

Morgan Stanley & Co. Incorporated **Martin Leibowitz**
Martin.Leibowitz@morganstanley.com
+1 (1)212 761 7597

Anthony Bova
Anthony.Bova@morganstanley.com
+1 (1)212 761 3781

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Portfolio Strategy

Beta Targeting: Tapping into the Appeal of 130/30 Active Extensions

Having a well-defined beta, even if different from the beta-one standard, can provide 130/30 “extension-like” characteristics. The essential feature is having a targeted beta, together with a minimal “beta gap” and sufficiently low beta volatility.

Without a clear beta target, market movements can confound any estimate of a fund’s alpha, tracking error, and/or information ratio. By making use of a formula that explicitly incorporates beta volatility, this paper explores the precision limits needed for a beta target to maintain its functional integrity.

The target beta should conform to the portfolio’s management style, rather than being forced to match the beta value ultimately required by the sponsor. With currently available overlay techniques, any target beta can be efficiently stretched (or compressed) to match the sponsor’s desired beta value.

The beta factor accounts for over 90% of the standard volatility of most US institutional funds, even those that are highly diversified. To control this volatility risk, sponsors must have some coherent beta estimates for their component portfolios. Beta targeting, especially within the more significant allocations, can greatly facilitate management of this critical risk control factor.

Varying degrees of beta volatility can be acceptable, allowing some (often-needed) flexibility in the management process. For tightly controlled enhanced index portfolios, the beta volatility must be close to zero. For more intense forms of active management, the information ratios can retain validity even with more sizable beta volatilities. However, beta targeting still remains the key to maintaining risk control even with more aggressive forms of “alpha hunting.”

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Beta Targeting: Tapping into the Appeal of 130/30 Active Extensions

Summary

With \$50B in assets thus far and continued growth expected in the future, active extension, or 130/30, strategies have become an increasing focus of both active equity managers and plan sponsors. The main beneficiaries of these asset flows have been long-only managers with previously established sponsor relationships.

In a typical "130/30" active extension, a long-only manager obtains an authorization to take short positions amounting to 30% of the original asset base, subject to full reinvestment of the proceeds into an additional 30% in long positions. The basic constraints on active extension funds are a beta of one, tracking errors maintained within reasonable bounds, and full reinvestment of the short proceeds to maintain the net long exposure of 100%. This structure inherently allows for more reliably measurable alphas, tracking errors, and information ratios. [1-26]

Thus far, the majority of active extension funds have been launched with a target beta of one relative to the S&P 500 or Russell 1000 and tracking errors of 2-6%. With such constraints in place, these strategies can be viewed as a literal "extension" of the basic equity allocation rather than as excursions into the realm of alternatives.

The target beta of one helps ensure that active extensions maintain risk characteristics that are similar to the initial long-only portfolios. This risk-similarity and the consequent inclusion within the basic equity allocation have been central to the surge in interest in 130/30-type funds. The question naturally arises as to whether other active equity strategies can be designed to draw upon this powerful "extension-like" appeal of 130/30 funds.

This paper makes use of a formula that incorporates a "beta volatility" concept to explore the multiple benefits of having a well-defined target beta combined with a sufficiently low beta volatility.

One immediate benefit that beta targeting shares with 130/30 extensions is the direct evidence of a tight risk-control process. Well-defined beta targets sharpen the measurement of skill-based active alphas as well as the associated tracking error. As these two metrics become more reliably measurable, their ratio (sometimes referred to as the information ratio) can help assess the statistical reliability of positive skill in the management process.

A second benefit from beta targeting is that it loosens the beta-one constraint and allows a much broader range of active equity strategies to be brought under the "extension" umbrella. Many long/short managers as well as long-only managers are more comfortable having portfolios with average betas other than one. By embracing a beta-targeting approach, they can retain their basic management process while attaining a sharper focus to their alpha generation and underlying tracking error. A beta-targeting approach would be particularly beneficial for currently long-only funds considering migration to a long/short format.

Another benefit from beta targeting relates to the risk structure of sponsor funds. A series of studies on asset allocation have shown that the "total beta" (in terms of US equity exposure) accounts for over 90% of the overall volatility of most US institutional portfolios. This high level of beta domination is common not only for the traditional 60% equity/40% bond portfolio, but also for highly diversified endowment-like funds with as little as 15-20% in US equity. This surprising result is due to the build-up of the "implicit betas" from the non-equity asset classes that have some level of statistical correlation with equity movements.

A well-defined beta target can play a key role in enabling sponsors to control this total beta risk. With a prescribed beta for a given fund component, the desired total fund volatility can be achieved by either adjusting the mixture of other fund assets or by applying a beta overlay at the fund level. (However, there may be cases where a sponsor prefers that the equity manager provide the overlay function needed to achieve the desired beta.)

With the total beta forming the dominant source of total fund volatility, other sources of volatility tend to be diversified away so that they have a relatively minor impact on total risk. Beta-targeted strategies help to more clearly identify the tracking errors that are reliably uncorrelated with the beta risk. By helping to minimize sponsor-level impact of such tracking errors, beta targeting can more readily accommodate aggressive alpha seeking that tends to incur high tracking errors.

Thus, in addition to enlarging the boundaries for "extension-like" status, beta targeting can provide a number of valuable benefits for both managers and sponsors.

Relative Volatility and Intrinsic Tracking Error

A fund's relative return is the difference between its total return and that of a prescribed benchmark. We will use the term "relative volatility" to refer to the standard deviation of these relative returns.

Consider a portfolio process with returns that are assumed to vary around some average beta that may or may not coincide with the benchmark. Then, apart from any alpha-based excess return, there are three sources of relative volatility that can be identified: 1) the "beta gap" between the fund's average beta value and the benchmark, 2) the "beta volatility" of the fund's actual beta at different points in time, and 3) an "intrinsic" tracking error that characterizes the fund's deviation from its beta-based returns.

The intrinsic tracking error can be viewed as the fund's active risk in the absence of any beta gap or beta volatility. However, any active strategy will have some discrepancy between the realized beta at a given point in time and the benchmark beta. Consequently, it will be the relative volatility that is perceived as the deviation from the benchmark, rather than the underlying intrinsic tracking error.

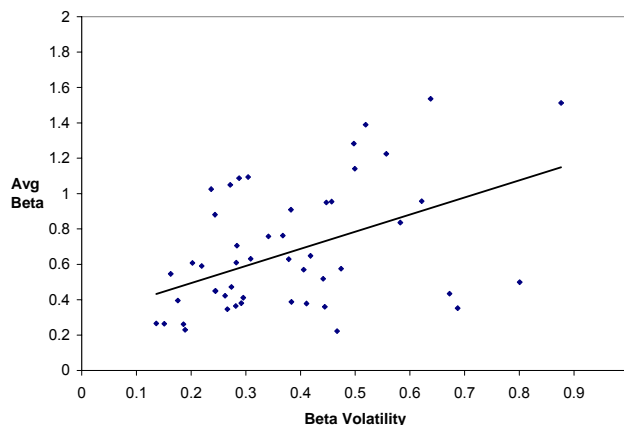
An explicit formula for the relative volatility can be derived for this three-component model (see Appendix). The beta gap and the intrinsic tracking error components are quite straightforward. However, the beta volatility term depends upon both the volatility and the average return of the reference market. The explicit formula can help in exploring the interaction of these multiple sources of relative volatility. The ultimate objective is to identify the beta-targeting conditions that can enable the relative volatility to act as a reasonable representation for the fund's intrinsic tracking error.

An Empirical Example

The three-component analysis of fund volatility can be illustrated by using a sample of 50 long/short funds from the MSCI database. Many long-short hedge fund managers do not structure themselves around a set beta target. Given their ability to change their gross and net exposures, the range of beta volatilities can be quite high. This can be seen in Exhibit 1, which shows a scatterplot of the average beta and beta volatility for this sample from 1999-2006.

Exhibit 1

Average Beta vs. Beta Volatility for Sample L/S Funds

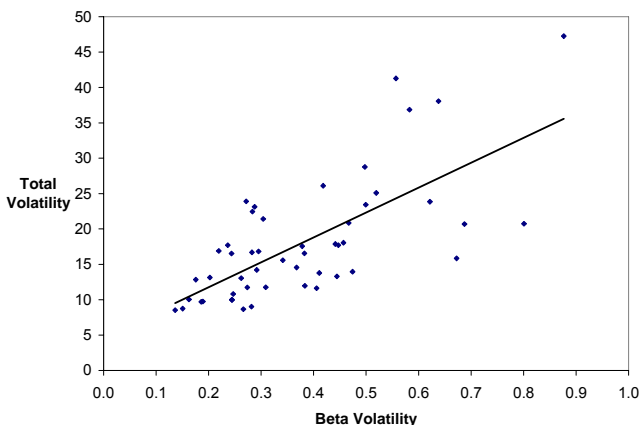


Source: Morgan Stanley Research. MSCI

Exhibit 2 plots the total volatility versus the beta volatility for the sample funds. There is a clear upward trend between the beta volatility and the absolute level of volatility. The higher average beta is associated with the larger beta volatilities, and this combination naturally results in higher total volatilities.

Exhibit 2

Total Volatility vs. Beta Volatility for Sample L/S Funds

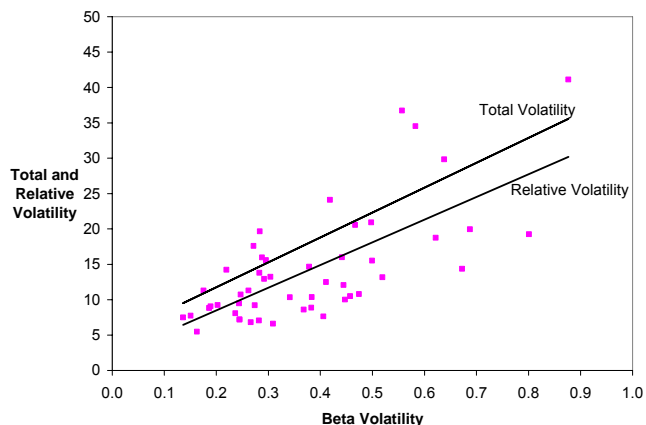


Source: Morgan Stanley Research. MSCI

Exhibit 3 now removes the average beta effect to uncover the relative volatility. The total volatility from Exhibit 2 is also displayed here as the higher regression line. The difference between the total volatility and the relative volatility is evident in the two regression lines.

Exhibit 3

Relative Volatility for L/S Funds



Source: Morgan Stanley Research, MSCI

A Monte Carlo Simulation

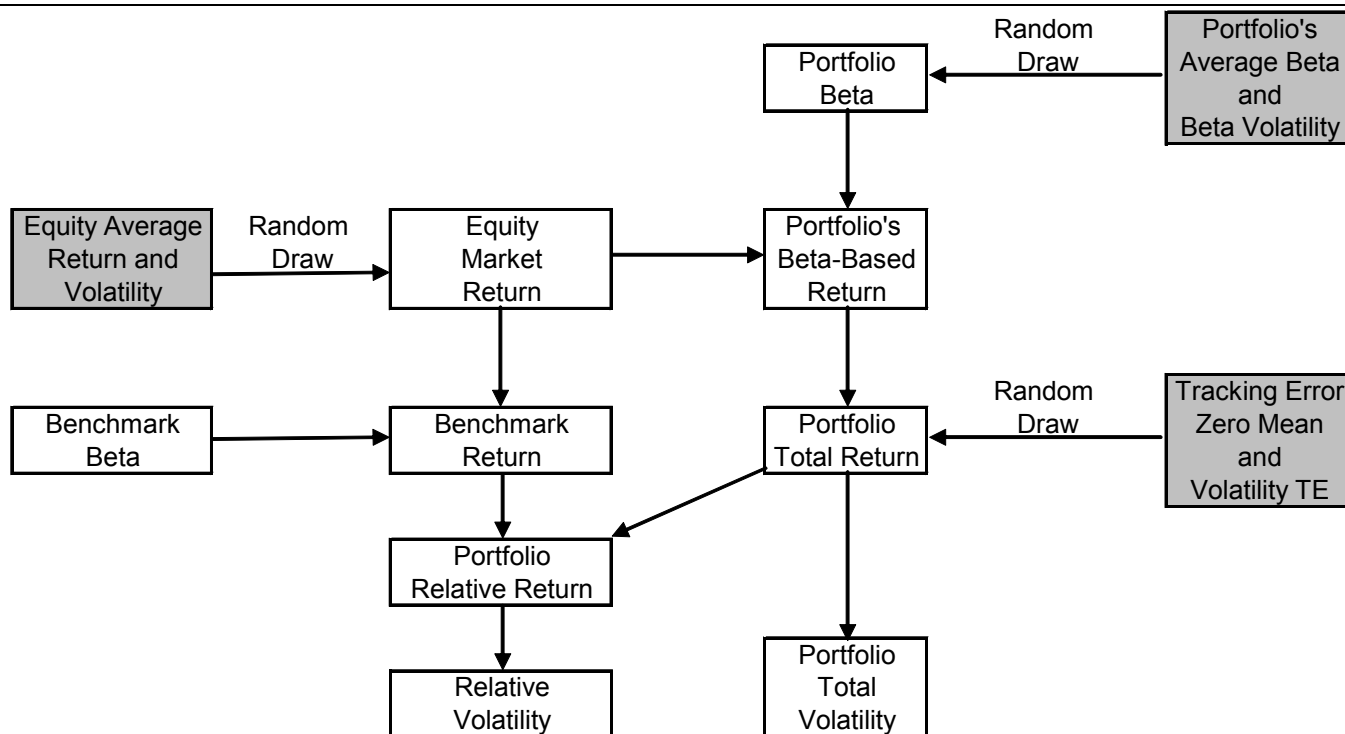
The above empirical results point in the right direction, but they are clouded by autocorrelations and various problems inherent

in estimating contemporaneous beta values. A Monte Carlo simulation that more directly reflects the dynamics of the three-component volatility model is depicted in the flow chart in Exhibit 4. For each run, a realized portfolio beta is first drawn from a beta distribution with a fixed mean value and a beta volatility. This realized beta is combined with a random market return to form the portfolio's beta-based return. A tracking deviation is then drawn from a distribution with a mean of zero and volatility equal to the intrinsic tracking error (TE). (For simplicity, the alpha term is neglected since it does not play a role in the volatility calculation.) The realized portfolio return is then found by adding the realized deviation to this beta-based return.

This process is repeated with fresh random draws, and the "total portfolio volatility" is defined to be the annualized standard deviation of the return series. The relative return is just the portfolio return less the product of the benchmark beta and the market return. The standard deviation of these returns is then referred to as the relative volatility.

Exhibit 4

Monte Carlo Simulation



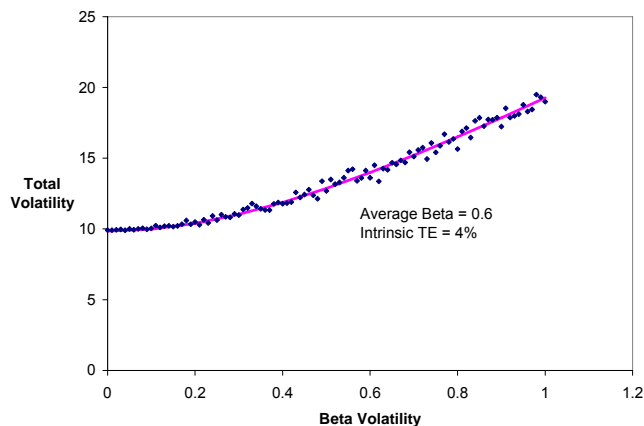
Source: Morgan Stanley Research

Exhibit 5 presents the simulation results for total portfolio volatility based upon 1000 random draws from the following three distributions:

- 1) a portfolio beta with an average value of 0.6 and with beta volatilities ranging from 0 to 1
- 2) an equity market return with an annual average value of 7% and a 15% volatility
- 3) an “intrinsic tracking error” with a mean of zero and 4% volatility

Exhibit 5

Total Volatility Simulations



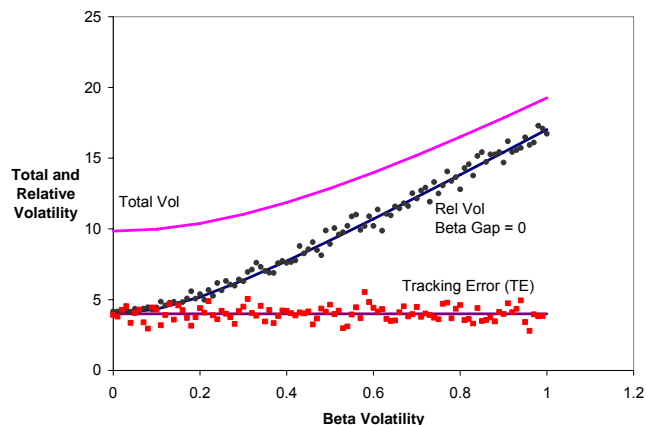
Source: Morgan Stanley Research

The solid line in Exhibit 5 is the expected result based on the three-component formula developed in the Appendix. It is interesting to see how the Monte Carlo results are tightly clustered around the formula line when the beta volatility is low. At higher beta volatilities, the scatter widens considerably.

The relative volatility of a fund depends on the benchmark. The top curve in Exhibit 6 represents the absolute level of volatility. The middle scatter is the relative volatility for a target beta that coincides with the portfolio’s average 0.6 beta (i.e., a beta gap of zero). The lowest scatter line reflects the 4% intrinsic tracking error. The distance between these two lower lines gives a sense of how the beta volatility contributes to the relative volatility.

Exhibit 6

Three Volatility Components



Source: Morgan Stanley Research

Exhibit 6 illustrates the benefit of having reasonable bounds on the beta volatility. With modest beta volatility, the relative volatility is close to the 4% TE. As the beta volatility moves toward higher levels, the relative volatility rises well above the 4% TE.

The Beta Volatility Formula

The Monte Carlo results in Exhibits 5 and 6 demonstrate that the three-component formula in the Appendix can serve as a satisfactory tool for exploring the interactions of the three volatility components.

In virtually any active strategy, there is almost sure to be some slippage between the intended beta target and the benchmark beta. Over any specific investment horizon, this slippage will result from the combination of the basic beta volatility and some (possibly unintentional) gap between the average beta and the benchmark beta. This slippage will lead to a relative volatility that exceeds the portfolio’s intrinsic tracking error. This relative volatility then appears as the measure of the fund’s active risk. Therefore, a key question is to what extent this relative volatility is a reasonably close proxy for the underlying tracking error. In other words, what are the allowable combinations of beta gap, beta volatility, and TE that keep the relative volatility sufficiently close to the TE. In the following section, we make use of the “beta volatility” formula to investigate a wide range of such combinations.

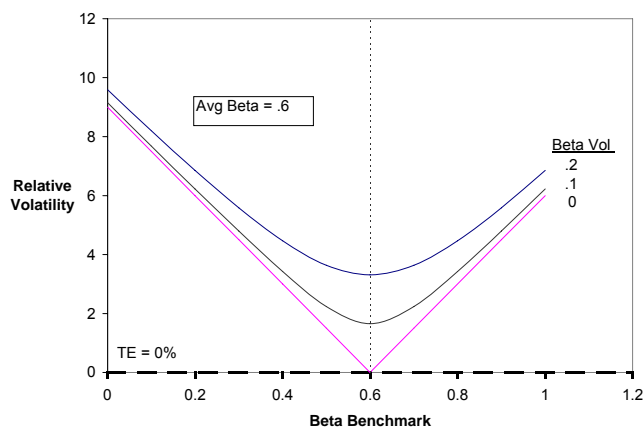
In the following series of exhibits, the formula values for the relative volatility are plotted against a range of benchmark betas. In all cases, the portfolio is assumed to have an average beta value of 0.6, so that the difference between the

April 20, 2007
Strategy

benchmark beta and 0.6 represents the beta gap. The three curves correspond to beta volatilities of 0, 0.1 and 0.2, and each exhibit is based on different TE levels. The purpose of these graphs is to visualize how the different combinations of beta gap and beta volatility affect the proximity of the relative volatility to the underlying intrinsic tracking error.

In Exhibit 7, the intrinsic tracking error (TE) is set at 0%, essentially reflecting a fund comprised of a 60% pure index fund and the remaining 40% in cash. As might be expected, virtually any level of beta gap or beta volatility would lead to unacceptable deviations from the index fund's objective.

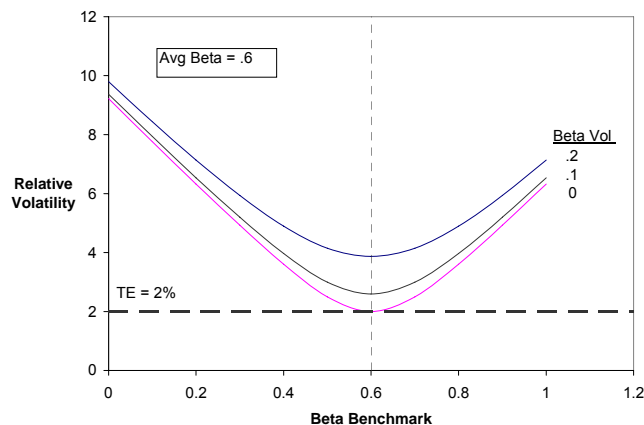
Exhibit 7
Relative Volatility vs. Benchmark Betas with TE = 0%



Source: Morgan Stanley Research

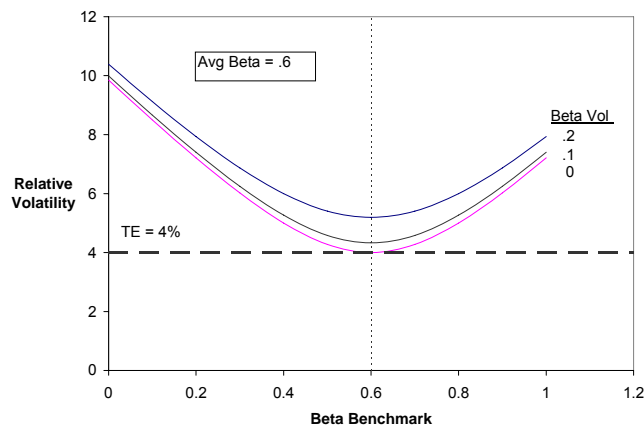
Exhibits 8, 9 and 10 show the comparable relative volatility curves for TE's of 2%, 4% and 8%, respectively. For the 2% and 4% TE, a "proxy function" could tolerate beta gaps of ± 0.1 or beta volatilities of 0.1 or lower. However, with an 8% TE, the TE curve flattens out considerably so that a beta gap of ± 0.2 might be acceptable, as long as the beta volatility remains below 0.2.

Exhibit 8
Relative Volatility vs. Benchmark Betas with TE = 2%



Source: Morgan Stanley Research

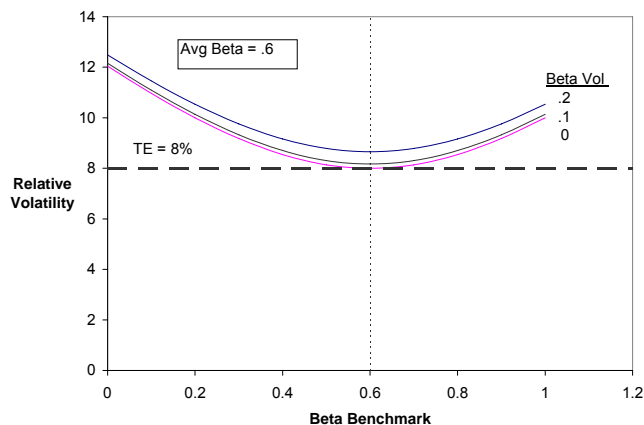
Exhibit 9
Relative Volatility vs. Benchmark Betas with TE = 4%



Source: Morgan Stanley Research

Exhibit 10

Relative Volatility vs. Benchmark Betas with TE = 8%

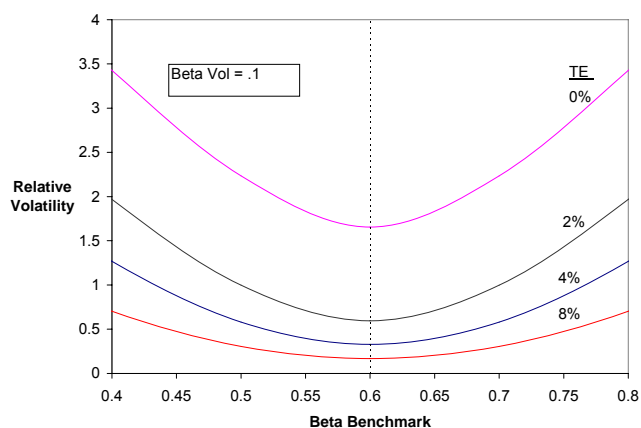


Source: Morgan Stanley Research

By enlarging the scale and focusing specifically on the 0.1 beta volatility curves from Exhibit 7-10, Exhibit 11 shows the deviation between the relative volatilities and the intrinsic TE. The flattening of these curves reflects the increasing dominance of the TE and the consequent ability to accept somewhat higher beta gaps.

Exhibit 11

Relative Volatility vs. Benchmark Betas



Source: Morgan Stanley Research

Alpha Measurement and Information Ratios

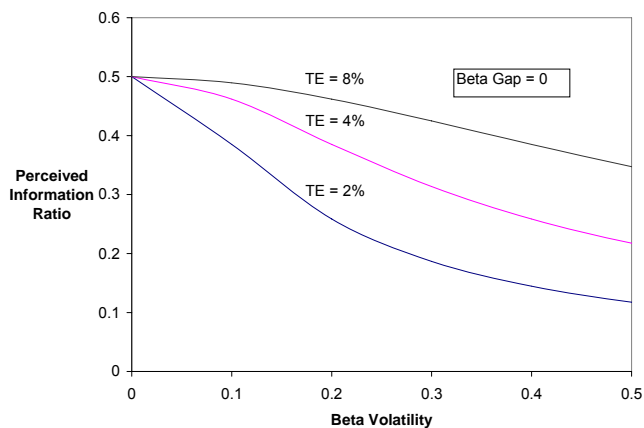
The active alpha is usually defined as an average return over the benchmark. When there is a significant beta gap, this average relative return will include a term that is the product of the beta gap and the average market return. Consequently, the clearest possible basis for measuring alpha would call for a

beta gap of zero. In turn, this would call for a reasonably well-defined beta target that is centered on the benchmark.

Even with a zero beta gap, beta volatilities will enlarge the perceived TE, resulting in distortion of the information ratio. Exhibit 12 provides a graphic illustration. In this exhibit, the “true” information ratio — the ratio of the expected active alpha to the intrinsic TE — is fixed at 0.5. For each TE curve, the alpha is presumed to be at a level that would yield this 0.5 information ratio, e.g., for the 4% TE curve, the assumed alpha value is 2%. With a beta gap taken to be zero, the “perceived” information ratio is based upon using the relative volatility in the denominator. As the beta volatility increases, it becomes evident how quickly the “perceived” information ratio falls below the true value of 0.5, especially for the lower TE’s

Exhibit 12

Beta Volatility Impact on Information Ratio



Source: Morgan Stanley Research

The information ratio serves as an important gauge of the statistical reliability of the fund’s ability to generate positive alphas over time. With rising beta volatilities, Exhibit 12 shows how quickly any evidence of positive skill is severely eroded. By establishing beta targets centered on a benchmark beta, and by endowing that target with integrity through a beta volatility that is appropriately constrained, the portfolio manager (and the sponsor) will have more assurance that the true “alpha-hunting” skills are being revealed.

Setting Comfortable Beta Targets

It is worth noting that for the 2-4% TE range, a minimal level of beta volatility is still tolerable as long as the beta gap is kept small. This suggests that, even at these modest TE levels, there is some flexibility in the beta targeting. In other words, the risk control procedures need not be so limiting as to

seriously hamper a manager's basic approach to active management.

This flexibility also extends to the manager's choice of the beta target itself. Many active managers have a style that centers around beta values other than one. This "natural beta" can be set as the target beta. With sufficiently low beta volatility to maintain this target's integrity, the resulting information ratio calculation would be a reasonable yardstick for the fund's alpha-producing reliability.

Moreover, a target beta set at some comfortable but non-standard level need not restrict the fund's or the sponsor's ability to "stretch" to a more standard beta for purposes of asset allocation or peer comparability. With overlays and/or portfolio reallocations, a given target beta can be efficiently transformed to virtually any value. The key to this transformation is having a beta target that has sufficiently low beta volatility.

There are certainly many established portfolios without explicitly named beta targets. On the one hand, some of these "untargeted" portfolios have beta values that are consistently centered on some average value. For such portfolios, it might be a small step to explicitly target an average beta value. The necessary risk control discipline for beta targeting can often be put in place without overly cramping the existing management style.

On the other hand, there are also situations where the beta targeting might prove quite counterproductive. One obvious example is managers that utilize broad-based tactical beta shifts as their basic return-seeking process. Another broad class consists of those managers, both long-only and long/short, that require as part of their competitive advantage the unconstrained pursuit of returns wherever they can be found.

The generation of positive excess returns, whether absolute or relative, is the paramount goal of all active management. Any new risk control discipline, including beta targeting, makes sense only to the extent that it fundamentally furthers this basic objective.

Beta Targeting and Total Fund Risk

The preceding section was concerned with how beta targeting can improve the portfolio's information ratio. However, the concept of a beta target can be beneficial in a number of other ways.

A well-defined target beta allows sponsors to better integrate specific portfolios within their risk budgets. In virtually all US

institutional portfolios, the expected total volatility is overwhelmingly dependent on the fund's co-movement with the equity market. This equity co-movement will typically account for 90% or more of the fund's volatility. This surprisingly high level of correlation is derived from the explicit equity percentage together with the accumulated implicit correlation from non-equity allocations. Thus, even highly diversified funds — those with as little as 15-20% allocated to domestic equity — will have expected levels of equity co-movement that are comparable to traditional 60/40 portfolios. [27-29]

This equity dominance can be quantified through the concept of an "implicit beta" based on the asset's expected correlation with equity movements. These implicit betas add to the explicit betas to form a fund's total beta, as shown in Exhibit 14. For most institutional funds, the total beta values are quite similar, falling between 0.55 and 0.65. Indeed, this similarity in the total beta values explains why most funds also have total volatilities in the 10-11% range.

Exhibit 14

Typical Diversification Does Not Materially Change Fund Volatility: 90%-plus Comes from Equity

	Correlation-Based Implicit Beta	B	C
Cash US Equity	1.00	60%	20%
Cash US Bonds	0.14	40%	20%
International Equity	0.77		15%
Emerging Mkt Equity	0.76		5%
Absolute Return	0.28		10%
Venture Capital	0.59		10%
Private Equity	0.98		10%
Real Estate	0.07		10%
Total		100%	100%
Total Volatility		11.17	10.45
Total Beta		0.65	0.57
% Volatility from Beta		96.7%	90.4%

Source: Morgan Stanley Research

For funds with multiple allocations to active equity and equity-related strategies, the diversification effects will be different for the three volatility components. To the extent that active alpha seeking is independently pursued, the TE's will

have minimal impact on the total fund volatility. Similarly, if the beta volatilities of the various portfolios are uncorrelated, then these volatility effects will also be diversified and hence have only a modest effect at the total fund level. However, the individual portfolio betas will add to the fund's total beta, so their effect cannot be diversified away. Since this total beta is the dominant source of fund volatility, each incremental beta contributes to a corresponding increase in total fund volatility.

Without beta targets, the sponsor will have little guidance on how to incorporate equity-related portfolios into a beta-based risk control format. Thus, having beta targets with some integrity serves a very concrete purpose.

Beta targeting can also be viewed as a way of translating an implicit beta based on a correlation model into a more explicit beta value. One might be tempted to argue that the standard covariance models are all that are needed. However, to the extent that the betas are uncertain, the covariance estimates themselves will also be ambiguous. Moreover, the key risk scenarios for beta-dominated funds tend to be associated with significant adverse movements in equities. The standard covariance analysis reflects asset behavior across a full range of scenarios, with a greater emphasis on the more frequent movements of modest magnitude. Consequently, standard

covariance analysis cannot address the special contingencies that create stress situations in practice. The total beta approach provides a much more direct (if still imperfect) gauge of a fund's vulnerability under such adverse conditions.

With the total beta playing such a dominant role in determining the fund's risk profile, a sponsor will want to have the best possible estimate of the beta contribution from each component portfolio. This would be especially true for funds with sizable allocations to equity-related portfolio strategies. The key to having these well-defined betas is first, to have prescribed targets, and then to maintain a reasonable beta volatility around them.

The Alpha/Beta Matrix

The term "alpha/beta barbell" generally refers to the spectrum of equity-related strategies that range from passive indexing on the far left to portable alpha formats on the far right. The alpha/beta matrix (Exhibit 15) is an attempt to place beta-targeted equity funds in a somewhat broader context that also incorporates non-equity asset classes. This rather anthropomorphic presentation is an expanded version of a classification of active strategies derived from a *Financial Analyst Journal* paper entitled 'Alpha Hunting and Beta Grazers' [30].

Exhibit 15

The Alpha/Beta Matrix

Metaphor	Betas	Management Styles	Nature of Alphas	Fund Level Effects		
				Fund Volatility	Model Risk	TE vs. Policy
Beta Grazing	Stapled	Passive Investing in Broad Equity/Fixed Income Markets	Risk Premium	Fundamental Source	Very Low	Zero
Alpha Hunting	Beta-Targeted	Risk-Controlled Active Equity Market Neutral Active Extension Some Hedge Funds	Active Management	Low	Low	Low
Alpha Gathering	Correlation-Based	Diversification into New Asset Classes	Implicit Correlation-Based Passive Alphas	Low	High	Low
Alpha/Beta Foraging	"Free Range"	Beta-Agnostic Opportunistic Investment Some Hedge Funds Macro Funds Some Concentrated Long-Only	Intense to Hyper Active	High	High	High

Source: Morgan Stanley Research

April 20, 2007

Strategy

“Beta grazers” are passive index funds that are content to access the risk premium in the most cost-efficient possible way.

“Alpha hunters” refers to those benchmark-centric strategies that seek active alpha returns, but do so in a risk-controlled fashion. Beta-targeted equity strategies would fall into this category. With beta targeting, the tracking error should be definitively uncorrelated with the beta factor, and consequently have little impact on the fund volatility. Thus, a beta-targeted equity strategy should incur relatively little “model risk,” i.e., where the return behavior deviates significantly from the modeled assumptions.

The next category is the “alpha gatherers,” which includes new asset classes with return/covariance models that are typically derived from some modification of historical statistics. The correlations with equity that are embedded in these models can be used to derive implicit beta values. In turn, these implicit betas suggest implicit alphas that represent the asset’s expected return beyond that associated with its correlation-based beta. These implicit alphas represent incremental expected returns for a beta-dominated fund making a new investment in the asset class.

However, there is always a question of past performance being a predictor of future returns, and the same question exists with respect to past correlations. These ambiguities become even more serious when the asset class is undergoing structural change and/or becoming more or less fashionable. The net result is that these implicit betas and alphas can be more vulnerable to model risk than beta-targeted equity strategies.

Finally, there are alpha/beta “foragers” who venture forth and opportunistically seek returns wherever they can be found. Even where return/covariance models do exist for this behavior, they will inspire little confidence. Consequently, it will always be difficult to estimate their effect on total fund risk, unless the allocations are kept small and very highly diversified.

All these return-seeking pursuits are often present in any given fund and each can prove valuable if successfully pursued. However, they do differ materially in the character of the risks entailed — and nature of their fund-level effects.

Beta-targeted alpha hunting appears to occupy a special and perhaps uniquely valuable niche. It provides identifiable beta values that can be incorporated into the sponsor’s risk budget. The residual TE risk should be inherently uncorrelated with the beta factor and hence mostly diversifiable at the fund level.

Finally, there is relatively little model risk clouding the projected behavior of such strategies. The key assumption — as always — is that the strategies can generate positive alpha returns, at least over sufficiently long horizons.

Conclusions

Beta targeting allows for clearer separation of the excess alpha return from the beta-based return. The manager’s performance, whether on a pure alpha or information ratio basis, surely becomes easier to measure once a beta target has been established.

For the sponsor, beta targeting also enables better control of the overall volatility risk. A desired level of portfolio volatility can be achieved by combining the individual portfolio betas with appropriate reallocations and/or beta overlays.

Many long-only as well as long/short funds intensively pursue alphas with a process that revolves around some average beta value but without specifying a formal beta target. The question naturally arises as to whether such funds, especially those with good records of alpha generation, can develop a closely related process that can tap into the evident interest in 130/30 active extension strategies.

In particular, can such funds maintain their comfortable and presumably successful style, while migrating from a somewhat ill-defined average beta to a more clearly specified beta target? Does such a beta target in itself capture the most desirable features of active extension? Finally, even with beta targets that fall below the active extension’s standard beta of one, can institutional sponsors bring themselves to include such funds within their active equity allocation?

Subject to certain conditions, we believe that all the preceding questions can be answered affirmatively. The key conditions are 1) that a beta target be specified, 2) that the drift around this beta target be contained within some reasonably modest level, 3) that the TE be reliably uncorrelated with the fund’s total risk, and 4) most importantly, that the alpha generating capability be sufficiently robust and positive so as to attest to the presence of positive management skill.

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April 20, 2007

Strategy

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Appendix

One standard formulation for an equity portfolio's return \tilde{r}_p is

$$\tilde{r}_p = \alpha + \tilde{\beta}_p \tilde{r}_e + \tilde{\varepsilon}$$

Where $\tilde{\beta}_p$ is the portfolio's beta, \tilde{r}_e is the return of the relevant equity market, $\tilde{\varepsilon}$ is the tracking error variable, and α is the excess return. The standard random variables on the right hand side of this expression are \tilde{r}_e and $\tilde{\varepsilon}$, with the latter usually assumed to have zero mean. For the analysis in this paper, this standard formulation must be slightly extended to allow the portfolio's beta $\tilde{\beta}_p$ to also become a random variable with mean $\bar{\beta}_p$ and standard deviation σ_{β} (A 2003 NBER paper provides a highly generalized treatment of the much broader question of factor errors [31]).

In the following analysis, the random variables \tilde{r}_e , $\tilde{\varepsilon}$, and now $\tilde{\beta}_p$, are treated in a non-parametric fashion, i.e., without any requirements on their distribution functions other than the existence of means and variances. All three are also assumed to be independent of one another. (However, while this independence assumption is certainly quite common, it should be pointed out that, in practice, extreme market movements are likely to create higher "stress betas").

Under these conditions, the expected portfolio return \bar{r}_p remains the same as under the standard model,

$$\begin{aligned} \bar{r}_p &= \alpha + E\{\tilde{\beta}_p \tilde{r}_e\} + E\{\tilde{\varepsilon}\} \\ &= \alpha + E\{\tilde{\beta}_p\}E\{\tilde{r}_e\} + 0 \\ &= \alpha + \bar{\beta}_p \bar{r}_e \end{aligned}$$

However, the variance $\sigma_{r_p}^2$ does become somewhat more complex. As a first step, we derive

$$\begin{aligned} E\{\tilde{r}_p^2\} &= E\{[\alpha + \tilde{\beta}_p \tilde{r}_e + \tilde{\varepsilon}]^2\} \\ &= \alpha E\{\alpha + \tilde{\beta}_p \tilde{r}_e + \tilde{\varepsilon}\} + E\{\tilde{\beta}_p \tilde{r}_e [\alpha + \tilde{\beta}_p \tilde{r}_e + \tilde{\varepsilon}]\} + E\{\tilde{\varepsilon} [\alpha + \tilde{\beta}_p \tilde{r}_e + \tilde{\varepsilon}]\} \\ &= \alpha \bar{r}_p + [\alpha \bar{\beta}_p \bar{r}_e + E\{(\tilde{\beta}_p \tilde{r}_e)^2\} + \bar{\beta}_p \bar{r}_e E\{\tilde{\varepsilon}\} + [0 + E\{\tilde{\varepsilon} \tilde{\beta}_p \tilde{r}_e\} + E\{\tilde{\varepsilon}^2\}]] \\ &= \alpha \bar{r}_p + [\alpha \bar{\beta}_p \bar{r}_e + E\{\tilde{\beta}_p^2\}E\{\tilde{r}_e^2\} + 0] + [0 + 0 + E\{\tilde{\varepsilon}^2\}] \\ &= \alpha \bar{r}_p + \alpha \bar{\beta}_p \bar{r}_e + E\{\tilde{\beta}_p^2\}E\{\tilde{r}_e^2\} + E\{\tilde{\varepsilon}^2\} \end{aligned}$$

The variance $\sigma_{r_p}^2$ can then be written as

$$\begin{aligned}
 \sigma_{r_p}^2 &= E\{\tilde{r}_p^2\} - \bar{r}_p^2 \\
 &= E\{\tilde{r}_p^2\} - [\alpha + \bar{\beta}_p \bar{r}_e]^2 \\
 &= \alpha[\alpha + \bar{\beta}_p \bar{r}_e] + \alpha \bar{\beta}_p \bar{r}_e + E\{\tilde{\beta}_p^2\} E\{\tilde{r}_e^2\} + E\{\tilde{\varepsilon}^2\} - [\alpha^2 + 2\alpha \bar{\beta}_p \bar{r}_e + (\bar{\beta}_p \bar{r}_e)^2] \\
 &= E\{\tilde{\beta}_p^2\} E\{\tilde{r}_e^2\} + E\{\tilde{\varepsilon}^2\} - (\bar{\beta}_p \bar{r}_e)^2 \\
 &= [\sigma_{\tilde{\beta}_p}^2 + \bar{\beta}_p^2][\sigma_e^2 + \bar{r}_e^2] + [\sigma_{\tilde{\varepsilon}}^2 + 0] - (\bar{\beta}_p \bar{r}_e)^2
 \end{aligned}$$

Thus, the formula for the total portfolio variance given random betas becomes

$$\sigma_{r_p}^2 = \sigma_{\tilde{\beta}_p}^2[\sigma_e^2 + \bar{r}_e^2] + \bar{\beta}_p^2 \sigma_e^2 + TE^2$$

where $\sigma_{\tilde{\beta}_p}^2$, σ_e^2 and TE^2 are the variances of $\tilde{\beta}_p$, \tilde{r}_e and $\tilde{\varepsilon}$, respectively.

This expression differs from the variance for the standard formulation

$$\beta_p^2 \sigma_e^2 + TE^2,$$

in the first term that depends on $\sigma_{\tilde{\beta}_p}^2$,

$$\sigma_{\tilde{\beta}_p}^2[\sigma_e^2 + \bar{r}_e^2]$$

With $\sigma_{\tilde{\beta}_p} = 0$, the two results coincide.

A second result needed in this development is the concept of the portfolio's return R relative to some benchmark target. The simplest characterization of this benchmark is through a fixed beta β_B that applies to the same reference market \tilde{r}_e . The relative return R then becomes

$$\begin{aligned}
 \tilde{R} &= \tilde{r}_p - \beta_B \tilde{r}_e \\
 &= \alpha + (\tilde{\beta}_p - \beta_B) \tilde{r}_e + \tilde{\varepsilon}
 \end{aligned}$$

The expected relative return is just

$$\begin{aligned}
 \bar{R} &= \alpha + (\bar{\beta}_p - \beta_B) \bar{r}_e \\
 &= \alpha + (\Delta\beta) \bar{r}_e
 \end{aligned}$$

where the expected difference between the two betas can be referred to as the "beta gap", $\Delta\beta$

The expression for the relative return has the same form as the portfolio return when the beta difference is substituted for the portfolio beta. Thus, since $\sigma_{\Delta\beta}^2 = \sigma_{\beta}^2$, the variance of relative returns can be immediately expressed as

$$\sigma_R^2 = \sigma_{\beta}^2[\sigma_e^2 + \bar{r}_e^2] + (\Delta\beta)^2 \sigma_e^2 + TE^2$$

The relative volatility σ_R is a measure of the deviation of the portfolio returns from the benchmark target. As such, it may be taken as a “perceived tracking error,” especially when there is a lack of visibility regarding the beta gap $\Delta\beta$ and/or the beta volatility σ_{β} . The “perceived tracking error” should be distinguished from the “intrinsic tracking error” TE that would remain even if the $\Delta\beta$ and σ_{β} effects could be removed either through more visible decomposition or by risk control revisions.

By incorporating a market effect, a beta gap will also affect the ex-post estimation of the portfolio’s excess return. Thus, with these distortions in both the numerator and the denominator, the ratio

$$\left(\frac{R}{\sigma_R} \right)$$

can become a seriously degraded form of the “intrinsic information ratio,”

$$\left(\frac{\alpha}{TE} \right)$$

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April 20, 2007
Strategy

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The Americas

1585 Broadway
New York, NY 10036-8293

United States

Tel: +1 (1) 212 761 4000

Europe

25 Cabot Square, Canary Wharf
London E14 4QA

United Kingdom

Tel: +44 (0) 20 7 425 8000

Japan

4-20-3 Ebisu, Shibuya-ku
Tokyo 150-6008

Japan

Tel: +81 (0) 3 5424 5000

Asia/Pacific

Three Exchange Square
Central

Hong Kong

Tel: +852 2848 5200