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Robustness of Smart Beta Strategies

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Outline

- Introduction
- Robustness Issues: Potential Sources of Lack of Robustness
- Improving Robustness
- Measurement of Robustness

Introduction: on the importance of robustness for Smart Beta

- In a 2014 survey, EDHEC Risk Institute found that the biggest hurdle for investment professionals to invest in smart beta strategies are concerns about robustness of their performance.

The strength of each hurdle was rated from 1 (weak hurdle) to 5 (strong hurdle).

Doubts over robustness of outperformance	3.62
Issues related to turnover and capacity	3.23
Limited information on risks	3.10
Limited availability of independent research	2.97
Limited availability of data	2.87
High licensing fees	2.82
Insufficient explanation of concepts behind offerings	2.76
Low transparency of rules	2.60
Insufficient number of offerings	2.40

Source: EDHEC Risk Alternative Equity Beta Survey. The survey was conducted as part of the Newedge "Advanced Modelling for Alternative Investments" Research Chair

Introduction: on the importance of robustness for Smart Beta

- Concerns over robustness are widely echoed in the media and industry:

"The **historical tests** that don't predict the future for smart beta strategies" (Financial News, May 2014)

"Market conditions … may present a headwind or tailwind for certain strategies. For example, compressed valuation spreads may present **a more challenging environment** for a value strategy" (Towers Watson 2014)

"…benchmarks are often being chosen for new products based on their attractive performance history. And, of course, **past performance** is no guarantee of future results." (Buckley, May 2013)

"But is there real investment merit in these new indices? Or are they simply the product of **data mining**? " (Morningstar, November 2013)

"Some alternative indices add value, but not necessarily under the same market conditions, investors need to understand the **underlying biases** and the overall fit in their portfolio before selecting the right benchmark" (Northern Trust, June 2012)

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What is Robustness of Smart Beta Performance?

Relative and Absolute Robustness

- In general, robustness refers to the capacity of a system to perform effectively in face of change. In statistics, models are said to be robust if they are not unduly affected by outliers or by small departures from model assumptions.
- In the context of smart beta strategies, two kinds of robustness need to be taken into account – ***relative robustness*** and ***absolute robustness***.

Relative robustness

- A strategy is assumed to be 'robust' if it is able to deliver similar outperformance in similar market conditions.
- E.g. A value factor index would be deemed robust if it aligns well with the value factor performance and does not suffer idiosyncratic losses due to any other causes including but not limited to stock specific and sector specific events.

Absolute robustness

- A strategy shown to outperform irrespective of prevailing market conditions , the absence of pronounced state and/or time dependencies, can be termed as robust in 'absolute' terms.
- Absolute robustness can be achieved by allocating across different rewarded sources of risks rather than concentrating in a single one.

Sources of Lack of Relative Robustness

Factor Fishing Risks

- Harvey et al [2013] document a total of 314 of factors with positive historical risk premium showing that the discovery of the premium could be a result of data mining. The practice of identifying merely empirical factors is known as "factor fishing" (see Ang [2013]).
- For e.g. many fundamental variables such as *sales*, *dividends*, *book value* and *cash flow* are used as proxies for value whereas *book-to-market* is **more consensual** factor

	Book Value	Sales	Dividends	Cash Flow	Composite	Book-to-Market	Earnings-to-Price
Annualized Returns	-1.16%	-0.79%	-1.23%	-0.93%	-0.51%	5.20%	4.59%
Statistically Significant?	No	No	No	No	No	Yes	Yes
p-Value	49.42%	81.21%	51.17%	80.25%	93.28%	0.05%	0.38%

Annualized Returns of long-short portfolios - Book Value factor is the daily return series of a cap-weighted portfolio that is long the 30% highest and short the 30% lowest book value stocks. Sales factor is the daily return series of a cap-weighted portfolio that is long the 30% highest and short the 30% lowest sales stocks smoothed over previous 5 years. Dividend factor is the daily return series of a cap-weighted portfolio that is long the 30% highest and short the 30% lowest dividends stocks smoothed over previous 5 years. Cashflow factor is the daily return series of a cap-weighted portfolio that is long the 30% highest and short the 30% lowest cash flows stocks smoothed over previous 5 years. Composite factor is the daily return series of a cap-weighted portfolio that is long the 30% highest and short the 30% lowest composite value that is the average of individual factor values in the US largest 500 market cap universe. Book-to-Market factor is the daily return series of a cap-weighted portfolio that is long the 30% highest and short the 30% lowest B/M stocks. Earnings-to-Price factor is the daily return series of a cap-weighted portfolio that is long the 30% highest and short the 30% lowest E/P stocks. The period of analysis is 31-Dec-1973 to 31-Dec-2013.

- A key requirement of investors to accept factors as relevant in their investment process is that there is a clear economic intuition as to why the exposure to this factor constitutes a systematic risk that requires a reward and is likely to continue producing a positive risk premium (Kogan and Tian [2013]).

Sources of Lack of Relative Robustness

Model Mining Risks – Illustration with Value-tilted Indices

- Model mining risk is the risk of having an index construction methodology which results in a good track record in back testing.
- We consider the impact of various specification choices on fundamental equity indexation strategies, which are commonly employed as a way to harvest the value premium - *variable selection* and *leverage adjustment*.
  - The outperformance of a fundamental equity indexation strategy is highly sensitive to strategy specification choices
  - The value factor performed poorly during the years 1999 and 2008. 'Total leverage adjusted' portfolio returns +5.3% while 'Operating leverage adjusted' portfolio returns just -4.0% indicating that the weighting scheme does not reliably capture the value premium.
  - In addition to be exposed to the value factor, the strategy is also exposed to some latent undesired risks resulting from proprietary definitions.

Criteria	Best performing		Worst performing		Max difference	Year
Variable selection	Earnings	-12.2%	Dividends	-23.0%	10.8%	1999
Leverage adjustment	Total leverage	5.3%	Operating leverage	-4.0%	9.3%	2008

Returns of best and worst performing variants for each specification of the fundamental weighting scheme on the universe of top 1000 US stocks. Portfolios are formed using fundamental data from the period January 1982 to December 2010. Data is obtained from Datastream and Worldscope. The table summarises the maximum calendar year difference between any two variants of fundamental indices which make different choices for one of two methodology ingredients (variable selection and leverage adjustment)

Sources of Lack of Relative Robustness

Model Mining Risks – Another Illustration

- Chasing historically best performing strategy does not guarantee better future performance.
- Both Volatility and Sharpe Ratios of actively selected strategies are not substantially different from those of Norm constrained portfolios with similar ENS.

Strategy	Specification	Returns	Volatility	Sharpe Ratio	Mean ENS
CW Benchmark	-	11.59%	17.28%	0.37	117
Minimum Volatility Strategies with different levels of weight constraints	λ = 2	14.01%	15.89%	0.55	345
	λ = 3	14.01%	15.11%	0.58	263
	λ = 4	13.98%	14.67%	0.60	221
	λ = 5	13.95%	14.40%	0.61	196
	Long Only	13.85%	13.54%	0.64	126
	Norm = 2	14.04%	13.77%	0.64	250
	Norm = 3	13.89%	12.72%	0.68	167
	Norm = 4	13.77%	12.13%	0.70	125
	Norm = 5	13.67%	11.75%	0.72	100
Active Strategy that selects the best performing (in total returns) Minimum Volatility Strategy in the past 'Y' years and holds it for next 1 year	Y = 2	13.78%	13.36%	0.64	217
	Y = 3	14.41%	13.61%	0.68	226
	Y = 4	14.28%	13.45%	0.67	223
	Y = 5	13.02%	14.00%	0.56	221

Performance of Minimum Volatility Strategies with different weight constraints.
Two types of weight constraints – lambda constraint and norm constraint – are analysed. Norm constraint controls the effective number of stocks. If Norm = 3 , then the effective number of stocks is at least one-third of the nominal number of securities. Lamda constraint specifies the investors' risk aversion coefficient. After optimisation an upper bound of λ/N and a lower bound of 1/ λN is imposed where N is the nominal number of securities. The correlation of stock returns is estimated using an implicit factor – PCA. Daily total returns in the period 23-Dec-1975 to 31-Dec-2013 are used in the analysis.

Sources of Lack of Relative Robustness

Unrewarded Risks of Weighting Schemes

Unrewarded Risks

Firm-Specific Risk

Risks that are specific to the company itself (its management, the risk of the poor quality of its products, the relevance of its R&D and innovation, etc.).

Portfolio theory considers it to be neither predictable nor rewarded, so it is better to avoid it by investing in a well-diversified portfolio.

Financial Risk Factors which do not carry a premium

The academic literature considers that commodity, currency, and sector risks do not have a positive long-term premium.

These risks can have a strong influence on the volatility, tracking error, or max relative drawdown over a particular periods.

Model-Specific Risk of Weighting Schemes

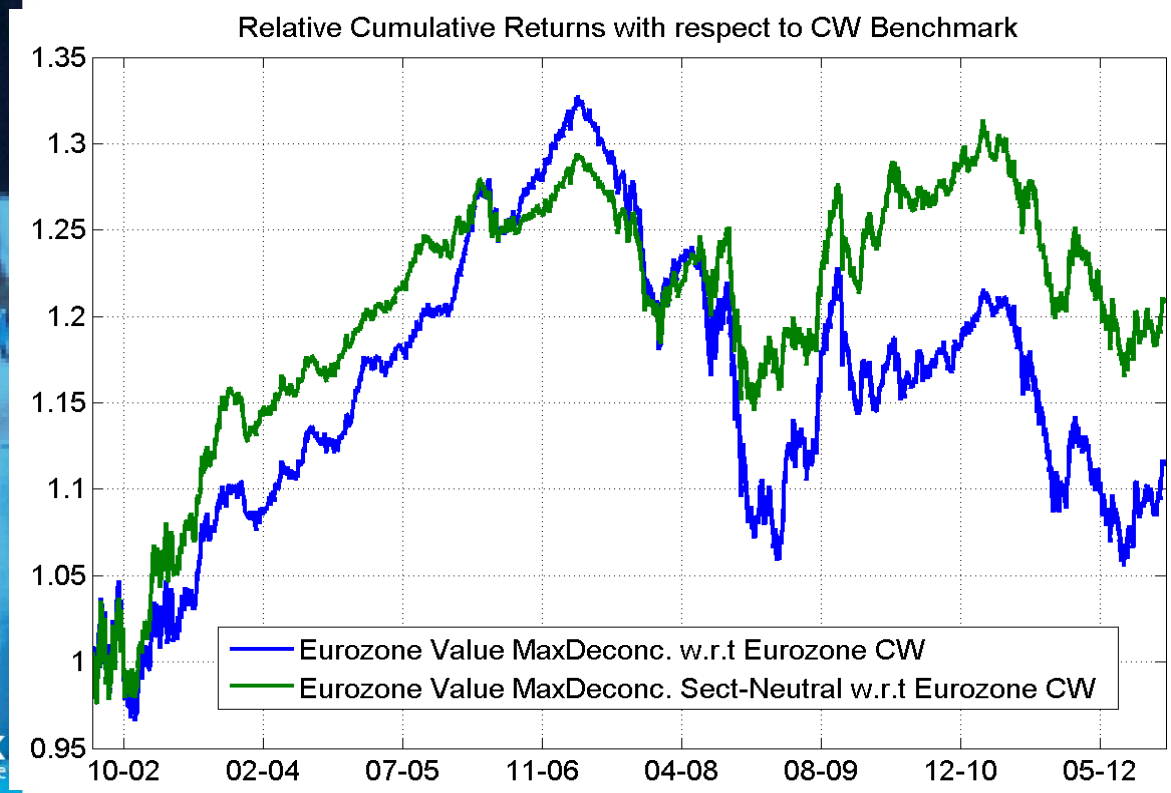
All weighting schemes have specific operational risk which depends on the diversification model used.

For e.g., robustness of Maximum Sharpe Ratio scheme depends on a good estimation of covariance matrix and expected returns.

Sources of Lack of Relative Robustness

Unrewarded Risks of Weighting Schemes

- Value strategies led to pronounced tilts towards financial sector stocks during the financial and sovereign debt crisis.
- Exposure to financial risk factor (sector risk in this case) may lead to short term outperformance but it is not rewarded in long term.



Performance of Scientific Beta Eurozone Value Maximum Deconcentration total return index in EUR and Scientific Beta Eurozone Value Maximum Deconcentration (Sector Neutral) total return index in EUR during the financial crisis. The benchmark is the cap weighted index on Scientific Beta Eurozone universe which consists of 300 stocks. Both value indices select top 50% stocks with highest book-to-market score in Eurozone universe. Maximum Deconcentration weighting maximizes portfolio de-concentration. Sector neutrality, when present, is achieved using linear constraint that forces same aggregate sector-per-sector weights as its cap-weighted reference index. Lastly, turnover control and liquidity adjustments are imposed at quarterly rebalancing.

Sources of Lack of Absolute Robustness

Strong Dependency on Individual Factor Exposures

- Popular smart beta strategies have embedded exposures to risk factors. Their performance thus depends on factor returns.
- Factor exposures are often concentrated in few factors making performance heavily dependent on one or two particular factors

FTSE RAFI USA 1000 Index *(31-Dec-1973 to 31-Dec-2013)*		
Monthly. Rel. Returns (over C.W.)	Negative Value Returns	Positive Value Returns
Negative Size Returns	**-0.77%**	0.52%
Positive Size Returns	-0.31%	**0.98%**

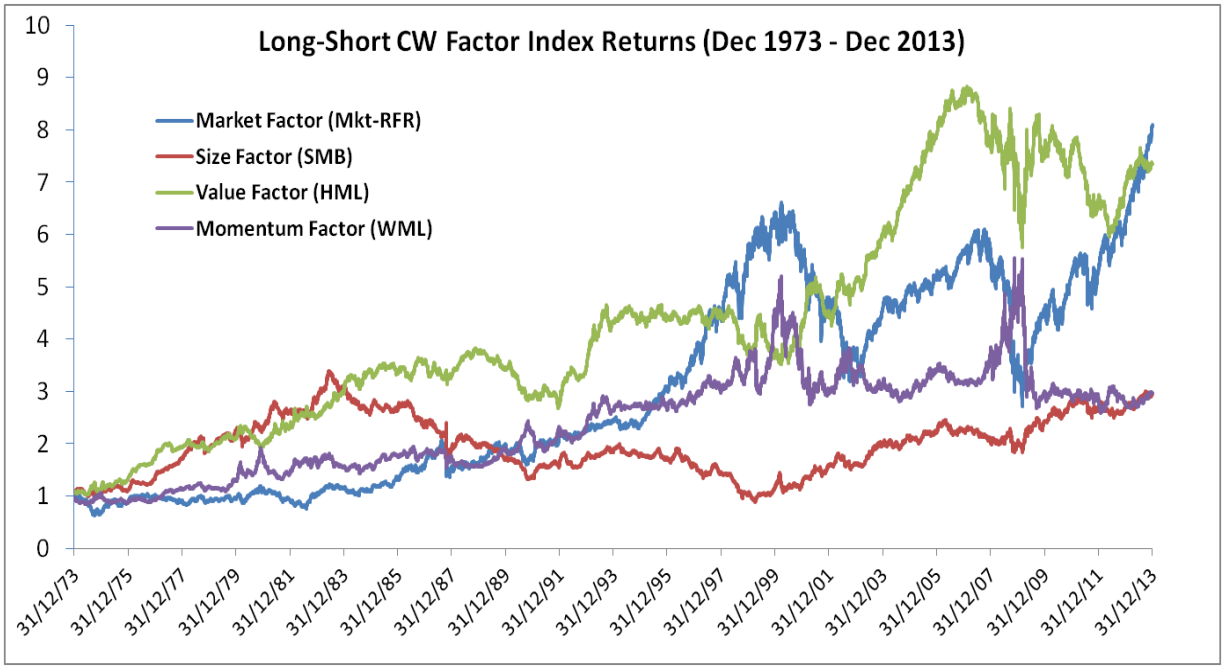
MSCI USA Minimum Volatility Index *(31-May-1988 to 31-Dec-2013)*		
Monthly. Rel. Returns (over C.W.)	Negative BAB Returns	Positive BAB Returns
Negative Market Returns	0.69%	**1.53%**
Positive Market Returns	**-1.37%**	-0.29%

Factor returns in each calendar month are used to classify the time period into different market conditions (positive/negative). All reported excess returns are ***monthly*** in nature. Daily total returns of the FTSE RAFI USA 1000 Index are obtained from Bloomberg. Monthly total returns of the MSCI USA Minimum Volatility Index are obtained from www.msci.com. The S&P-500 Index (Datastream) is used as market factor. Small size (SMB) and Value (HML) factors are obtained from Kenneth French data library. Betting-Against-Beta (BAB) factor is obtained from Andrea Frazzini data library.

Sources of Lack of Absolute Robustness

Strong Dependency on Individual Factor Exposures

- More generally, exposure to a single factor is risky in absolute terms. Periods of poor performance in all factors are common throughout history and the underperformance occurs at different points in time.
- In fact, the economic explanation for the existence of a risk premium is that exposure to such a factor is undesirable for the average investor because it leads to losses in bad times



Cumulative Returns of Factors – Factors are from SciBeta US Long-Term Track Records. All statistics are based on simulated long-term track records. The Market factor is the daily return of the cap-weighted index of all stocks that constitute the index portfolio in excess of the risk-free rate. Small size factor is the daily return series of a cap-weighted portfolio that is long cap-weighted market portfolio deciles 6-8 (NYSE, Nasdaq, and AMEX) and short the 30% largest market-cap stocks from the top 500 stock universe. Value factor is the daily return series of a cap-weighted portfolio that is long the 30% highest and short the 30% lowest B/M ratio stocks in the US 500 universe. Momentum factor is the daily return series of a cap-weighted portfolio that is long the 30% highest and short the 30% lowest 52 weeks (minus the most recent 4 weeks) past return stocks of the US 500 universe. The "Secondary Market US Treasury Bills (3M)" is the risk-free rate in US Dollars. The analysis is based on daily total returns from 31/12/1973 to 31/12/2013.

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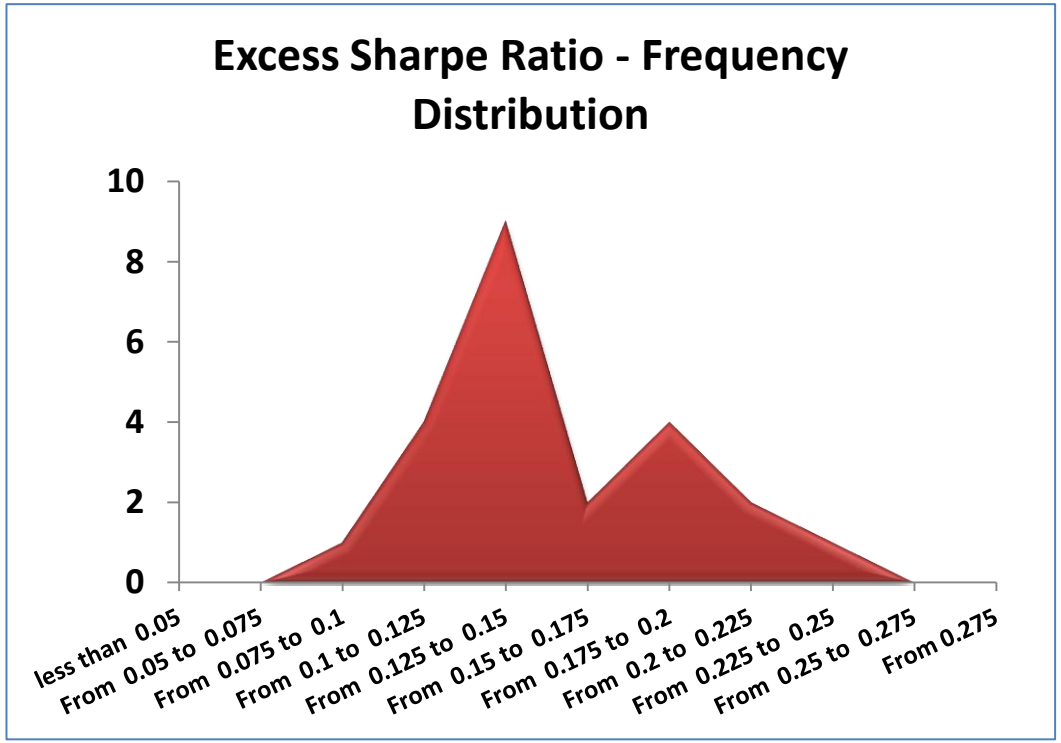
Avoidance of Data Mining

- Ad hoc methodologies open the door to datamining or model mining.
  - Consistency is best safeguard against **post hoc** index design, or **model mining** (i.e. test an infinite number of smart beta strategies, and publish the ones that have good results).
  - Packaged indices that represent **bundles of methodological choices**, do not allow investors to obtain a view on the sensitivity of performance to index specification choices.
  - **Ad hoc methodologies** expose investors to a risk of **unintended consequences and ill-defined risk exposures.**

Avoidance of Data Mining

Importance of Consistent Framework

- Safeguard against *post hoc* index design - It prevents model mining by limiting the number of choices by which indices can be constructed.
- A range of outcomes gives a more informative view than a single specification which could always have been picked. An index that performs well across multiple specification choices is more robust than an index that performs only in a single specification choice which very well could have been by chance rather than because of the robustness of the strategy.



ERI SciBeta Diversified Multi-Strategy Indices with 23 different stock selection choices built upon a consistent framework and their corresponding Cap-Weighted benchmarks are used. The analysis is based on daily total returns from 31/12/1973 to 31/12/2013. The chart represents the frequency distribution of difference in Sharpe Ratios of multi-strategy indices over their corresponding cap-weighted benchmarks for 23 different stock selection choices.

Avoidance of Data Mining

Inconsistency across Factor Indices: Illustration

Factor	Index	Stock selection	Weighting Scheme	Risk controls
MSCI Index Methodologies				
Size	MSCI Equal-Weight Index	All stocks in CW parent index universe	Equal-weighted	None
Value	MSCI Value-weighted index	All stocks in CW parent index universe	Score adjusted by investability factor	None
Mom.	MSCI Momentum Index	Selection by momentum score (fixed number of constituents to target 30% market cap coverage)	Market cap * momentum score	Cap on weight of individual security
Low Vol.	MSCI Minimum Volatility Index	All stocks in CW parent index universe	Optimisation to minimise portfolio risk	Sector and country weight constrarints Cap on multiple of market cap of individual security
Yield	MSCI High Dividend Yield Index	Select stocks with dividend yield > 1.3x parent index dividend yield	Market cap weighted	Cap on weight of individual security

Avoidance of Data Mining

Inconsistency over Time

- Many index providers have replaced already existing factor indices with new indices tracking the same factors. The launch of such indices has been argued to resemble to practices among fund management houses which create new funds when the track records of existing funds is not satisfactory.
- Example of an index replacement: Russell launched a new brand of 'High Efficiency Factor Indices' (HEFI) when it already had indices in the market for tracking the same factors.

USA Russell Factor Indices	Methodology	Time Period	Annual Returns	Annual Volatility	Sharpe Ratio
Russell 1000 High Efficiency Momentum	Tilt the portfolio based on Momentum score taking MC weight of stock in the Russell 1000 Index as starting point.	01/01/2005 to 31/12/2013	8.69%	21.62%	0.33
Russell 1000 High Momentum	Cap weight up to 200 highest momentum stocks in Russell 1000 Index.		8.05%	20.59%	0.31
Russell 1000 High Efficiency Low Vol	Tilt the portfolio based on Low Volatility score taking MC weight of stock in the Russell 1000 Index as starting point.	01/01/2005 to 31/12/2013	7.89%	17.73%	0.36
Russell 1000 Low Volatility	Cap weight up to 200 highest least volatile stocks in Russell 1000 Index.		7.69%	16.35%	0.37
Russell 1000 High Efficiency Value	Tilt the portfolio based on Value score (B/M and E/P ratios) taking MC weight of stock in the Russell 1000 Index as starting point.	31/12/2003 to 31/12/2013	9.76%	22.55%	0.36
Russell 1000 Value	Tilt the portfolio based on Value probability (B/M, sales per share growth, I/B/E/S growth) taking market cap weight of stock in the Russell 1000 Index as starting point.		7.56%	21.96%	0.27

Russell Factor Indices Performance Comparison *- All statistics are annualized and daily total returns are used for the analysis.*

Improving Relative Robustness

Robust Risk Parameter Estimation

The sample covariance matrix based on historic returns is very sensitive to outliers leading to poor performance of risk-based portfolio strategies (Chan et al. 1999).

- Factor models can be used to generate robust risk estimates.
  - A factor model only considers persistent correlations due to exposure to common return drivers
  - A factor model reduces the number of parameters that we have to estimate.

Number of stocks	50	100	500
Parameters in full sample cov.	1275	5050	125250
Parameters in 5 factor model	315	615	3015
Parameters in one factor model	101	201	1001

- Implicit factor models are particularly suitable as input in diversification schemes:
  - Advantage: The “Let the data talk” approach avoids taking on factor selection risk.
  - Drawback: One may recover factors that don’t matter (sample risk). For robustness, one thus needs to limit the number of factors. This can be done using a formal criterion from Random Matrix Theory (RMT) to limit the number of factors.

Improving Relative Robustness

Improved Diversification through Weight Constraints

- One serious concern with optimization based weighting schemes, is that the stocks with the highest estimation error may receive the highest weight – "*Error Maximization*". This could lead to the problem of concentration in fewer stocks or in specific sectors.
- State-of-the art practice uses a set of constraints to achieve robust portfolios and avoid concentration in its indices:
  - **Long Only Constraints** facilitate implementation and lead to more robust portfolios (*Jagannathan and Ma [2003]*).
  - **Deconcentration Constraints** ensure sufficiently balanced weights across constituents
    - impose an upper and a lower bound on the weight of each constituent.
    - Norm Constraints put limits on the overall amount of concentration in the portfolio which leads to better out-of-sample risk and return properties (*DeMiguel et al [2009]*).

Improving Relative Robustness

Diversification of Model Risks

Combination of weighting schemes[1]

Diversified Multi-Strategy

➲ **Diversify model-specific risk**[2]

Exploit low correlation of parameter estimation errors

Single Diversification Strategies

- Maximum Deconcentration
- Diversified Risk Weighted[3]
- Maximum Decorrelation
- Efficient Minimum Volatility
- Efficient Max. Sharpe Ratio

➲ **Diversify stock-specific risk**

1. *Diversified Multi-Strategy indices equal-weight each of the five diversification strategies.*
2. *See Timmermann (2006), Kan and Zhou (2007), Tu and Zhou (2010), Amenc, Goltz, Lodh, Martellini (2012) on benefits of combining portfolio strategies.*
3. *This weighting scheme was formerly known as "Diversified Risk Parity".*

Improving Absolute Robustness

Avoiding Concentration in a Single Factor

- The reward for exposure to these factors has been shown to vary over time (see e.g. Harvey [1989]; Asness [1992]; Cohen, Polk and Vuolteenaho [2003]).
- The indices are not perfectly correlated with each other which shows a potential for diversification across factors.
- There is strong intuition suggesting that multi-factor allocations will tend to result in improved risk-adjusted performance.

US Long Term (Dec 1973 – Dec 2013)		Diversified Multi Strategies			
		Mid Cap	Momentum	Low Vol	Value
Diversified Multi Strategies	Mid Cap	100%	69%	64%	86%
	Momentum		100%	63%	66%
	Low Volatility			100%	71%
	Value				100%

Correlation of Relative Returns across Factor-Tilted Multi-Strategy Indices

The table shows the correlation of the relative returns of four Scientific Beta Factor-Tilted Multi-Strategy Indices (mid cap, momentum, low volatility, and value) over the cap-weighted benchmark. The analysis is based on daily total return data from 31 December 1973 to 31 December 2013 (40 years)

Improving Absolute Robustness

Avoiding Concentration in a Single Factor

Ann. Excess Returns over broad CW	Mid Cap Div. Multi-Strategy	Multi-Beta Multi-Strategy EW
Top 25% Quarters by SMB factor returns	27.83%	15.76%
Bottom 25% Quarters by SMB factor returns	-10.04%	-4.08%
Ann. Excess Returns over broad CW	**Momentum Div. Multi-Strategy**	**Multi-Beta Multi-Strategy EW**
Top 25% Quarters by MOM factor returns	7.42%	0.90%
Bottom 25% Quarters by MOM factor returns	-1.38%	7.40%
Ann. Excess Returns over broad CW	**Low Volatility Div. Multi-Strategy**	**Multi-Beta Multi-Strategy EW**
Top 25% Quarters by Low Vol factor returns	12.82%	5.72%
Bottom 25% Quarters by Low Vol factor returns	-7.98%	3.88%
Ann. Excess Returns over broad CW	**Value Div. Multi-Strategy**	**Multi-Beta Multi-Strategy EW**
Top 25% Quarters by HML factor returns	21.16%	13.67%
Bottom 25% Quarters by HML factor returns	-7.76%	-3.61%

The quarters are divided into top and bottom 25 percentile based on returns of HML, SMB and Low Volatility factors. SMB factor is the daily return series of a cap-weighted portfolio that is long cap-weighted market portfolio deciles 6-8 (NYSE, Nasdaq, and AMEX) and short the 30% largest market-cap stocks in the investible universe. HML factor is the daily return series of a cap-weighted portfolio that is long the 30% highest and short the 30% lowest B/M ratio stocks in the investible universe. Low Volatility factor is the daily return series of a cap-weighted portfolio that is long the 30% lowest and short the 30% highest 104 week returns volatility stocks of the investible universe. The analysis is based on daily total return data in USD from 31/12/1973 to 31/12/2013 (40 years). All statistics are annualized. Underlying investible universe consists of largest 500 USA stocks. Benchmark is the cap-weighted portfolio of all stocks in the investible universe. Data source: Bloomberg and www.scientificbeta.com.

Importance of Transparency

- Smart Beta "Indices" which do not fulfill basic requirements for index transparency open the door to discretionary fine-tuning of back-tests by providers.

  - If **ground rules are ambiguous**, it may not be clear for example what the rules are used to include or exclude stocks or the weighting scheme may not be transparent.
  - If **access to data** (historical returns, constituent lists and weights) is limited, no independent analysis can be conducted leaving it unclear whether the ground rules have been implemented free of discretion by the provider.

The Challenge of Transparency of Ground Rules
Illustrations

- Indices come with ground rules, but they often contain ambiguities which prevent replication of the methodology by independent parties

  - **Unclear variable definitions in factor indices:** The Goldman Sachs Equity Factor Index World uses 7 fundamental measures to compute a quality score but there is no disclosure on the time period to which the variables pertain.

  - **Insufficient information on risk model in minimum volatility indices:** The MSCI Minimum Volatility index uses the proprietary Barra Equity model to estimate the covariance matrix. The Barra Equity model or its precise methodology (exact definition of factors, number of factors) are not openly available.

  - **Ambiguity on Implementation procedures:** Russell's High Efficiency Factor Indexes use a non-linear probability (NLP) algorithm to weight stocks. The algorithm results in "unconstrained active weights" ranging from -1 to +1. A breakpoint is used to determine the number of overweight and underweight positions in the index. There is no disclosure on how this breakpoint is generated.

Recap - Best Practices to Improve Robustness

Category	Best Practices: Requirements for Robustness	Common practice: Risk of Lack of Robustness
Methodology	Consistent Framework	Ad hoc Methodologies open the door for data mining / model mining
Factor Definitions	Simple, Tried and Tested Factors. E.g. Price to book for 'value'	Complex, Proprietary and Unproven Factor Definitions E.g. Use of proprietary variables, adjustments or constraints
Weighting scheme	Diversification of model risk and robust risk parameter estimation	Choice of a single weighting model and high sensitivity to input parameters
Transparency	Full Transparency -Free access to historical constituents and weights and unambiguous ground rules	Opaque and restricted or no access to back test data with ambiguous ground rules

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Measurement of Robustness

- A wide range of measures allows assessing robustness. We categorize these measures into 2 groups – one instrumental in assessing relative robustness and the other used for assessing absolute robustness.

Relative Robustness Measures	Absolute Robustness Measures
• Relative drawdown analysis • Factor attribution exercise	• Extreme risk measures • Outperformance probability • Performance conditional on market condition

- We provide the definition of each robustness measure and explain its relevance through relevant illustrations using Scientific Beta's single beta and multi-beta factor indices.
- The individual factor tilted indices - mid-cap multi-strategy index, momentum multi-strategy index, low volatility multi-strategy index and value multi-strategy index - offer exposure to the desired risk factor to capture its premium.
- ERI Scientific Beta offers two variants of multi-beta multi-strategy index – Equally Weighted (EW) and Equal Risk Contribution (ERC).

Measurement of Relative Robustness

Drawdown and Relative Drawdown

- Drawdowns may occur in any strategy. A requirement for robustness is that such drawdowns can be explained, i.e. that performance follows an economic rationale rather than being due to statistical artifact.
  - **Absolute** drawdowns of all strategies correspond to the heavy drawdowns of cap-weighted indices and are about the same size as those observed for CW indices.
  - **Relative** drawdowns occur when the underlying factor under-performs.

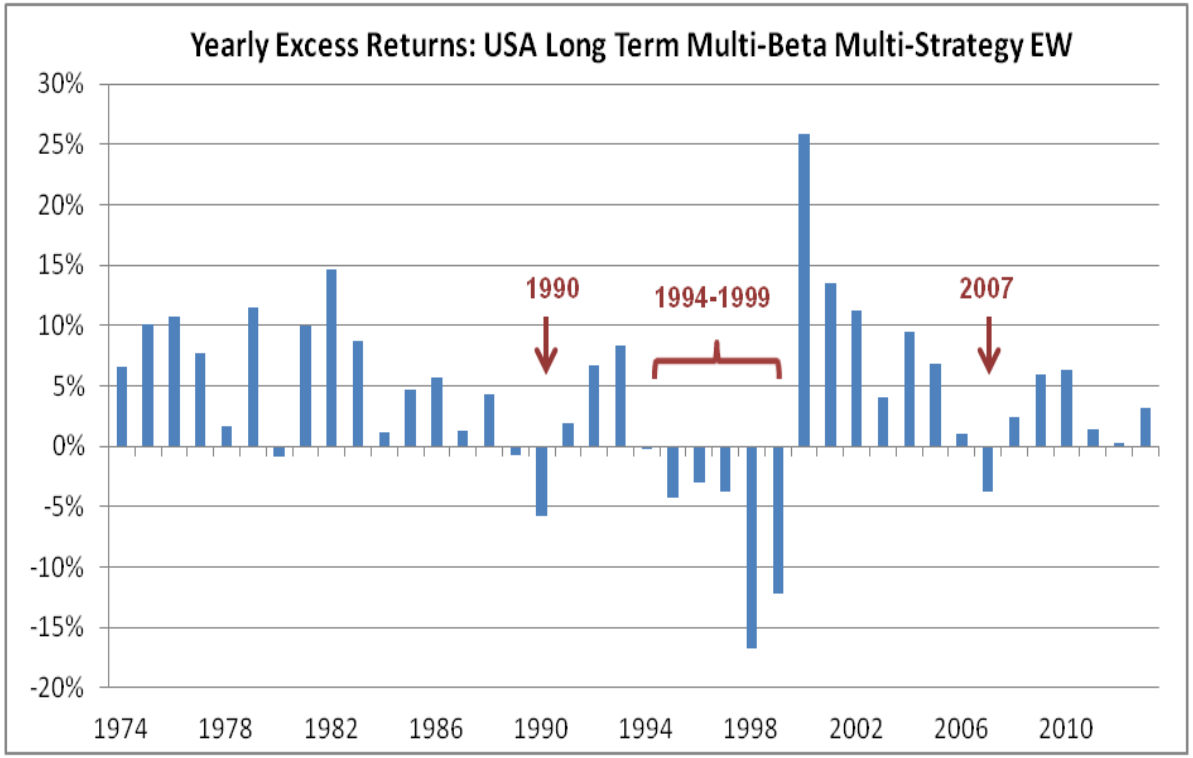
US Long Term (Dec 1973 – Dec 2013)	Sci Beta US Broad CW	Diversified Multi Strategies					
		Mid Cap	Momentum	Low Vol	Value	Multi-Beta Multi-Strategy EW	Multi-Beta Multi-Strategy ERC
Absolute DrawDown							
Maximum Drawdown	54.53%	58.11%	49.00%	50.13%	58.41%	53.86%	53.30%
Start of Maximum DD	Oct-07	Jul-07	Jul-07	Jun-07	Jun-07	Jun-07	Jun-07
Maximum Loss Point	Mar-09	Mar-09	Mar-09	Mar-09	Mar-09	Mar-09	Mar-09
Recovery Completed on	Mar-12	Dec-10	Feb-11	Feb-11	Feb-11	Jan-11	Jan-11
Relative DrawDown							
Maximum Relative DD	-	42.06%	17.28%	43.46%	32.68%	33.65%	28.74%
Start of Max Rel DD	-	Mar-94	Mar-94	Sep-93	Mar-94	Mar-94	Mar-94
Maximum Loss Point	-	Mar-00	Dec-99	Mar-00	Mar-00	Mar-00	Mar-00
Recovery Completed on	-	Sep-01	Apr-01	Sep-01	Mar-01	Apr-01	Apr-01

The analysis is based on daily total returns data from 31/12/1973 to 31/12/2013 (40 years). The benchmark used is the CW index based on broad universe of 500 stocks. Maximum Drawdown represents the maximum loss an investor can suffer from investing in the strategy at the highest point and selling at the lowest. It is the largest single drop from peak to bottom in the value of a portfolio (before a new peak is achieved).

Measurement of Relative Robustness

Relative Drawdown cont.

- The relative drawdown analysis allows us to understand the cause of underperformance of strategy in relation to underlying factor performance.
- For multi-beta multi-strategy index, the three prominent underperformance periods coincide with the poor performance of HML and SMB factors relative to broad market.



1990 collapse of the junk bond market: HML factor underperformed (*change in corporate credit spread and value factor are correlated – Avramov et al [2007]*).

1994-1999 Build-up of technology bubble
Large, high beta, growth stocks outperform
Concentration of CW indices pays off temporarily

04/2007-01/2008 "Quant Meltdown"
"In July 2007, the performance of … factors such as Small-Minus-Big (SMB) market-cap and High-Minus-Low (HML) book-to-market factors began a downward trend" (Khandani and Lo 2010)

The analysis is based on daily total returns data from 31/12/1973 to 31/12/2013 (40 years). The benchmark used is the CW index based on broad universe of 500 stocks. Excess returns over the CW benchmark in the plots are yearly (non annualized).

Measurement of Relative Robustness

Factor Exposure

- Many studies have underlined the importance of factor exposures (Jun and Malkiel [2007], Blitz and Swinkels [2008]) as it provides information on relative robustness by indicating if the strategy is tilted to the intended risk factor(s) ex-post and if the risk and performance of the strategy is explained by the said factor(s).
- Single factor indices show desired factor exposure (beta) ex-post. Mid-Cap index has 0.31 SMB beta, Momentum index has 0.17 MOM beta, and Value index has 0.31 HML beta.
- The multi-beta allocations benefit from a positive exposure to all rewarded factors.

US Long Term (Dec 1973 – Dec 2013)	Diversified Multi Strategies					
	Mid Cap	Momentum	Low Vol	Value	Multi-Beta Multi-Strategy EW	Multi-Beta Multi-Strategy ERC
Annual Alpha	**2.66%**	**1.84%**	**2.85%**	**2.33%**	**2.45%**	**2.35%**
Market Beta	**0.93**	**0.94**	**0.78**	**0.91**	**0.89**	**0.89**
SMB Beta	**0.31**	**0.16**	**0.02**	**0.16**	**0.16**	**0.15**
HML Beta	**0.16**	**0.09**	**0.14**	**0.31**	**0.17**	**0.16**
MOM Beta	0.00	**0.17**	0.00	**0.03**	**0.05**	**0.06**
R-Squared	92.20%	95.52%	90.14%	95.00%	94.76%	95.46%

Factor exposures – The table reports the factor exposure of Scientific Beta Diversified MultiStrategy US Long Term Track Records using Carhart four factor model. The Multi Beta Diversified Multistrategy is the equal combination of the four Diversified Multistrategies with stock selection based on mid cap, momentum, low volatility, and value respectively. . The MultiBeta ERRC Allocation is an optimized combination of the four tilted indices in which beginning of quarter optimal weights of the component indices are determined from the covariance the daily relative returns of the component indices over the last 6 quarters (18 months), so as to obtain (in sample) equal contributions to the tracking error. Factors are from SciBeta US Long Term Track Records. *The Market factor is the daily return of cap-weighted index of all stocks that constitute the index portfolio in excess of the risk free rate. Small size factor is the daily return series of a cap-weighted portfolio that is long CRSP cap weighted market portfolios 6-8 (NYSE, Nasdaq, AMEX) and short 30% largest market cap stocks of CRSP S&P 500 universe. Value factor is the daily return series of a cap-weighted portfolio that is long 30% highest and short 30% lowest B/M ratio stocks of CRSP S&P 500 universe. Momentum factor is the daily return series of a cap-weighted portfolio that is long 30% highest and short 30% lowest 52 weeks (minus most recent 4 weeks) past return stocks of CRSP S&P 500 universe. The "Secondary Market US Treasury Bills (3M)" is the risk-free rate in US Dollar. All statistics are annualized. The analysis is based on daily total returns from 31/12/1973 to 31/12/2013.*

Measurement of Absolute Robustness

Extreme Risk

- The extreme risk such as EVT 1% VaR and EVT 1% CVaR of smart beta strategies is less than that of the cap-weighted benchmark.

US Long Term (Dec 1973 – Dec 2013)	Sci Beta US Broad CW	Diversified Multi Strategy					
		Mid Cap	Momentum	Low Vol	Value	Multi-Beta Multi-Strategy EW	Multi-Beta Multi-Strategy ERC
Absolute Extreme Risks							
Annual Returns	10.95%	15.67%	14.57%	13.90%	15.70%	15.04%	14.84%
EVT 1% VaR	2.37%	2.10%	2.15%	1.90%	2.12%	2.04%	2.04%
EVT 1% CVaR	2.91%	2.55%	2.64%	2.32%	2.59%	2.49%	2.49%
Ret to EVT 1% CVaR ratio	0.12	0.25	0.22	0.23	0.25	0.24	0.24
Monthly EVT 1% CVaR(F)*	10.65%	9.66%	10.06%	8.73%	10.37%	9.50%	9.43%
Relative Extreme Risks							
Excess Returns	-	4.72%	3.62%	2.95%	4.75%	4.09%	3.88%
EVT 1% VaTER	-	0.89%	0.65%	0.79%	0.77%	0.67%	0.64%
EVT 1% CVaTER	-	1.09%	0.80%	0.97%	0.94%	0.82%	0.78%
Ret to EVT 1% CVaTER ratio	-	0.27	0.28	0.19	0.31	0.31	0.31
Monthly EVT 1% CVaTER(F)*	-	2.96%	2.52%	3.03%	2.47%	2.22%	2.18%

*Complete stock universe consists of 500 largest stocks in USA. S&P-500 is used as the cap-weighted benchmark. The table shows summary statistics of extreme risks of the MBMS and Single Factor Multi-Strategies from 31 December 1973 to 31 December 2013 (40 years). The corresponding statistics of the cap-weighted reference index (Broad CW) are also reported.**

Measurement of Absolute Robustness

Outperformance Probability

- **Definition:** The probability of outperformance is defined as the empirical frequency of outperforming the cap-weighted reference index over a given investment horizon, and is calculated using a rolling window of (1/3/5) year length and 1-week step size.
- **Usage:**
  - It is a tool to assess *absolute robustness* as it takes in to account time sensitivity and sample dependency of strategy performance.
  - It can differentiate between two strategies which have similar long term performance where one has small but consistent outperformance while the other benefits from few periods of high gain combined with long runs of losses.
- **Limits:** Longer sample period improves reliability of this measure. However, one must not forget this measure remains purely historic and therefore it's interpretation must be taken cautiously.

US Long Term (Dec 1973 – Dec 2013)	Diversified Multi Strategies					
	Mid Cap	Momentum	Low Vol	Value	Multi-Beta Multi-Strategy EW	Multi-Beta Multi-Strategy ERC
Outperf Probability (1-Y)	68.07%	68.22%	67.24%	70.43%	74.17%	74.26%
Outperf Probability (3-y)	74.69%	84.52%	76.45%	78.83%	80.43%	80.64%
Outperf Probability (5-y)	78.99%	91.19%	85.28%	88.29%	90.26%	90.37%

Daily total returns in USD in the period from 31-Dec-1973 to 31-Dec-2013 (40 years) are used in the analysis. Underlying investible universe consists of largest 500 USA stocks. Benchmark is the cap-weighted portfolio of all stocks in the investible universe. Probability of outperformance is the historical empirical probability of outperforming the cap-weighted benchmark over an investment horizon of 1/3/5 years irrespective of the entry point in time. It is computed using a rolling window analysis with window length corresponding to the investment horizon and one-week step size. Data source: www.scientificbeta.com.

Measurement of Absolute Robustness

Conditional Performance – Stock Market Cycles

- The performance of smart beta strategies varies over market phases (Gonzalez and Thabault [2013]).
- Single factor indices have high degree of relative robustness, indicated by overall high outperformance in full period, but they are not robust in absolute terms. The multi-beta allocations on the other hand are highly robust in absolute terms.

Market Conditions	US Long Term (Dec 1973 – Dec 2013)	Diversified Multi Strategies					
		Mid Cap	Momentum	Low Vol	Value	Multi-Beta Multi-Strategy EW	Multi-Beta Multi-Strategy ERC
Bull Markets	Ann. Rel Returns	5.12%	3.28%	-0.99%	3.54%	2.79%	2.71%
	Annual Tracking Error	5.76%	4.04%	5.11%	5.00%	4.38%	4.13%
	Information Ratio	0.89	0.81	-0.19	0.71	0.64	0.66
Bear Markets	Ann. Rel Returns	3.83%	3.77%	8.12%	5.99%	5.49%	5.14%
	Annual Tracking Error	8.33%	6.26%	7.94%	7.12%	6.57%	6.12%
	Information Ratio	0.46	0.60	1.02	0.84	0.83	0.84
Months with Positive Markets	Ann. Rel Returns	7.22%	3.30%	-5.13%	4.05%	2.37%	1.91%
	Annual Tracking Error	6.01%	4.38%	5.51%	5.30%	4.67%	4.41%
	Information Ratio	1.20	0.75	-0.93	0.76	0.51	0.43
Months with Negative Markets	Ann. Rel Returns	2.34%	3.35%	8.65%	4.60%	4.77%	4.78%
	Annual Tracking Error	7.57%	5.47%	6.96%	6.37%	5.84%	5.43%
	Information Ratio	0.31	0.61	1.24	0.72	0.82	0.88

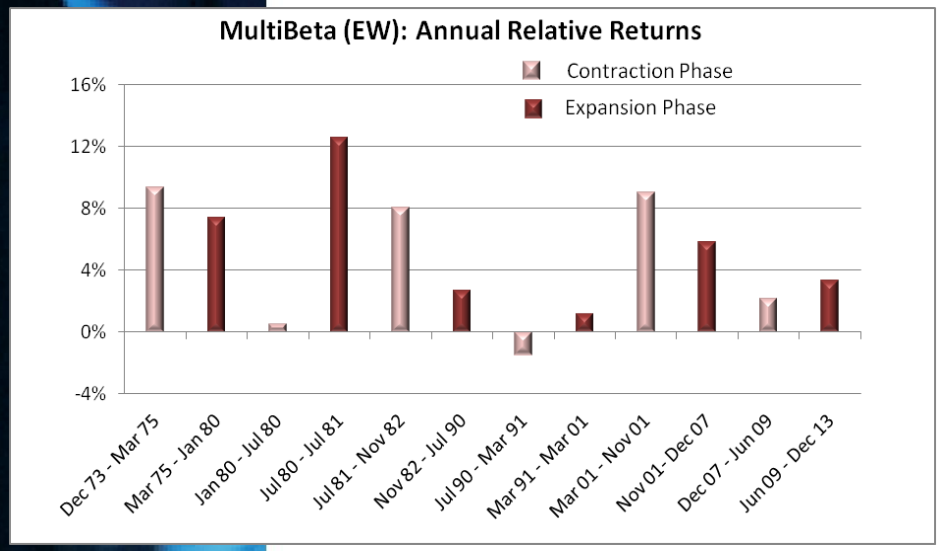
***Multi Beta Allocation** – The table shows the conditional performance and risk of multi-beta multi-strategy indices with single-beta multi-strategy indices. The Multi Beta (EW) Diversified Multistrategy is the equal combination of the four Diversified MultiStrategy indices with stock selection based on mid cap, momentum, low volatility, and value respectively. The Multi Beta (ERC) Diversified Multistrategy is the equal relative risk contribution combination of the four indices. Calendar quarters with positive benchmark returns comprise bull markets and the rest constitute bear markets. All statistics are annualized and daily total returns from 31-December-1973 to 31-December-2013 are used for the analysis. CRSP S&P-500 index is used as the cap-weighted benchmark. Source: scientificbeta.com.*

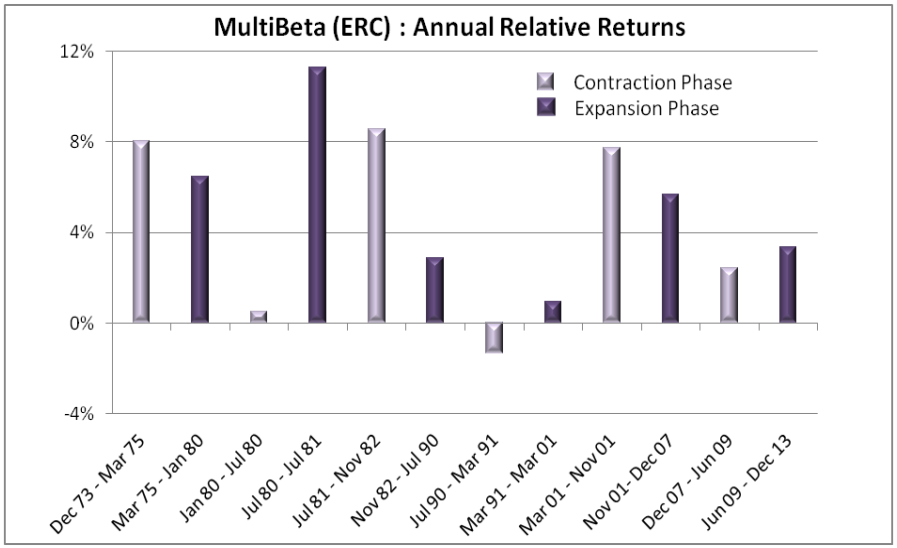
Measurement of Absolute Robustness

Conditional Performance – Economic Cycles

- Combining factors in a Multi-Beta Benchmark leads to smooth outperformance across economic regimes.

US Long Term (Dec 1973 – Dec 2013)	Contraction Periods						Expansion Periods					
	Mid Cap	Mom	Low Vol	Value	EW MBMS	ERC MBMS	Mid Cap	Mom	Low Vol	Value	EW MBMS	ERC MBMS
Ann. Rel Returns	6.29%	3.67%	5.67%	4.66%	5.19%	4.96%	4.34%	3.60%	2.47%	4.80%	3.87%	3.67%
Information Ratio	0.69	0.52	0.74	0.60	0.75	0.75	0.70	0.82	0.42	0.89	0.80	0.82





Multi Beta Allocations – *The Multi Beta (EW) Diversified Multistrategy is the equal combination of the four Diversified MultiStrategy indices with stock selection based on mid cap, momentum, low volatility, and value respectively. The Multi Beta (ERC) Diversified Multistrategy is the equal relative risk contribution combination of the four indices. Contraction and expansion periods are defined by NBER US Business cycles (http://www.nber.org/cycles/cyclesmain.html). Contractions comprise the days from peak to trough of business cycles, and expansions comprise the days from trough to peak of business cycles . All statistics are annualized and daily total returns from 31-December-1973 to 31-December-2013 are used for the analysis. CRSP S&P-500 index is used as the cap-weighted benchmark.*

Conclusions

- It is essential that smart beta strategy performance reporting be accompanied with measurement of relative and absolute robustness of its performance.
- The lack of relative robustness arises mainly from data mining, non-robust weighting methodologies and that of absolute robustness comes from undiversified factor exposures.
- Relative robustness can be improved by reducing all sources of unrewarded risks with the use of consistent framework (to prohibit data mining), robust parameter estimation techniques, weight constraints, and strategy specific risk.
- Absolute robustness can be achieved through allocating across several rewarded factors.