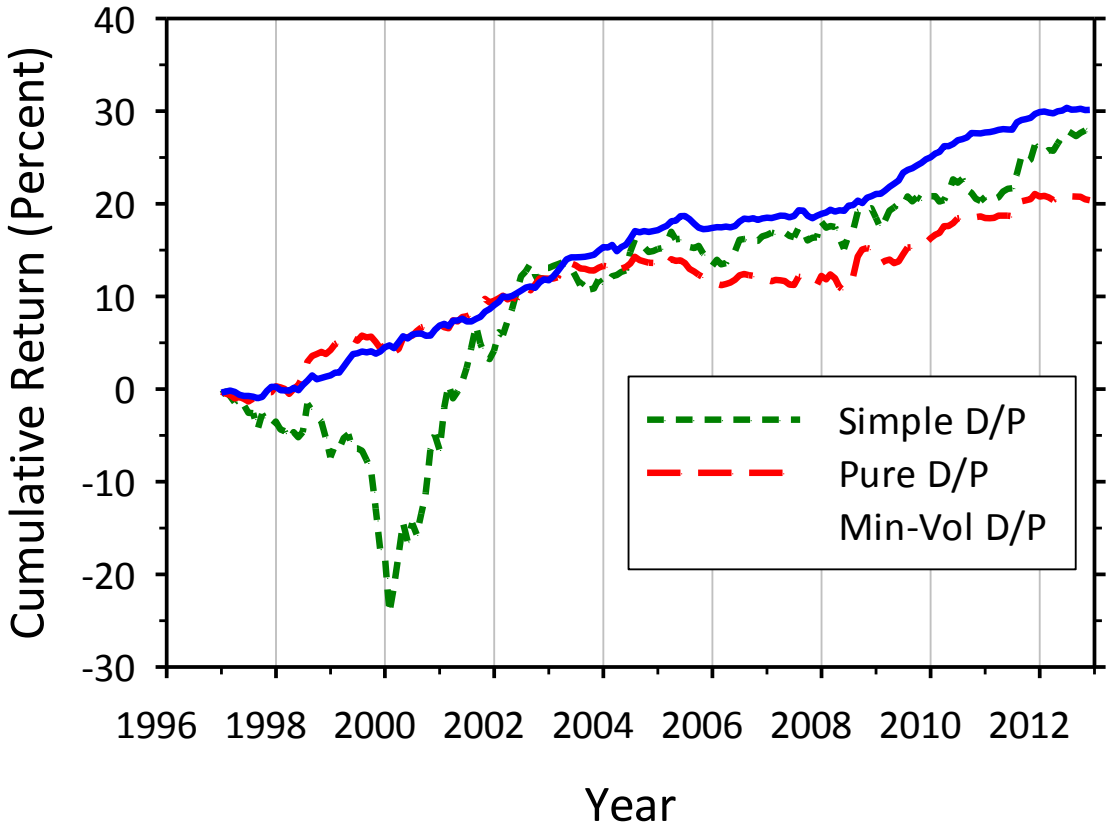
Dividend Yield

- Net returns of the three factor portfolios were comparable
- Volatilities were strikingly different



D/P	Simple	Pure	M-Vol
Return	1.71	1.27	1.88
Risk	4.47	1.55	0.98
IR	0.39	0.67	1.74

- Min-Vol factor portfolio was largely unaffected by Internet Bubble

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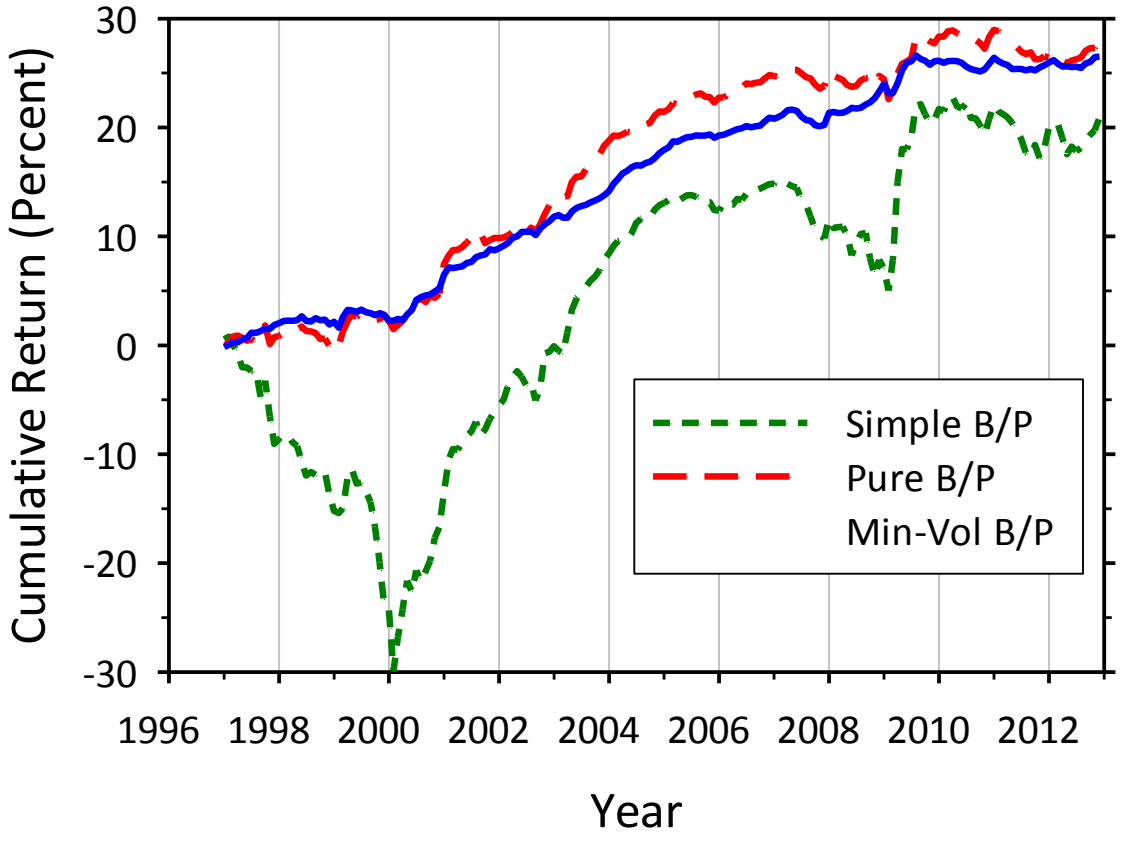
Book-to-Price

- Similar return/risk profile as Earnings Yield and Dividend Yield factors



B/P	Simple	Pure	M-Vol
Return	1.30	1.74	1.66
Risk	4.66	1.81	1.09
IR	0.31	0.96	1.50

- Min-Vol factor portfolio was largely unaffected by Internet Bubble

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Combining Multiple Alpha Signals

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Combining Alpha Signals

- Objective: To construct a composite alpha signal based on several distinct signals (*descriptor alphas*)
- Example: Earnings Yield, Book-to-Price, Dividend Yield
- Questions:
  - *Should one use pure factors?*
  - *Should one use min-vol factors?*
  - *How should the signals be combined?*

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Combining Pure Alpha Factor Portfolios

- Form optimal combination of pure alpha factors
- Obtain weights by solving 3x3 optimization problem:
- Expected Return
  - Obtain *IR* using expanding window (five-year minimum)
  - Scale predicted *IR* by forecast risk to get predicted returns
- Risk
  - Use 3x3 block of GEM3S factor covariance matrix

- By construction, optimal portfolio has exposure only to pure alpha factors
- Problem: portfolio does not have maximum *IR ex ante*

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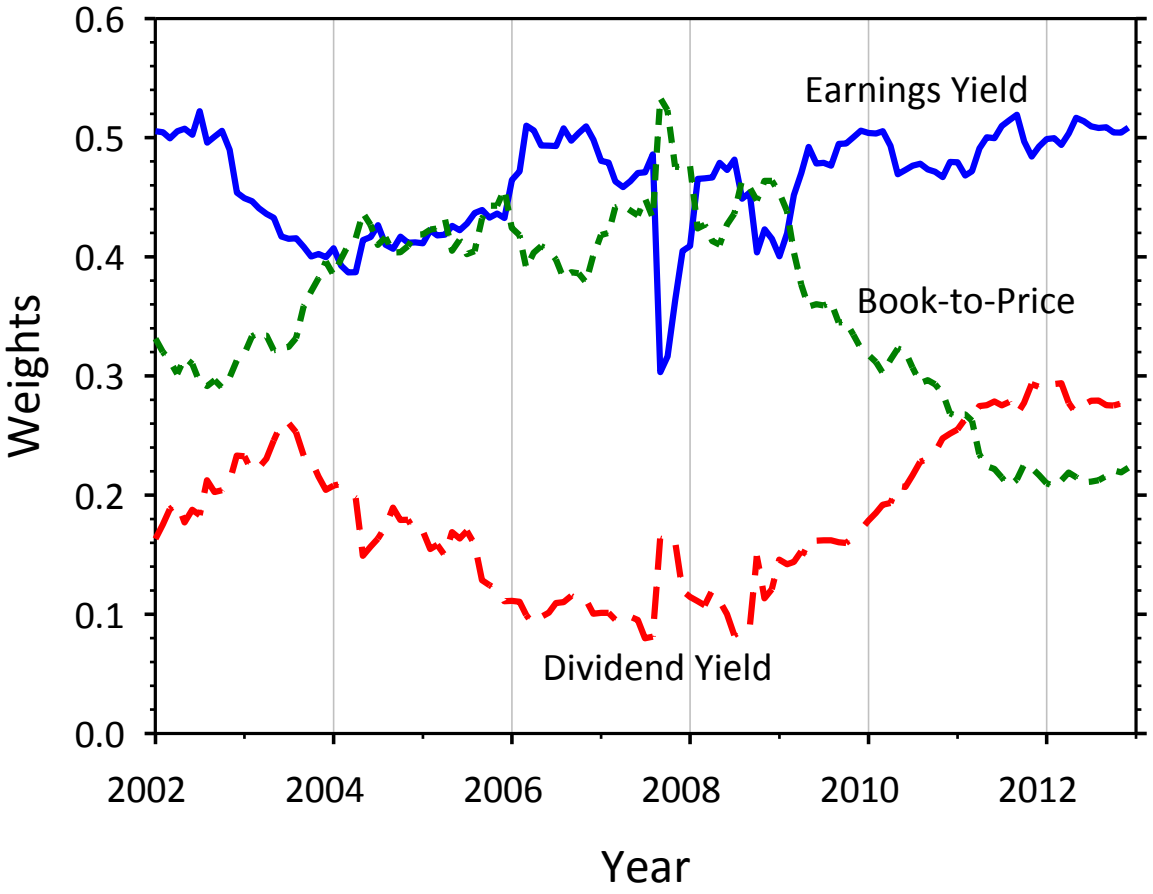
Pure Alpha Factor Weights versus Time

- Weights were relatively stable, except during "Quant Meltdown"



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Intuition Behind Weights

- Volatility of Earnings Yield was low in start of August 2007
- Sharp drop in weight of Earnings Yield as volatility spikes over month

Factor	Info Ratio	Volatility	Expected Return	Correl (E/P)	Correl (D/P)	Correl (B/P)	Weight
Earnings Yield	1.59	0.90	1.43	1.00	-0.15	-0.06	0.49
Dividend Yield	0.03	0.80	0.02	-0.15	1.00	0.02	0.08
Book-to-Price	1.21	0.78	0.94	-0.06	0.02	1.00	0.43

Aug 2007

Factor	Info Ratio	Volatility	Expected Return	Correl (E/P)	Correl (D/P)	Correl (B/P)	Weight
Earnings Yield	1.49	2.62	3.92	1.00	-0.21	0.01	0.30
Dividend Yield	0.10	1.46	0.15	-0.21	1.00	-0.03	0.16
Book-to-Price	1.16	1.10	1.28	0.01	-0.03	1.00	0.53

Sept 2007

GEM3S Model

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Combining the Min-Vol Factor Portfolios

- Form optimal combination of min-vol alpha factors
- Obtain weights by solving 3x3 optimization problem:
- Expected Return
  - Obtain expected return of min-vol factors as a weighted average of expected returns of pure factors
  - Only the alpha factors contribute
- Risk
  - Use GEM3S to construct the 3x3 covariance matrix of min-vol factor portfolios
- Optimization will provide min-vol portfolio weights to maximize *IR*
- Min-vol portfolio weights can be converted to descriptor weights
- Optimal portfolio has exposure to all risk factors

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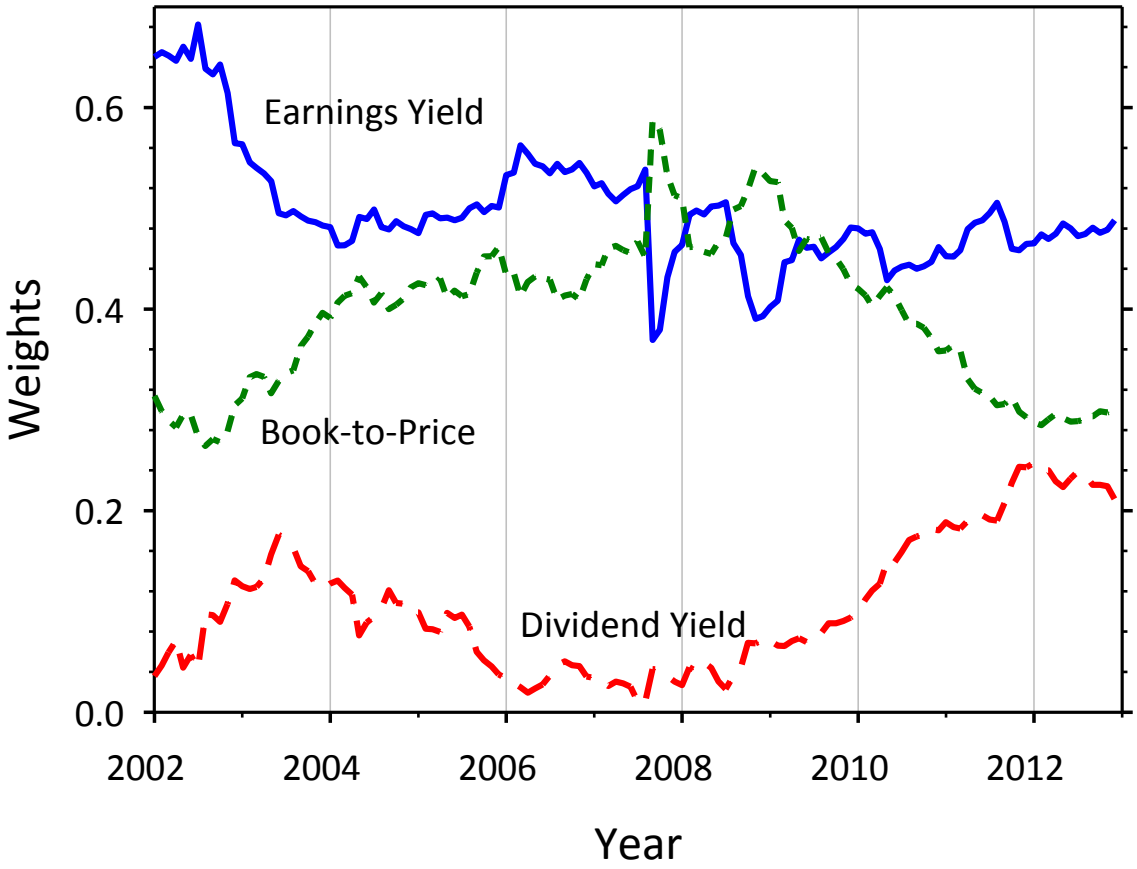
Stability of Min-Vol Portfolio Weights (w_k)

- Earnings Yield weight drops sharply after Quant Meltdown



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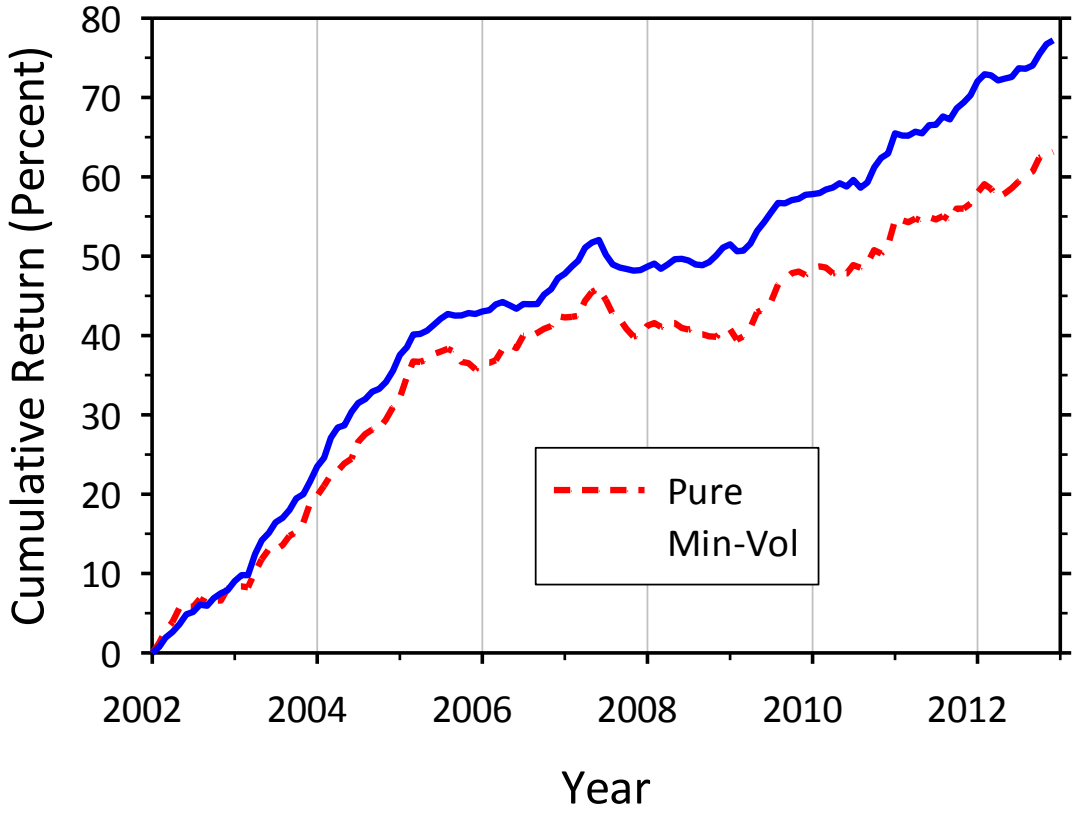
Optimal Combined Alpha Signal: Cumulative Performance

- Min-vol portfolio had higher return than pure portfolio (by luck?)
- Min-vol portfolio had lower volatility (by design)



Portfolio	Pure	M-Vol
Return	1.81	2.25
Risk	1.07	0.87
IR	1.94	2.78

Sample Period:
Jan-2002 to Dec-2012

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Characteristics of Optimal Portfolio

- Only the three alpha factors contribute to active risk
- Pure alpha factors have negative correlation with pure Momentum factor, positive correlation with World factor

Factor	Exposure	Volatility	Correlation	Risk Contrib
World	-0.004	11.25	0.00	0.00
Banks	0.005	3.66	0.00	0.00
Momentum	0.054	2.91	0.00	0.00
Earnings Yield	0.559	1.01	0.60	0.34
Book-to-Price	0.338	1.16	0.40	0.16
Dividend Yield	0.317	0.82	0.17	0.05
USA	0.010	3.64	0.00	0.00

31-Dec-2012

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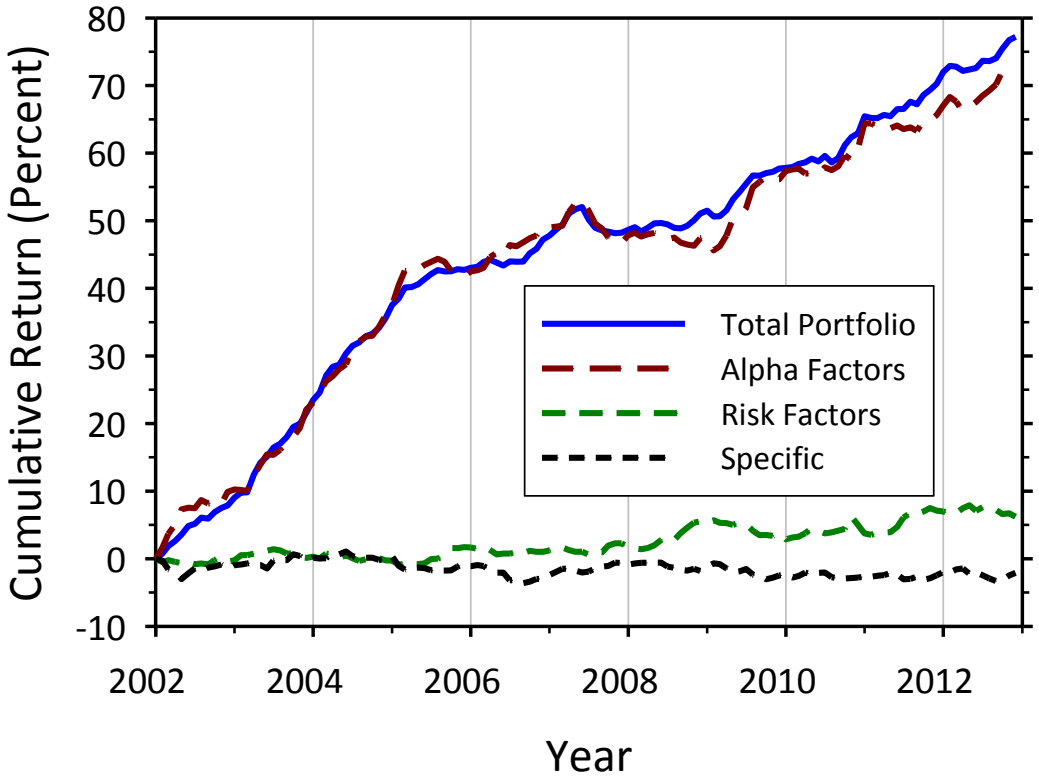
Return Attribution

- Alpha factors accounted for almost the entire portfolio return
- Risk factors and specific portion contributed very little



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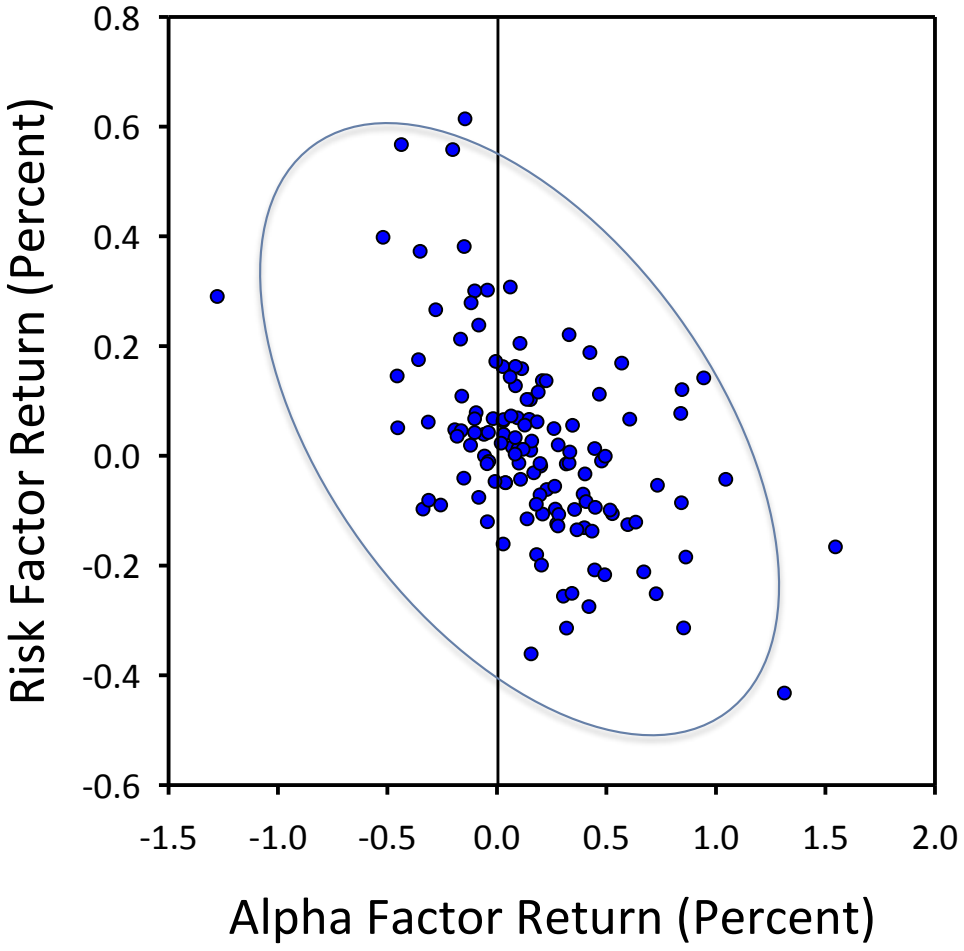
Do Risk Factors Provide a "Free Lunch?"



- Risk factor returns were strongly negatively correlated (-0.52) with alpha factors
- Risk factors reduced portfolio risk without hurting portfolio return

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Summary

- Several ways to capture risk premia:
  - Simple factor portfolios tilt on desired exposure without considering other factors
  - Pure factor portfolios tilt on desired factor but hedge all other factor exposures
  - Min-vol factor portfolios exploit correlations to minimize risk
- Alpha factors exhibit directional drift; risk factors drift sideways
- Min-vol portfolios form "building blocks" for combining alpha signals
- Alpha signal weights can be determined by solving optimization problem over the subspace of alpha factors
- Combining pure alpha factors leads to sub-optimal portfolios

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Technical Appendix

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Outline

- Factor portfolios (Simple, Pure, Min-Vol)
- Alpha factors versus risk factors
- Empirical Comparison
  - Performance of simple, pure, and min-vol factors
- Combining Alpha Signals
  - Pure factors
  - Min-vol factors

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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

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

- Portfolio has non-zero exposures to other risk factors

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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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Min-Vol Factor Portfolios

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

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

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

Return of min-vol factor portfolio k

- Ω_{nk}^C gives the weight of stock n in min-vol factor portfolio k
- Min-vol portfolios form building blocks for combining alpha signals

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Risk Attribution for Min-Vol Factor Portfolios

- Pure factor portfolios are uncorrelated with min-vol factor portfolios
- Pure factors contribute zero to risk of min-vol factor portfolios

$$\mathrm{cov}\left(\Omega_m^P, \Omega_k^C\right) = \left(\Omega_m^P\right)' V\left(V^{-1} X_k\right) = 0 \quad if \quad m \neq k$$

- Example: Momentum factor (31-Dec-2012)

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World	0.04	11.25	0.00	0.00
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USA	-0.02	3.64	0.00	0.00

- Pure World factor negatively correlated with Momentum factor

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Alpha Factors versus Risk Factors

- Segment the explanatory variables into "alpha" factors and "risk" factors:

$$r_n = \sum_{k(\alpha)} X_{nk}^{(\alpha)} f_k^{P(\alpha)} + \sum_{k(\sigma)} X_{nk}^{(\sigma)} f_k^{P(\sigma)} + u_n$$

- Alpha factors have "drift"
- Expected value of pure factor return is non-zero:

$$E\left[f_k^{P(\alpha)} \right] = \alpha_k^P$$

- Risk factors have no drift:

$$E\left[f_k^{P(\sigma)} \right] = 0$$

- Risk factors can hedge alpha factors without impacting expected returns

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Computing Realized Information Ratios

- Define the realized alpha and realized risk of a factor:

$$\tilde{\alpha}_k = 12\left(\frac{1}{T}\sum_t f_{kt}\right)$$ Realized alpha (annualized)

$$\tilde{\sigma}_k = \sqrt{12}\left[\frac{1}{T}\sum_t\left(f_{kt} - \bar{f}_k\right)^2\right]^{1/2}$$ Realized risk (annualized)

- Report realized Information Ratio using *standardized* returns:

$$z_{kt} = \frac{f_{kt}}{\sigma_{kt}} \rightarrow IR_k = \sqrt{12}\left[\frac{mean\left(z_k\right)}{std\left(z_k\right)}\right]$$ Realized *IR* (annualized)

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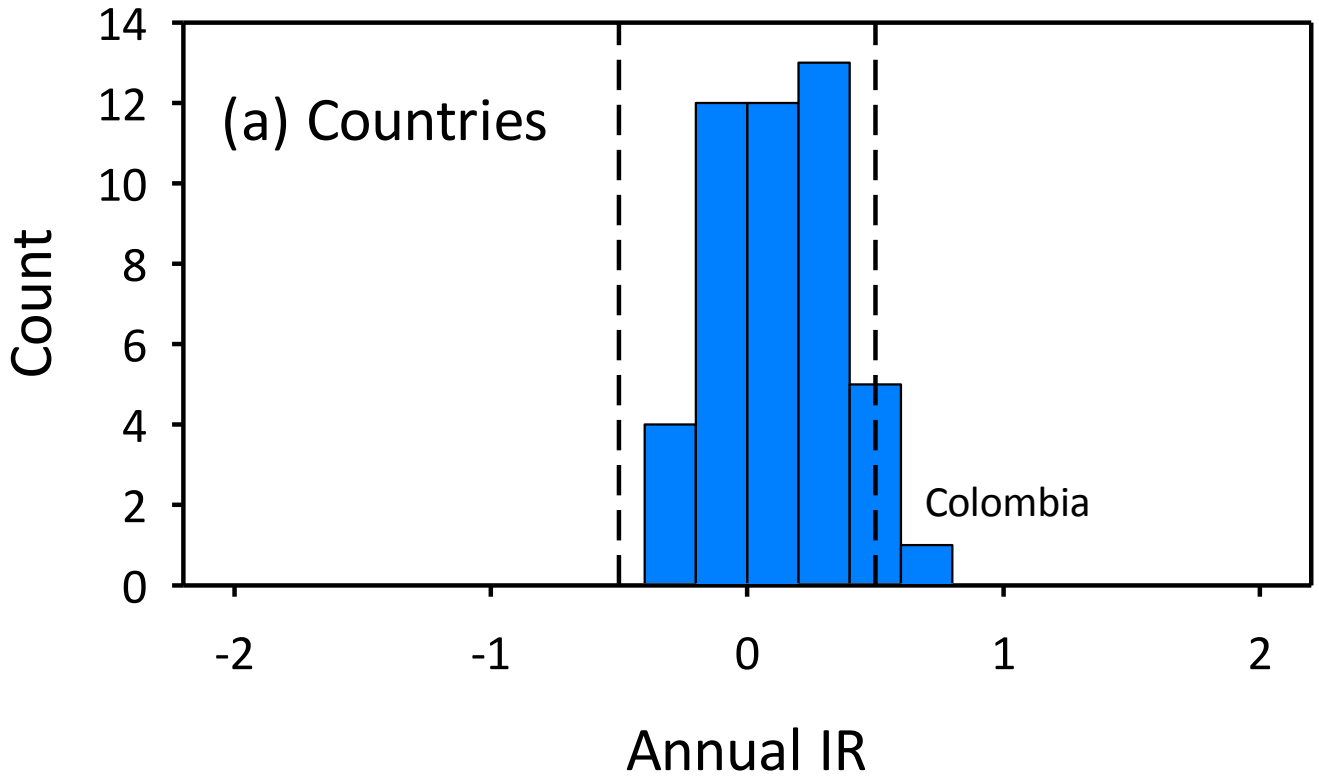

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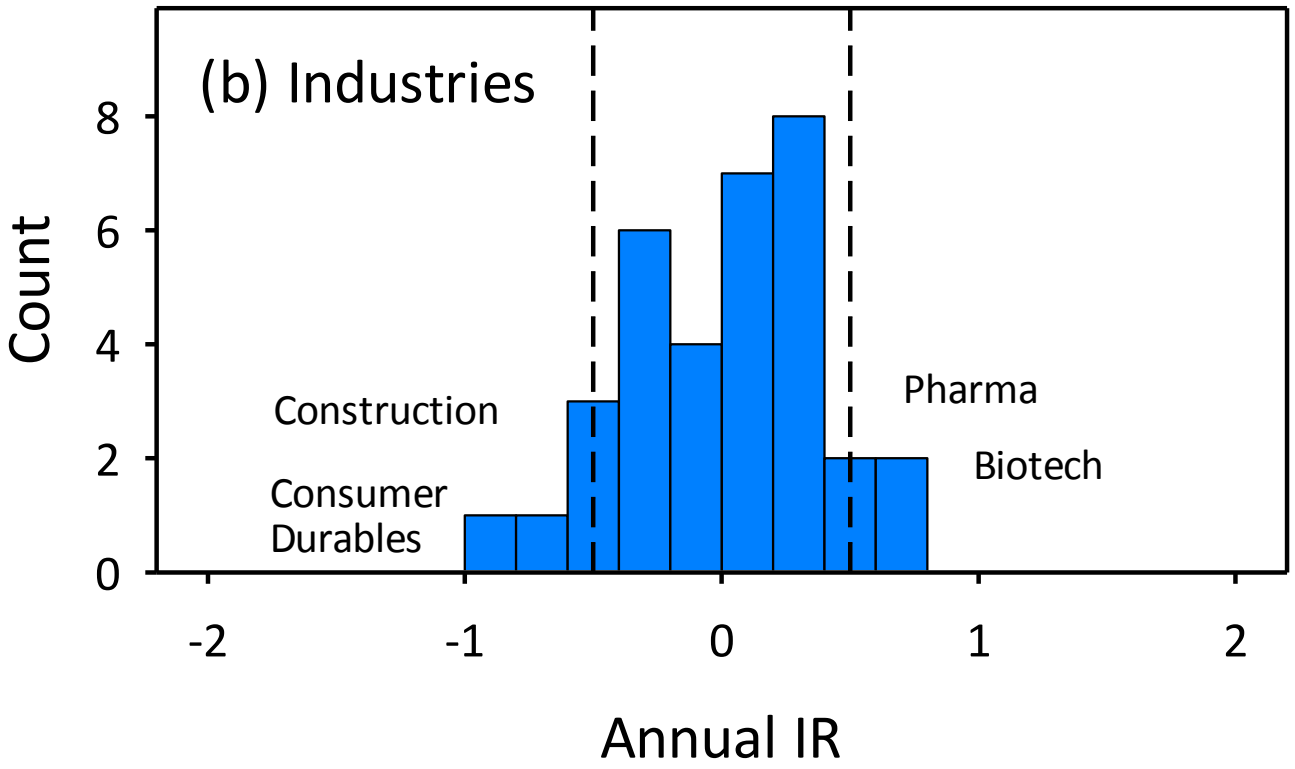

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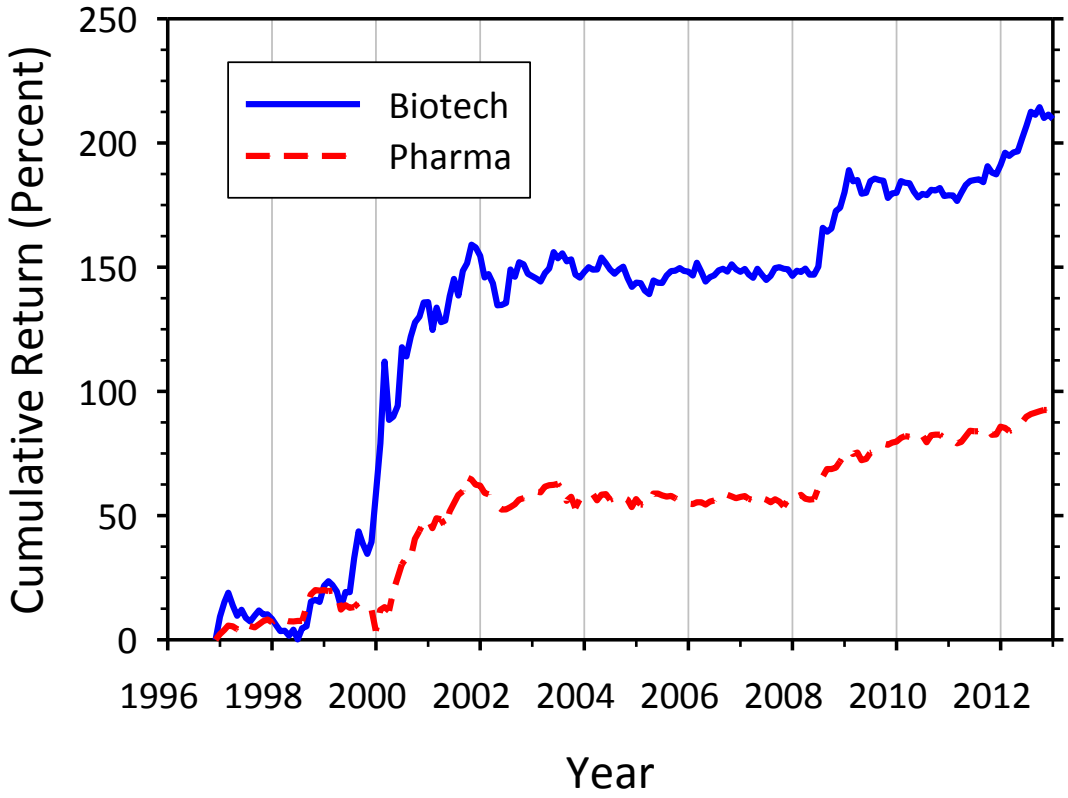

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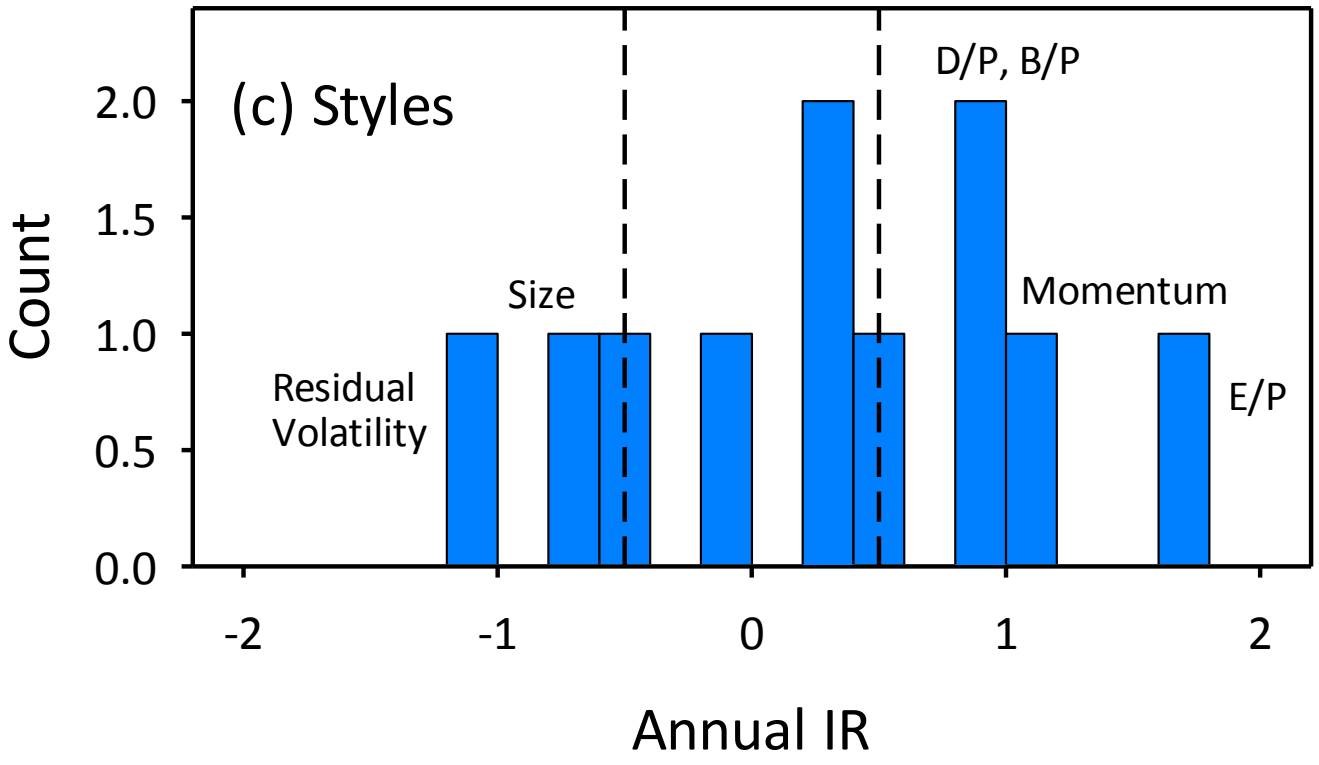

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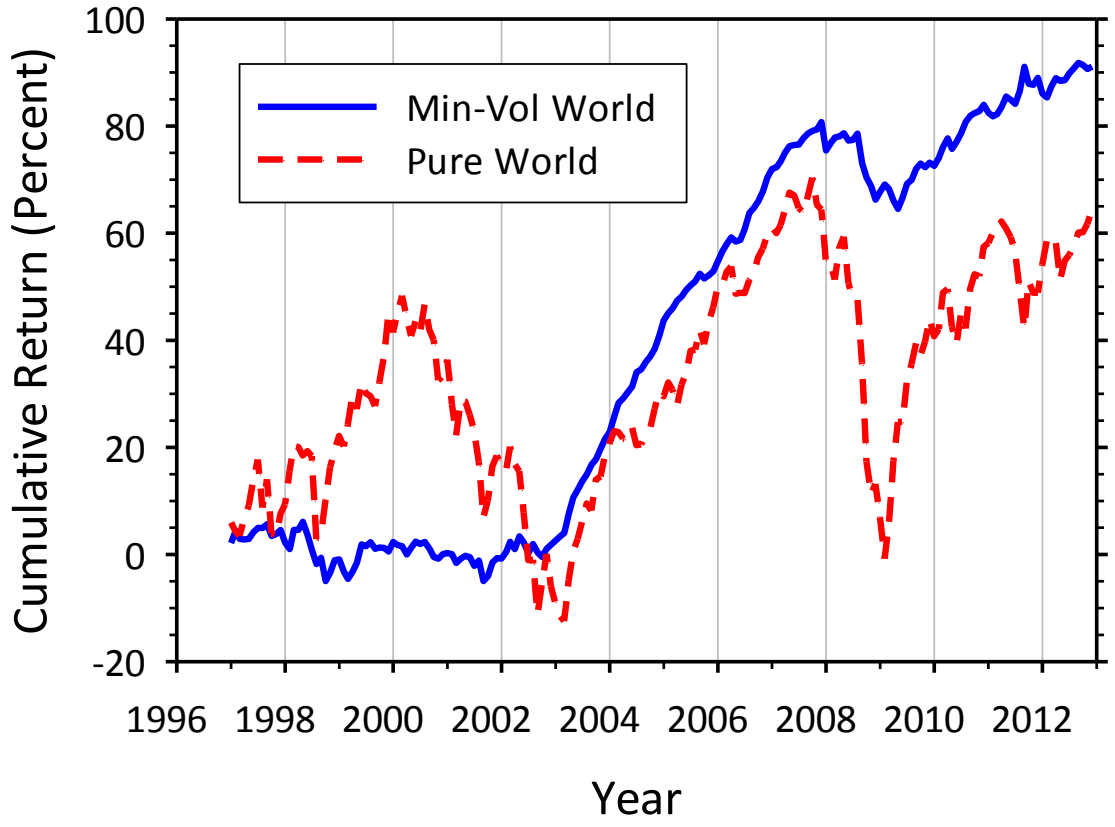

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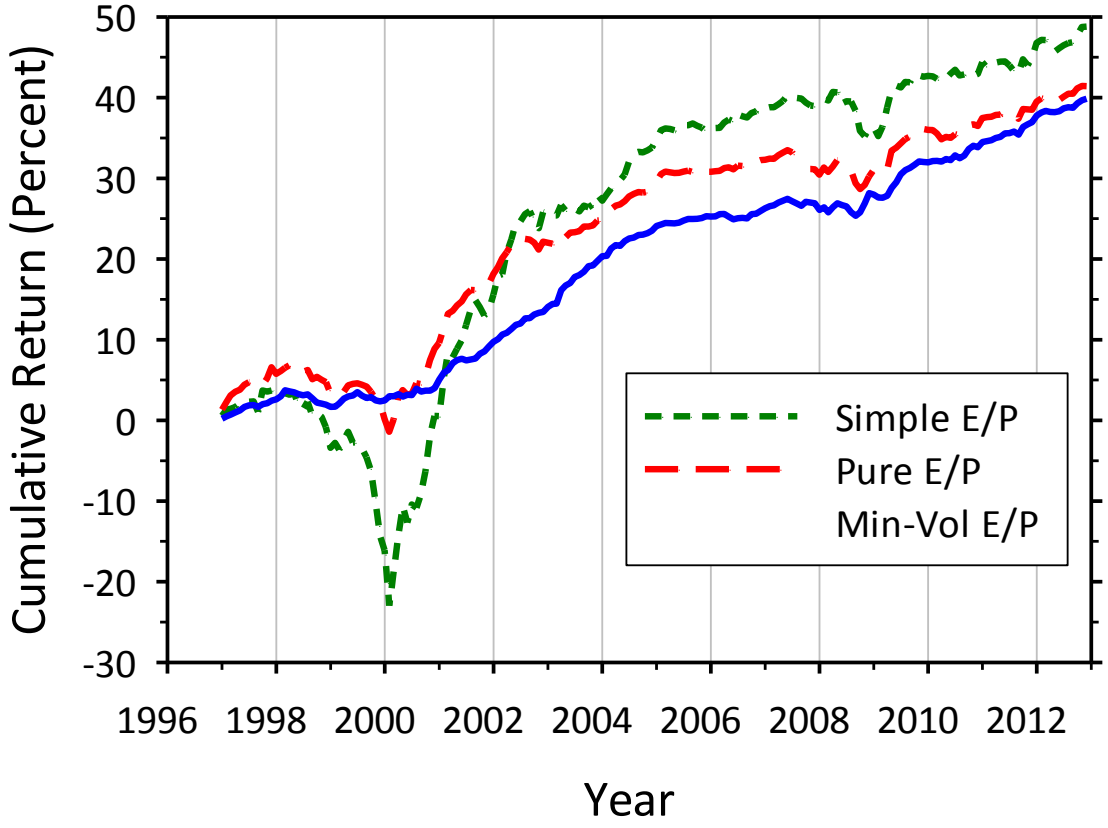

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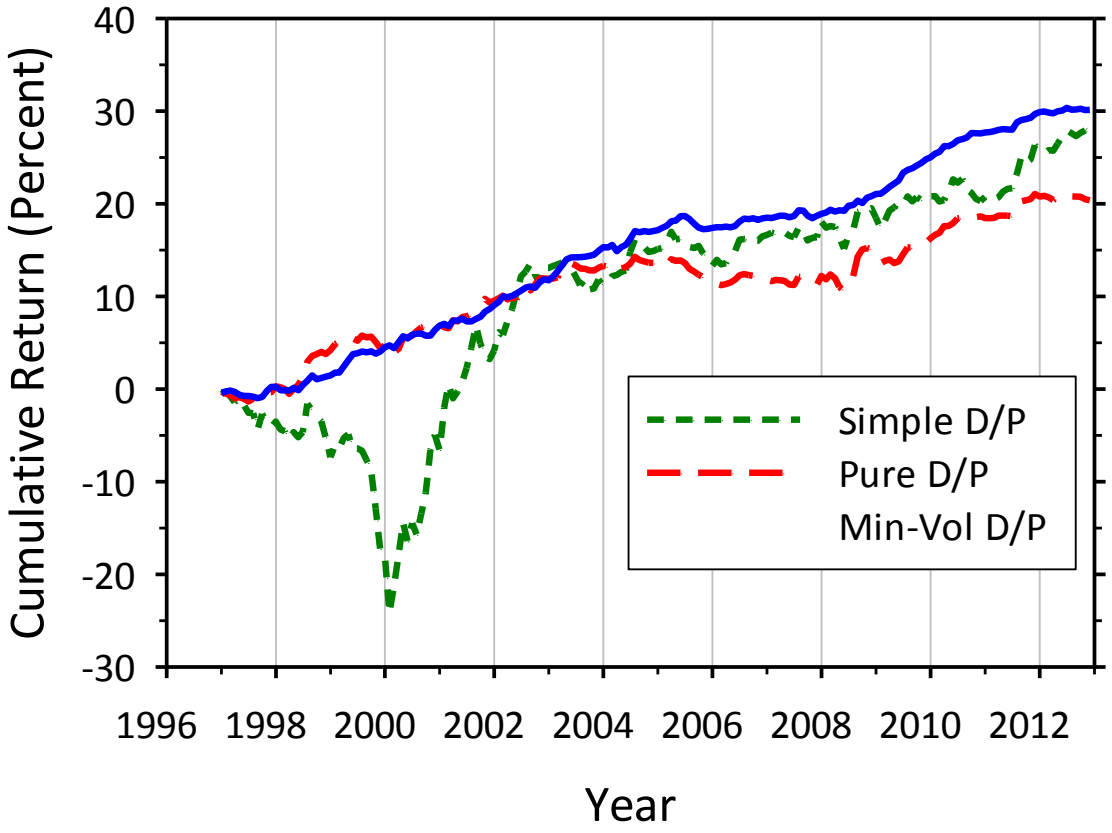
- Net returns of the three factor portfolios were comparable
- Volatilities were strikingly different



D/P	Simple	Pure	M-Vol
Return	1.71	1.27	1.88
Risk	4.47	1.55	0.98
IR	0.39	0.67	1.74

- Min-Vol factor portfolio was largely unaffected by Internet Bubble

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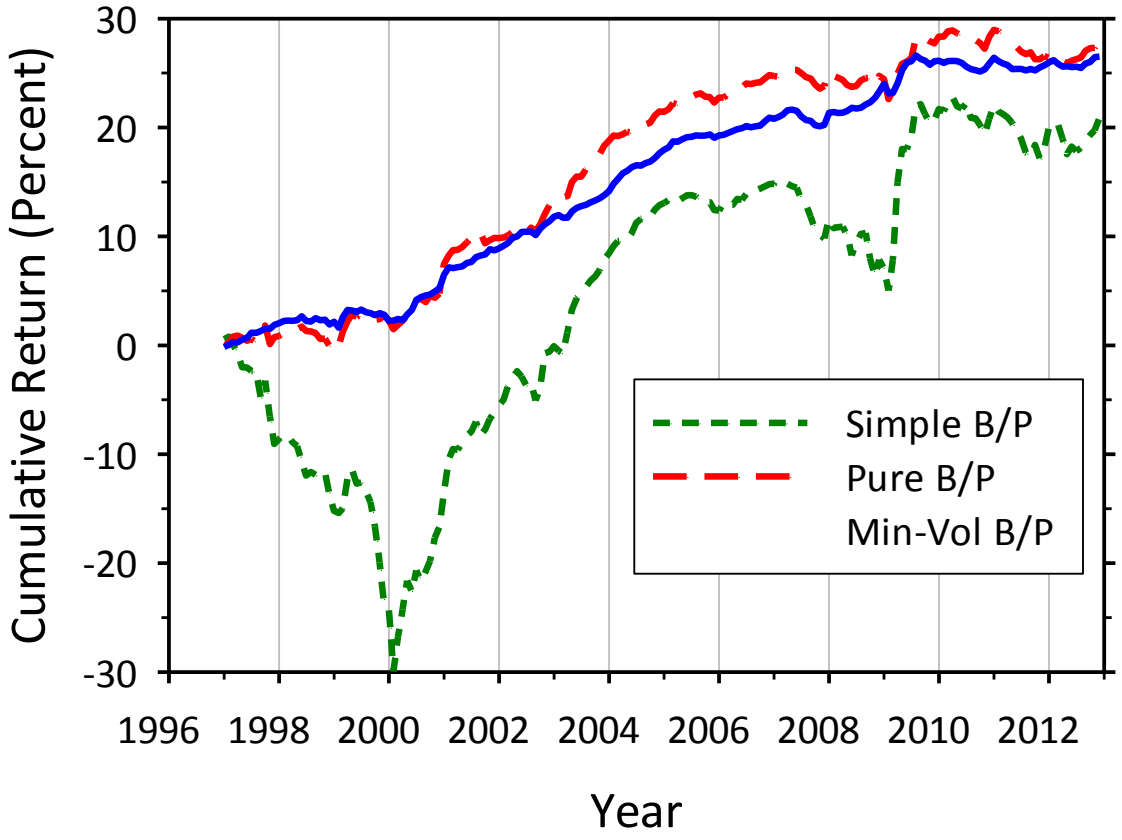
Book-to-Price

- Similar return/risk profile as Earnings Yield and Dividend Yield factors



B/P	Simple	Pure	M-Vol
Return	1.30	1.74	1.66
Risk	4.66	1.81	1.09
IR	0.31	0.96	1.50

- Min-Vol factor portfolio was largely unaffected by Internet Bubble

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Combining Multiple Alpha Signals

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Combining Alpha Signals

- Objective: To construct a composite alpha signal based on several distinct signals (*descriptor alphas*)
- Example: Earnings Yield, Book-to-Price, Dividend Yield
- Questions:
  - *Should one use pure factors?*
  - *Should one use min-vol factors?*
  - *How should the signals be combined?*

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Combining Pure Alpha Factor Portfolios

- Form optimal combination of the pure alpha factors

$$h^P = F^{-1}\alpha^P$$

- h^P: optimal alpha factor weights (3x1 vector)
- F : pure alpha factor covariance matrix (3x3 matrix)
- α^P: expected returns for the pure alpha factors (3x1 vector)
- Obtain alphas using expanding-window *IR* and pure factor risk forecast:

$$\alpha_k^P = IR_k^P \sigma_k^P$$

- Use first five years of data set to train the *IR* estimates
- By construction, optimal portfolio has exposure only to pure alpha factors
- Problem: portfolio does not have maximum *IR ex ante*

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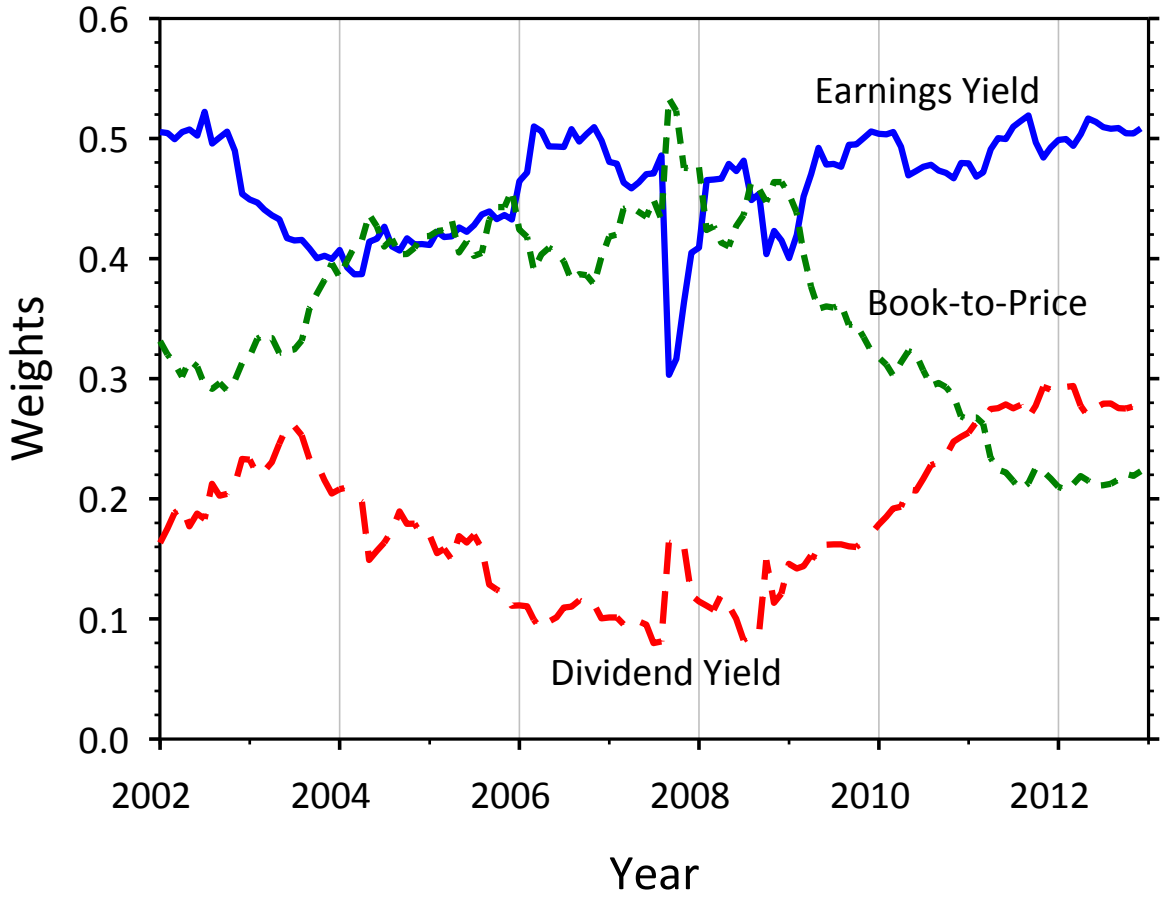
Pure Alpha Factor Weights versus Time

- Weights were relatively stable, except during "Quant Meltdown"



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Intuition Behind Weights

- Volatility of Earnings Yield was low in start of August 2007
- Sharp drop in weight of Earnings Yield as volatility spikes over month

Factor	Info Ratio	Volatility	Expected Return	Correl (E/P)	Correl (D/P)	Correl (B/P)	Weight
Earnings Yield	1.59	0.90	1.43	1.00	-0.15	-0.06	0.49
Dividend Yield	0.03	0.80	0.02	-0.15	1.00	0.02	0.08
Book-to-Price	1.21	0.78	0.94	-0.06	0.02	1.00	0.43

Aug 2007

Factor	Info Ratio	Volatility	Expected Return	Correl (E/P)	Correl (D/P)	Correl (B/P)	Weight
Earnings Yield	1.49	2.62	3.92	1.00	-0.21	0.01	0.30
Dividend Yield	0.10	1.46	0.15	-0.21	1.00	-0.03	0.16
Book-to-Price	1.16	1.10	1.28	0.01	-0.03	1.00	0.53

Sept 2007

GEM3S Model

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Combining the Alpha Signals

- Composite alpha is a linear combination of "descriptor" alphas

$$\alpha_n = \sum_k v_k X_{nk}^{(\alpha)}$$ Composite alpha

$$h = V^{-1}\alpha = \sum_k v_k V^{-1} X_k^{(\alpha)}$$ Optimal portfolio for composite alpha

- Question: How to determine the optimal descriptor weights v_k ?

$$h_k = s_k V^{-1} X_k^{(\alpha)}$$ Min-vol portfolio k

- The optimal portfolio is a weighted sum of min-vol portfolios:

$$h = \sum_k w_k h_k = \sum_k w_k s_k V^{-1} X_k^{(\alpha)} \rightarrow \boxed{v_k = w_k s_k}$$

- We still need to solve for the min-vol portfolio weights w_k

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Determining Min-Vol Portfolio Weights

- Let G be the (3x3) covariance matrix of min-vol factor portfolios:

$$G_{kl} = h_k' V h_l$$

- Let α^C is the 3x1 vector of expected returns for min-vol alpha factors
- Obtain min-vol alphas as linear combination of pure alpha factors:

$$\alpha_k^C = \sum_{m(\alpha)} X_{km}^C \alpha_m^P$$

- Optimal weights are given by the (3x3) optimization:

$$\boxed{w = G^{-1}\alpha^C}$$

- Optimal portfolio now has exposure to all alpha/risk factors

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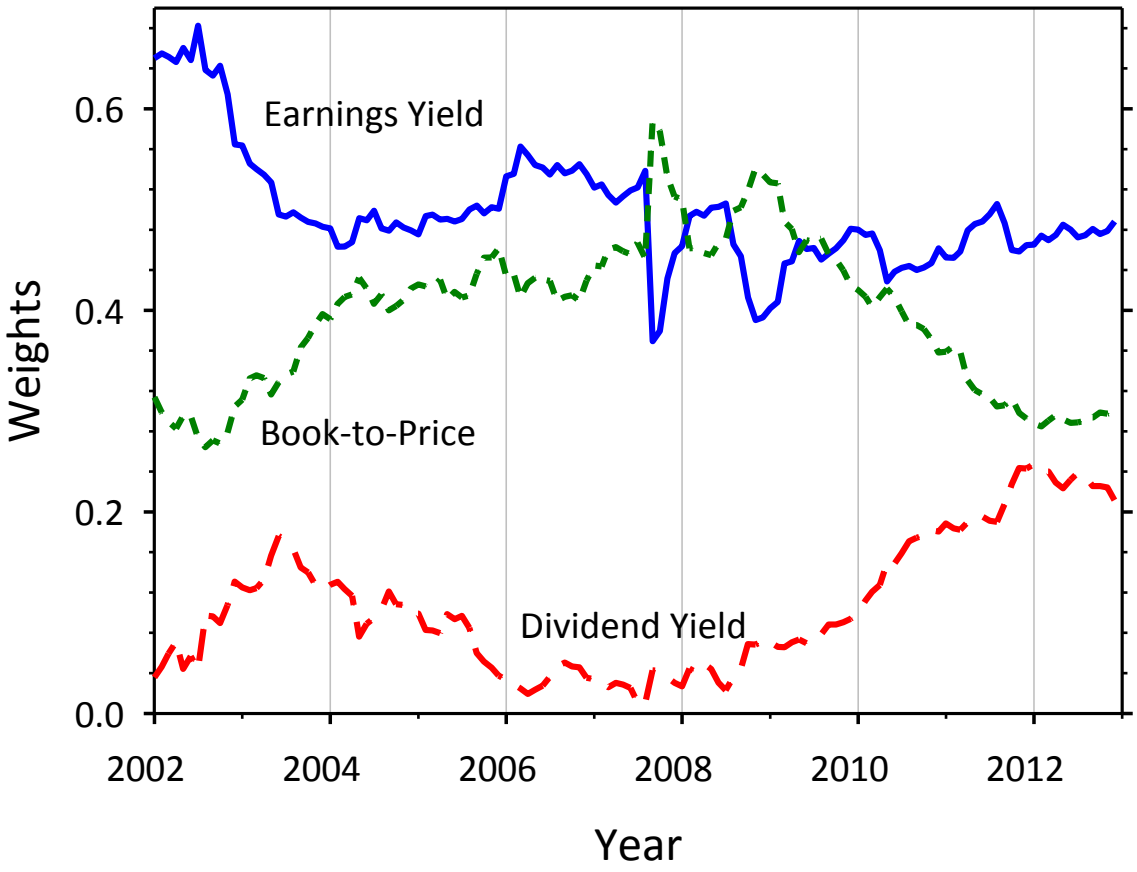
Stability of Min-Vol Portfolio Weights (w_k)

- Earnings Yield weight drops sharply after Quant Meltdown



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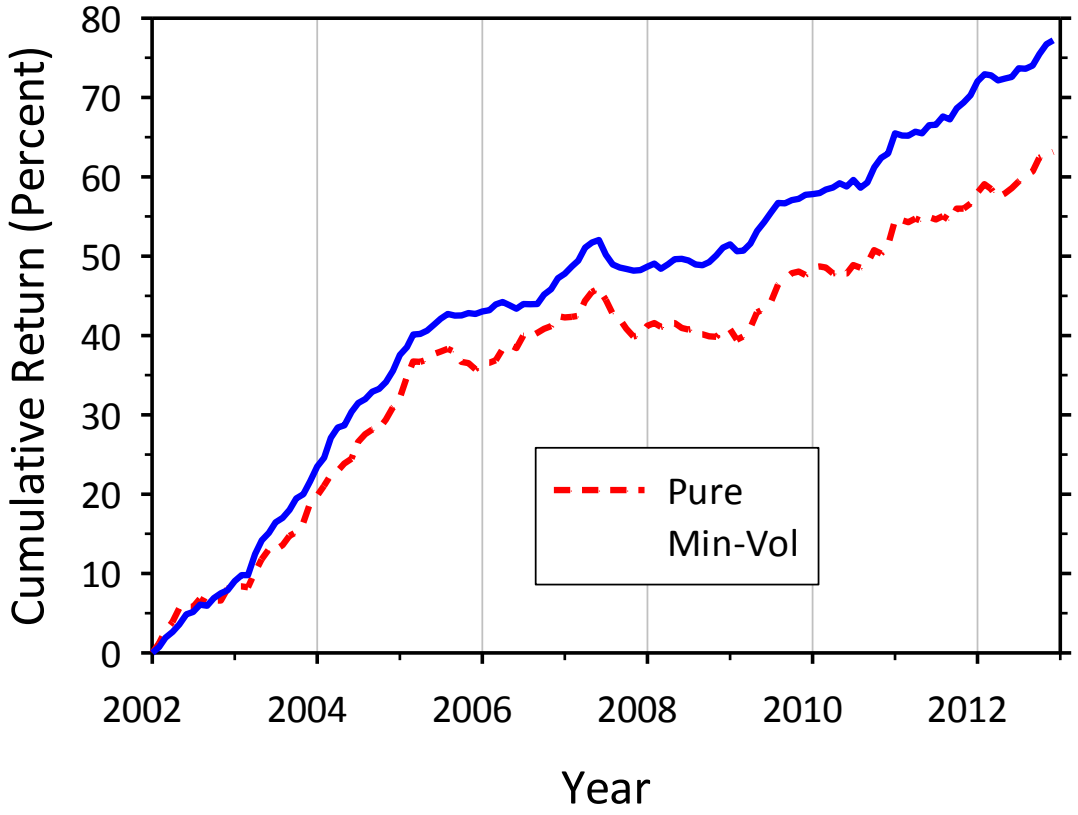
Optimal Combined Alpha Signal: Cumulative Performance

- Min-vol portfolio had higher return than pure portfolio (by luck?)
- Min-vol portfolio had lower volatility (by design)



Portfolio	Pure	M-Vol
Return	1.81	2.25
Risk	1.07	0.87
IR	1.94	2.78

Sample Period:
Jan-2002 to Dec-2012

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Characteristics of Optimal Portfolio

- Only the three alpha factors contribute to active risk
- Pure alpha factors have negative correlation with pure Momentum factor, positive correlation with World factor

Factor	Exposure	Volatility	Correlation	Risk Contrib
World	-0.004	11.25	0.00	0.00
Banks	0.005	3.66	0.00	0.00
Momentum	0.054	2.91	0.00	0.00
Earnings Yield	0.559	1.01	0.60	0.34
Book-to-Price	0.338	1.16	0.40	0.16
Dividend Yield	0.317	0.82	0.17	0.05
USA	0.010	3.64	0.00	0.00

31-Dec-2012

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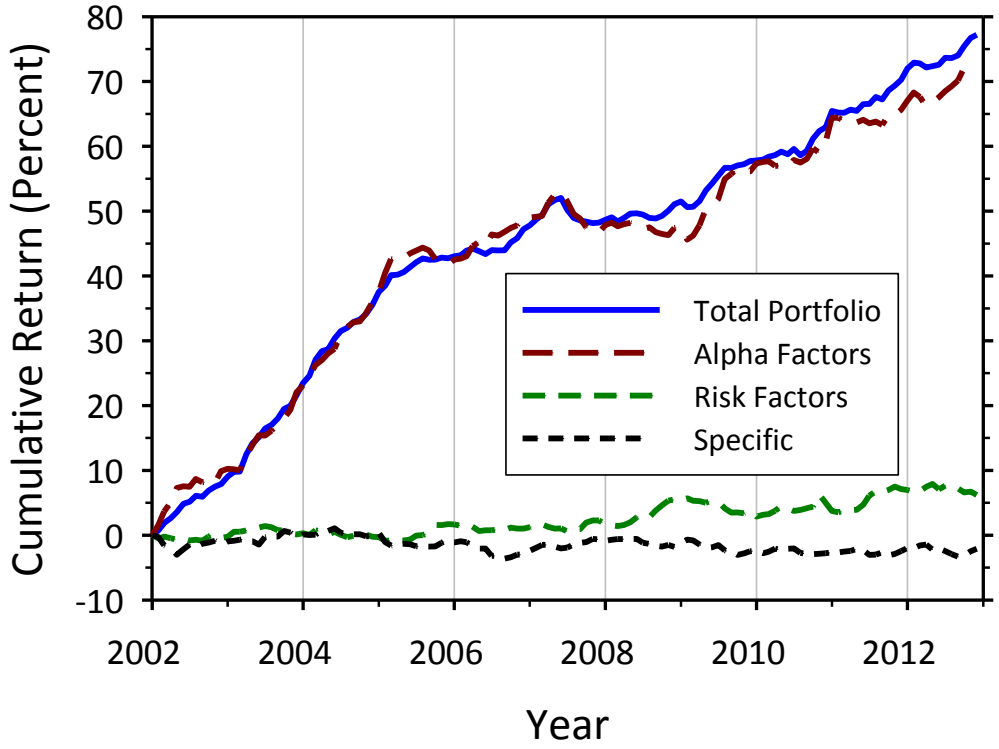
Return Attribution

- Alpha factors account for almost the entire portfolio return
- Risk factors and specific portion contributed very little



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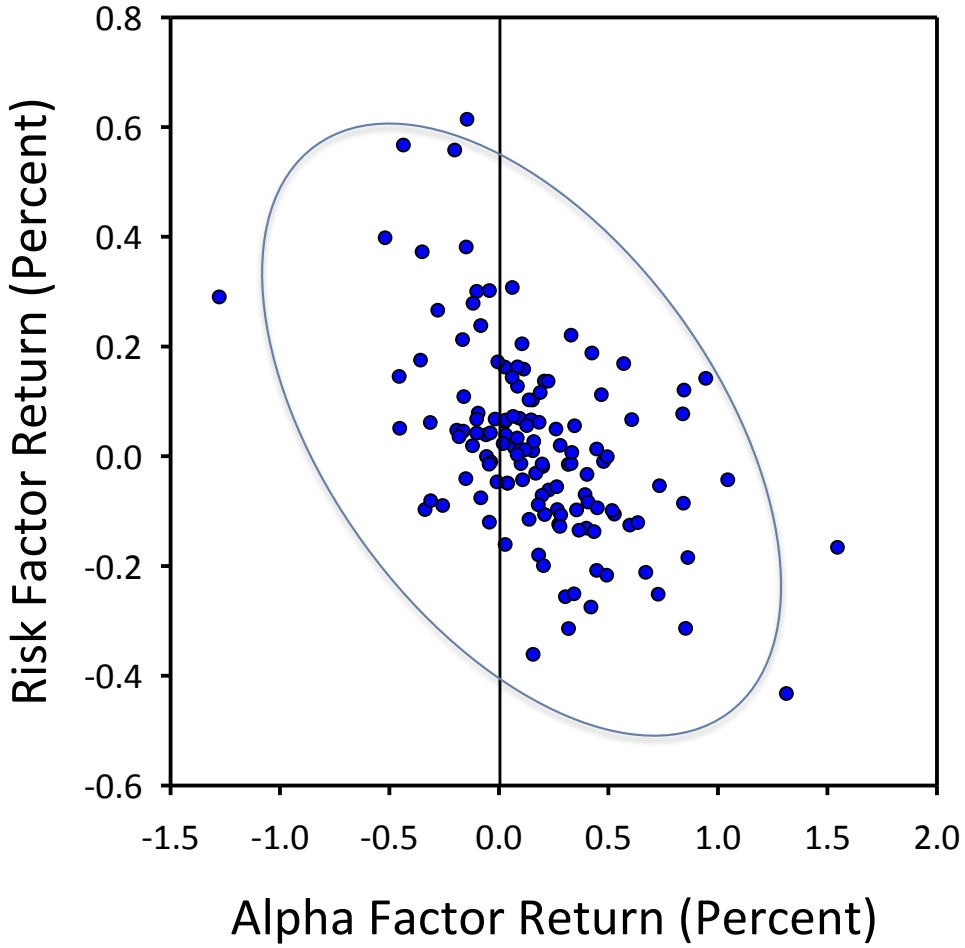
Do Risk Factors Provide a "Free Lunch?"



- Risk factor returns were strongly negatively correlated (-0.52) with alpha factors
- Risk factors reduced portfolio risk without hurting portfolio return

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Summary

- Several ways to capture risk premia:
  - Simple factor portfolios tilt on desired exposure without considering other factors
  - Pure factor portfolios tilt on desired factor but hedge all other factor exposures
  - Min-vol factor portfolios exploit correlations to minimize risk
- Alpha factors exhibit directional drift; risk factors drift sideways
- Min-vol portfolios form "building blocks" for combining alpha signals
- Alpha signal weights can be determined by solving optimization problem over the subspace of alpha factors
- Combining pure alpha factors leads to sub-optimal portfolios

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