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UNDERSTANDING MUTUAL FUND AND HEDGE FUND STYLES USING RETURN-BASED STYLE ANALYSIS

Arik Ben Dor, Ravi Jagannathan†, and Iwan Meier**

We illustrate the use of return-based style analysis in practice using several examples. We demonstrate the importance of selecting the right style benchmarks and how the use of inappropriate style benchmarks may lead to wrong conclusions. For example, when style analysis is applied to sector-oriented funds, the set of benchmarks should include sector or industry indexes. We show how asset turnover and style graphs over time can be used to ensure right inference about the effective style of a fund, and how to extend return-based style analysis to analyze hedge fund styles. In the examples we consider, return-based style analysis provides insights not available through commonly used peer evaluation alone.

1 Introduction

During the past three decades, the direct holdings of corporate equities by individuals has come down and the holdings through money management institutions has correspondingly increased. Mutual funds and pension funds held almost 40% of US corporate equities by the end of 2001, more than three times the 14% they held in 1970.[1] Mutual funds, in particular, have become an attractive vehicle for individual investors for investing in financial assets. An estimated 52% of US households invest in mutual funds. While in 1990 mutual funds as a group were holding assets worth $1 trillion, the number reached $7 trillion in 2001. Approximately half of this was accounted for by equity funds.[2] The 8307 mutual funds in December 2001 held 21 percent of the $13.9 trillion of outstanding, publicly traded US equities.[3]

By holding stocks through institutions managed by professional money managers, individual investors and plan sponsors have been able to reap the benefits of diversification and specialization. However, this benefit is not without cost. Indirect holding of equities by relying on fund managers introduces invisible agency costs in addition to visible fees. This is due to the need to monitor the actions of fund managers to ensure compliance with stated objectives and to evaluate their performance.

The menu of mutual funds available to an investor is large, ranging from domestic real-estate stock funds, international funds invested in emerging

*Kellogg School of Management at Northwestern University.

†Kellogg School of Management and National Bureau of Economic Research.

markets, to municipal bond funds designed for investors who are subject to federal income tax. For example, Morningstar, a prominent source of information on mutual funds, reports returns on four broad categories (domestic stock funds, international stock funds, fixed-income funds, and municipal bond funds) which are further divided into 48 sub-categories. The Investment Company Institute enumerates 33 investment objective categories. These classifications by themselves, however, are not very helpful in deciding how to allocate the money across the different fund categories.

When allocating capital among several fund managers, individual investors and plan sponsors have to ensure that their investment objectives are met, the bets taken by the different managers do not cancel out, and management fees that they pay are related to performance. The large number of fund categories and the diversity in investment objectives even within narrow fund categories makes it difficult to understand how the returns on different funds interact with each other. Hence, there is a need for a conceptual framework that helps individual investors and plan sponsors understand what a fund manager is doing. Sharpe (1988, 1992a) provides one framework, "return-based style analysis", that is attractive for that purpose. In this paper, we show how return-based style analysis can provide information not available through commonly used peer-group comparisons alone. We discuss common pitfalls that a user of return-based style analysis should be aware of. We also provide guidelines for choosing the right style benchmarks, interpreting estimated style changes, and checking robustness of the style characterization based on the use of different optimization criteria.

To the casual observer, it may appear that portfolio-composition-based style analysis would convey more information about the style of an actively managed fund than return-based style analysis. This need not be true. To see why, consider a manager who provides portfolio insurance by synthetically creating a put option on the market index through active trading. An investor would be able to identify that the manager is indeed providing a put option based on return-based style analysis using appropriately chosen benchmarks and judiciously chosen options on the benchmarks. It may be difficult to arrive at that conclusion based on an examination of the manager's portfolio holdings at different points, even for an analyst who is trained in derivative mathematics. In our view, portfolio-composition-based and return-based style analyses are complements rather than substitutes.

Many popular hedge fund strategies generate returns that exhibit low average correlations with stock and bond returns. However, the correlations could be high under certain market conditions, especially periods associated with large movements in stock and bond prices. Therefore, return-based style analysis using standard asset classes will have difficulty in characterizing the risks in hedge fund strategies with sufficient accuracy. We discuss the modifications that are necessary to apply return-based style analysis to hedge funds.

The rest of the paper is organized as follows. Section 2 contains a review of the methodology of return-based style analysis. Section 3 shows how the technique can be used in practice. Some common pitfalls are discussed in Section 4. In Section 5, we show how to modify the methodology to examine hedge funds. We summarize and conclude in Section 6.

2 Methodology

2.1 Linear factor models and return-based style analysis

Linear factor models are commonly used in investment analysis for generating inputs for portfolio

optimization. Consider the linear N-factor model given below that decomposes the return $r_{i,t}$ on security i in period t into two parts: the first is a linear function of the factors and the second is orthogonal to the first part.

$$r_{i,t} = a_{i,0} + a_{i,1}f_{1,t} + a_{i,2}f_{2,t} + \cdots + a_{i,N}f_{N,t} + \varepsilon_{i,t} \quad (1)$$

The coefficients $a_{i,n}$, $n = 1, 2, \ldots, N$, measure the sensitivity of the return on security i, $r_{i,t}$, to the nth factor, $f_{n,t}$, and $\varepsilon_{i,t}$ is the component of $r_{i,t}$ that cannot be explained by the N factors. In addition, the residual (non-factor component), $\varepsilon_{i,t}$, for asset i is uncorrelated with that for asset j. This last property is what distinguishes the linear factor model given in Eq. (1) from a standard multiple regression exercise. Commonly used factors include returns on asset classes and unexpected changes in macroeconomic variables. In Sharpe's (1988) return-based style analysis, there is no intercept term, $a_{i,0}$, every factor is a return on some asset class, and the coefficients sum to unity.

Consider an active portfolio manager who is restricted to investing a fraction $b_{p,n}$ of the amount given to him in asset class $n = 1, 2, \ldots, N$. The only discretion allowed is to pick securities from within each asset class. An investor can either give the funds to the active portfolio manager or hold a passive portfolio with fractions $b_{p,n}$ invested in the nth asset class index, $x_{n,t}$. The returns on the two strategies will not, in general, be the same. The difference, $e_{p,t} = r_{p,t} - [b_{p,1}x_{1,t} + b_{p,2}x_{2,t} + \cdots + b_{p,N}x_{N,t}]$, arises from the manager selecting to weight securities within a given asset class differently than the corresponding asset class index. Knowing the properties of the *selection* component, $e_{p,t}$, will be helpful to an investor who is considering allocating the funds to the active portfolio manager. In general, a portfolio manager will have some flexibility regarding the fraction $b_{p,n}$ invested in each asset class, n. Hence, the investor who allocates funds to the active portfolio manager would also be interested in finding out how the manager distributed the funds across the different asset classes in addition to picking securities within each asset class. Sharpe's (1988) return-based style analysis helps identify the effective style of the active portfolio manager given by the asset class exposures, $b_{p,n}$, $n = 1, 2, \ldots, N$, and separate the selection component, $e_{p,t}$, from the return provided by the manager, $r_{p,t}$.

The *effective style* of a fund manager are those asset class coefficients, $b_{p,1}, \ldots, b_{p,N}$, that minimize the variance of the error terms $e_{p,t}$ in the asset class factor model given in Eq. (2a) subject to the constraints (2b) and (2c):

$$r_{p,t} = [b_{p,1}x_{1,t} + b_{p,2}x_{2,t} + \ldots + b_{p,N}x_{N,t}] + e_{p,t} \quad \text{for } t = 1, 2, \ldots, T \quad (2a)$$

$$\text{s.t. } b_{p,n} \geq 0 \quad \text{for } n = 1, 2, \ldots, N \quad (2b)$$

$$b_{p,1} + b_{p,2} + \cdots + b_{p,N} = 1 \quad (2c)$$

where $r_{p,t}$ is the return on the managed fund, the factor $x_{n,t}$, $n = 1, 2, \ldots, N$, is the period t return on the nth asset class—often called nth *style benchmark index*—and the portfolio weights $b_{p,n}$ are constrained to be positive and add up to unity. When applying return-based style analysis to hedge funds in Section 5, we will eliminate constraint (2b) and allow the manager to take short positions.[4]

Inserting the optimal weights $b_{p,n}$ in Eq. (2a) and rearranging, we can express the excess return of the portfolio over the style benchmark as

$$e_{p,t} = r_{p,t} - [b_{p,1}x_{1,t} + b_{p,2}x_{2,t} + \cdots + b_{p,N}x_{N,t}] \quad (3)$$

The component $[b_{p,1}x_{1,t} + b_{p,2}x_{2,t} + \cdots + b_{p,N}x_{N,t}]$ is that part of the return, $r_{p,t}$, that is due to the manager's effective style, also referred to as the *style benchmark return*. The difference between the return and the manager's effective style, $e_{p,t}$, given on the left-hand side is referred to as the selection component of the manager's return. The standard

deviation of the selection component is the *style benchmark tracking error* of the fund.[5]

2.2 Role of adjusted R^2 measure in choosing style weights

Return-based style analysis estimates the weights for the N given style benchmarks by minimizing the variance of the tracking error, subject to the constraints (2b) and (2c). Let R^2, a measure of the goodness-of-fit, be given by

$$R^2 = 1 - \frac{\text{var}(e_p)}{\text{var}(r_p)} \tag{4a}$$

R^2 equals 1 minus the ratio of the variance of the tracking error to the variance of the return on the managed portfolio. Note that the statistic will equal 1 if the model fits perfectly, that is, there is no tracking error. Then, minimizing the variance of the tracking error is the same as maximizing the R^2 measure given in Eq. (4a).[6]

Typically, one would let the data determine the appropriate number and type of style benchmarks to use in a particular application. Increasing the number of style benchmarks will reduce the tracking error in any given sample. However, the style coefficients will be estimated with less precision reducing the confidence one can have on the estimates. One way to take this effect into account would be to adjust the measured R^2 downward by a penalty that increases with the number of style benchmarks used. The commonly used *adjusted* R^2 measure of the goodness-of-fit is given by

$$\text{Adjusted } R^2 = 1 - \left(\frac{T-1}{T-N}\right) \times \frac{\text{var}(e_p)}{\text{var}(r_p)} \tag{4b}$$

where N is the number of asset classes and T the number of observations. $\text{Var}(e_p)$ is the variance of excess returns of the fund over the style benchmark.

2.3 An alternative: the Akaike information criterion

An alternative to choosing style weights that maximize adjusted R^2 would be to choose style weights that minimize the *Akaike information criterion* (AIC), especially in situations where the number of asset classes is large.[7] The AIC is given below:

$$\text{AIC} = T \times \log\left[\frac{\text{var}(e_p)}{T}\right] + 2N. \tag{4c}$$

For every subset of the N asset classes the value of the above criterion is calculated. The subset that produces the smallest information criterion is selected. The use of the AIC is obviously computationally more complex but can eliminate asset classes that do not contribute much to the fit of the model. The AIC penalizes additional variables more heavily than the adjusted R^2 measure. Our default criterion is R^2 and whenever the adjusted R^2 or AIC is used it is indicated in the text.

2.4 The effective style of a multi-manager portfolio

An attractive property of return-based style analysis is the straightforward extension from a single manager to a multi-manager portfolio as shown by Sharpe (1988). Consider the example of a plan sponsor who allocates the available funds across several money managers. Denote by w_p the proportion of money allocated to manager p. In total, there are $p = 1, 2, \ldots, P$ portfolio managers and R_t is the plan sponsor's overall portfolio return. The aggregation involves two steps. First, identify the style of each manager separately. Second, sum up the exposures of all managers for each asset class, weighted by the fraction of money allocated to each manager. Formally, the *effective mix* of the overall portfolio is

described by

$$R_t = \sum_{p=1}^{P} w_p r_{p,t}$$
$$= \left[\sum_p w_p b_{p,1}\right] x_{1,t} + \left[\sum_p w_p b_{p,2}\right] x_{2,t} + \cdots$$
$$+ \left[\sum_p w_p b_{p,N}\right] x_{N,t} + \left[\sum_p w_p e_{p,t}\right] \quad (5)$$

The brackets are the money-weighted exposures to the asset classes. Consider the first asset class with returns $x_{1,t}$. Each portfolio manager p has an exposure of $b_{p,1}$ to asset class 1. Manager p has a weight w_p in the overall portfolio. The summation over all managers measures the exposure of the plan sponsor to the first asset class.

3 Return-based style analysis in practice

3.1 Data and asset class specifications

For illustrating the use of return-based style analysis in practice, we use monthly return data for open-end mutual funds (net-of-fee) from the Morningstar database along with the StyleAdvisor® software of Zephyr Associates Inc.[8]

We follow standard practice and use the 3-month Treasury bills as the cash equivalent.[9] Intermediate- (maturities between 1 and 10 years) and long-term Treasury bonds (with maturities beyond 10 years) are represented using two Salomon Brothers Treasury indexes: SSB Treasury 1–10 yr and SSB Treasury 10+ yr. Level shifts and twists in the shape of the term structure affect longer maturities differently. The SSB Corporate Bond index serves as the benchmark for US corporate bonds. It captures the dynamics of credit spreads over Treasury bonds that compensate investors for incurring default risk.

We use returns on the Russell 3000 index, produced by the Frank Russell Company, to measure the performance of publicly traded common stocks incorporated in the US and its territories. The index includes the 3000 largest US companies (based on market capitalization) and represents approximately 98% of the publicly traded US equity. The Russell 3000 constituents are ranked annually and split into two subsets. The largest 1000 stocks constitute the Russell 1000 index and the remaining companies comprise the Russell 2000 index. The companies in each index are further assigned to value and growth subindexes. Russell uses a combination of the price-to-book ratio and the consensus forecast for the long-term growth from I/B/E/S (Institutional Brokers Estimate System) to classify the stocks into value and growth. Stocks with high price-to-book or price-to-earnings ratios are classified as growth stocks since a high P/E ratio indicates high expected rates of earnings growth in the future, whereas stocks with low price-to-book or price-to-earnings ratios define value stocks.

The value and growth part of the different indexes typically earn different returns over time and appear to respond differently to economy-wide, pervasive shocks. The interested reader is referred to Siegel (1998) who provides an in-depth discussion of the distribution of value and growth stocks among different index aggregates and reviews the performance patterns in the past; and Dimson *et al.* (2002) who extend the analysis of historic returns to the last 101 years for 16 countries. The four Russell 3000 subindexes seem to fulfill Sharpe's (1988, 1992a) desirable properties: (i) market-capitalized, (ii) exhaustive, (iii) mutually exclusive,[10] and (iv) replicable. They also represent the typical four quadrants used to visualize the style of a domestic equity manager in a style box.

To cover the performance of foreign investments we include three global equity Morgan Stanley Composite Indexes (MSCI). The MSCI EASEA index

represents Europe, Australasia, and the Far East, excluding Japan. For Japan, the MCSI country index is added separately. The MSCI Emerging Markets Free (EMF) proxies for equity investments in emerging countries—currently (April 2002) 27 countries are covered. The add-on "Free" indicates that the index accounts for country-specific restrictions on share ownership by foreigners. The Lehman non-US bond index is designed to measure the performance of fixed-income investments outside the US. Appendix A provides a detailed description of the selected indexes.

3.2 An example: Vanguard Windsor

We use monthly return data on the Vanguard Windsor fund (ticker VWNDX) for the period January 1988 to December 2001 to illustrate the application of return-based style analysis. Morningstar classifies the fund as a large-cap value fund. In the annual report of October 2001, Vanguard declares the Russell 1000 Value index as the "best fit" for the Windsor fund. In the investment objective, they position themselves as a value fund that primarily "invests in large- and mid-capitalization common stocks [. . .]".

The *style box* in Figure 1 provides a first snapshot of the nature of Windsor's investment style.[11] StyleAdvisor uses by default four quadrants to classify an investor along the two dimensions value/growth and small-cap/large-cap.[12] The four Russell 3000 subindexes form the *style basis*. They span the range of the axis coordinates from −1 to 1 and mark the midpoints of the quadrants. Table 1 illustrates the calculations to determine the position of Vanguard Windsor within the style box. The four cells in the center contain the exposures from return-based style analysis. Then, sum up the exposures for each of the two columns (value and growth) and rows (large and small) and weight by the coordinate value of the four groups (+1 or −1). The resulting position is shown in the lower right cell: value/growth = −0.972 and size = 0.652. The style box indeed classifies the fund as a mostly large-cap value fund.

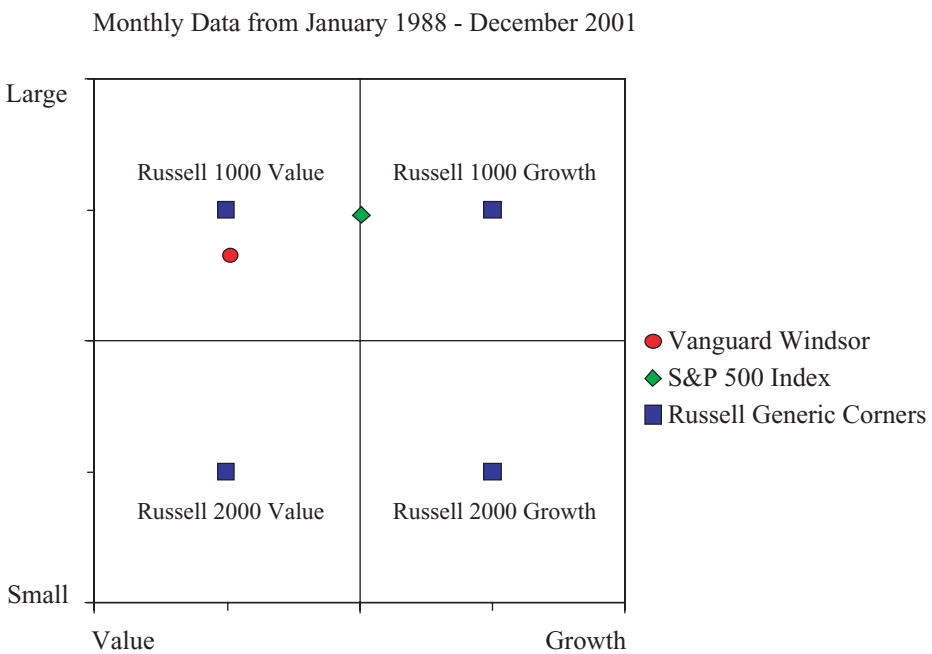

Figure 1 Vanguard Windsor style box.

Table 1 Style box for Vanguard Windsor

Generic Corners	Coordinates	Value −1	Growth +1	Sum
Large	+1	0.812	0.000	0.812
Small	−1	0.160	0.000	−0.160
	Sum	−0.972	0.000	−0.972/0.652

The exposures are from the return-based style analysis results in Figure 2. The rows and columns labeled 'Sum' take the sum weighted by the coordinate (+1 or −1). The lower right cell displays the position in the style box.

The results of return-based style analysis in Figure 2 provide more details. A passive portfolio with 81.2% invested in the Russell 1000 Value and 16.0% invested in the Russell 2000 Value—plus a fraction of 2.8% in MSCI Emerging Markets—characterizes the style of Windsor best over the given period. The small exposure to the MSCI Emerging Market index may pick up some of the deviations due to different weighting of stocks when compared to the Russell 1000 Value and Russell 2000 Value subindexes, stock picking, or changing style over time. We will address changing styles later in Section 4.5. The 12 asset classes explain 85.6% of the monthly returns of Windsor as measured by the R^2 and depicted in the pie chart in Figure 3. Excluding the last four indexes that are not relevant for a US domestic equity fund, the weights are 82.1% for the Russell 1000 Value and 17.9% for the Russell 2000 Value index. The explanatory power remains approximately the same with $R^2 = 85.5\%$. Alternatively, we could use the full set of twelve assets and minimize the AIC criterion instead of R^2. As a result of the imposed penalty for additional parameters, the optimization assigns a zero exposure to the MSCI Emerging Markets index and the exposures to the two Russell value indexes are exactly the same as if we exclude the indexes measuring exposure to foreign investments.

Using the S&P 500, a commonly used benchmark for large-cap funds, instead of the style benchmark explains only 65.9% of the variation in returns of Vanguard Windsor. Return-based style analysis

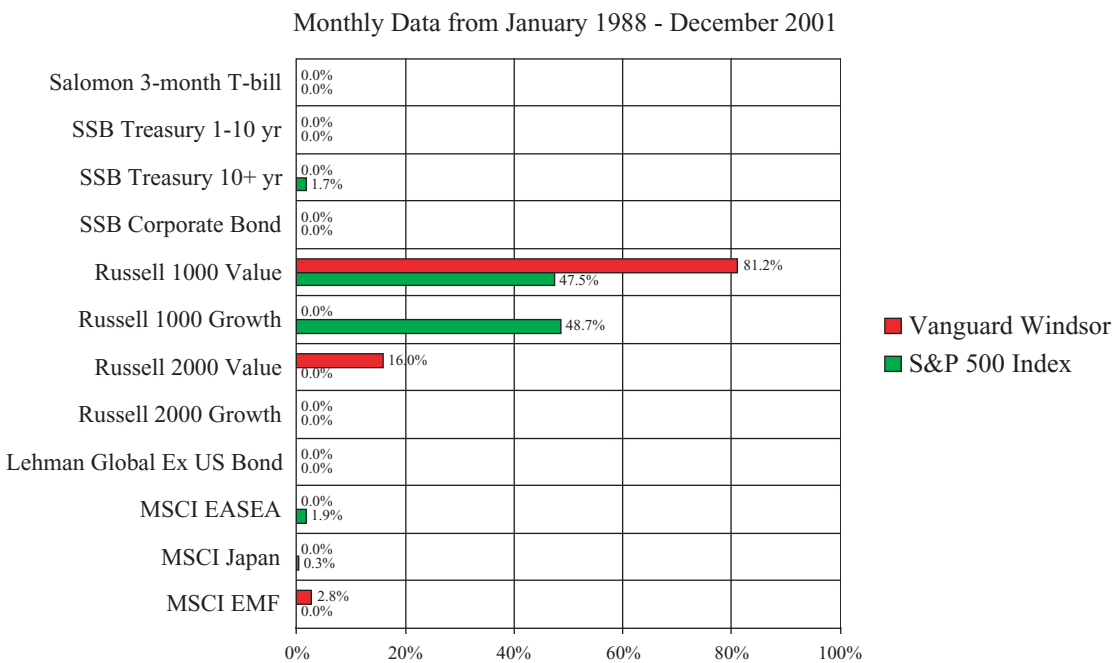

Figure 2 Return-based style analysis for Vanguard Windsor.

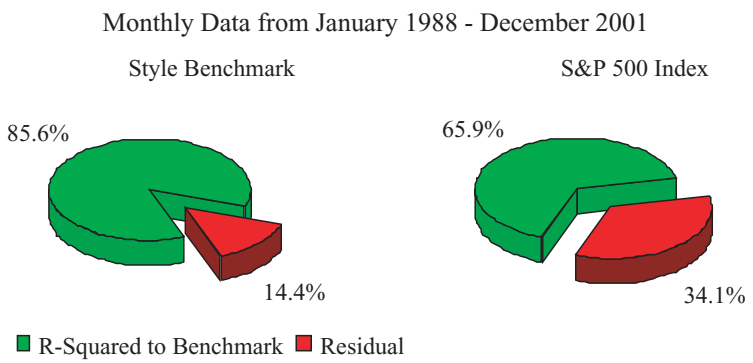

Figure 3 Performance attribution for Vanguard Windsor.

conveys additional information on the typical asset-mix of the fund. The effective style of the S&P 500 benchmark is substantially different from that of Vanguard Windsor. A style benchmark with 47.5% in the Russell 1000 Value, 48.7% in the Russell 1000 Growth, with the balance split between MSCI EASEA, SSB Treasury 10+ yr and MSCI Japan, explains 99.1% of the return variance in the S&P 500. In terms of effective style, Vanguard Windsor is mostly a large-cap value fund whereas the S&P 500 gives equal weighting to large-cap value and growth. The low R^2 in the return-based style analysis for Vanguard Windsor, when compared to the S&P 500, suggests substantial active management.

3.3 Performance analysis

Next, we analyze potential *style changes* over time following Sharpe (1992a). As discussed above, we apply the methodology to monthly returns on the Vanguard Windsor fund from January 1988 to December 2001. For each month, we use the past 60 monthly returns to determine the style. Thus, the first calculation uses data from January 1988 to December 1992 to assess the style on December 1992. The 60-month window is then moved forward by 1 month and the style is recalculated.

The dynamics of the changes in style for Vanguard Windsor are portrayed in Figure 4. Each shaded area represents the percentage contribution of the asset class to the style. At the start of 1994, the exposure to the Russell 2000 Value reached almost 40%, the remaining 60% were attributed to the Russell 1000 Value. The exposure to the small-cap value index was gradually substituted until 1997. During the period from 1998 to 2000, the fund developed some exposure (up to 11.3% in October 1998) to the Russell 2000 Growth. From October 1997 onwards, the fund began investing a substantial amount (3–12%) in securities whose returns can be best described by the MSCI EMF index.

Given the changes in style over time, the question arises how to assess the performance of the fund. We apply the following out-of-sample performance procedure. As described above, we calculate the style of the fund each month. To evaluate the performance in month t, we use the style benchmark calculated using data from $t - 60$ to $t - 1$. We then compare the return the style benchmark would have yielded during month t and compare it to the actual return of the fund. The difference is the performance of the fund due to selection.

Figure 5 depicts the return differences between Vanguard Windsor and two benchmarks: the S&P 500 and the style benchmark. Each data point describes the return difference between the fund and the benchmark over the past 60 months. The graph reveals that Vanguard outperformed the S&P 500

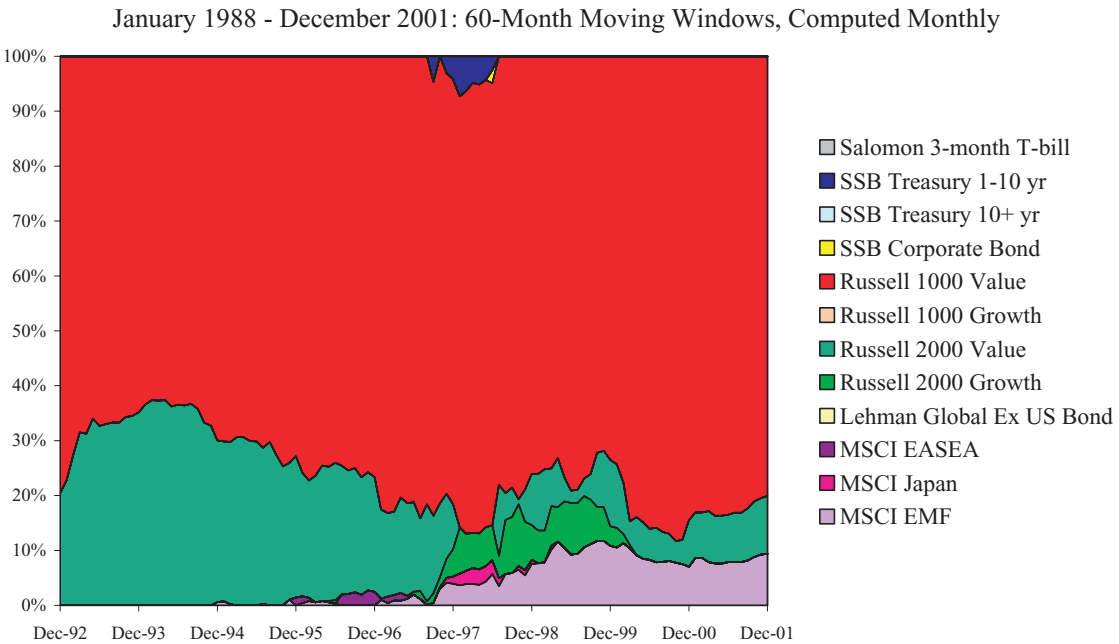

Figure 4 Style changes of Vanguard Windsor.

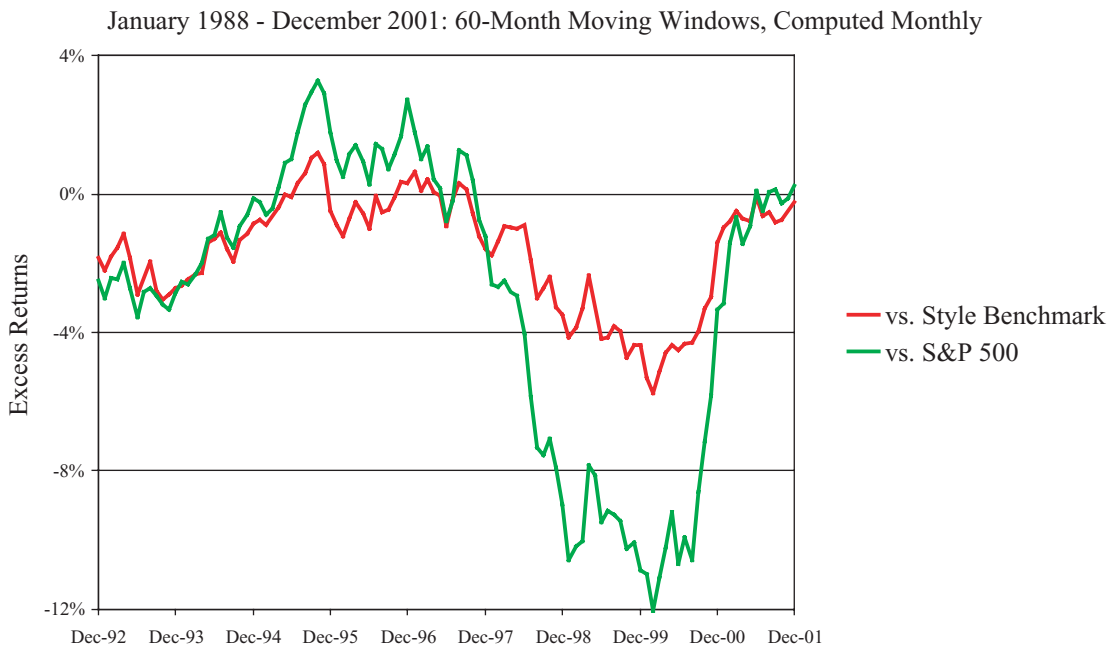

Figure 5 Vanguard Windsor versus style and market benchmark.

initially. During the late 1990s, the performance was less favorable, with a dip of −12.0% in early 2000. If we use the style benchmark instead, the deviations are less pronounced in both directions, confirming that the fund more closely tracks the style benchmark than the S&P 500. The performance of the fund relative to the style benchmark looks worse than when compared to the S&P

500. The annualized average excess return of the fund is −0.64% against the style benchmark and −0.49% against the S&P 500. The cumulative excess return over the 9 years is −50.14% and −38.06%, respectively.

3.4 Growth and income funds

In this section, we demonstrate how return-based style analysis reveals incremental information beyond the fund's self-stated classification and investment policy as described in the prospectus.[13] We compare the style of four domestic funds with an identical name (growth and income): The Alliance Growth & Income (ticker CABDX), Goldman Sachs Growth and Income Fund (GSGRX), Putnam Fund for Growth and Income (PGRWX), and the Vanguard Growth and Income Fund (VQNPX).[14] In the prospectus, all funds declare that they aim to seek long-term growth of capital and income by picking currently undervalued stocks as their target. The funds focus on common stocks of established companies with the potential for growth and that are expected to pay dividends—the income component. They use a bottom–up approach and fundamentals to determine undervalued companies and do not take any sector or market timing bets. Appendix B summarizes the funds' objectives, size, and fee structure based on the prospectuses as of December 2001. Based on this information, it is a difficult task for the investor to perceive stylistic differences. Morningstar classifies the funds as large-cap value funds, with the exception of Vanguard that is considered to be a blend of large-cap value and growth stocks.

Alliance Capital annotates that their Growth and Income fund selects "stocks of good quality" and "may also invest in fixed-income and convertible securities". The style analysis in Figure 6 shows that the fund primarily invests in large-cap value stocks (76.8% Russell 1000 Value) but has also a considerable exposure of 17.5% to large-cap growth stocks (Russell 1000 Growth). There is no evidence that the fund actually holds a position in fixed-income

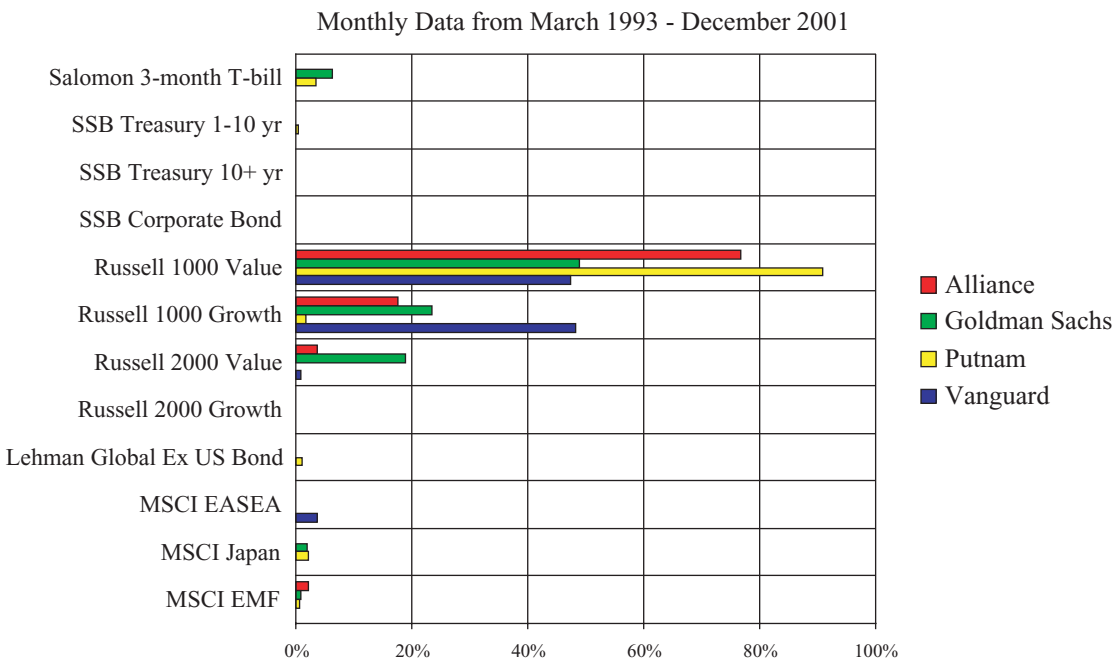

Figure 6 Growth and income funds.

or convertible securities that would also manifest in positive weights for fixed-income asset classes.

For the Goldman Sachs Growth and Income Fund, 6.3% is attributed to short-term T-bills. This complies with the statement in the prospectus that "the fund may also invest up to 35% of its total assets in fixed-income securities". Their self-declared investment style is value, which is only partially confirmed by the style analysis with a total exposure to large and small-cap value stocks of 67.6% (48.8% Russell 1000 Value and 18.8% Russell 2000 Value). The fund faces a substantial exposure of 23.4% to the Russell 1000 Growth index. According to the prospectus, Goldman Sachs may invest up to 25% in foreign markets. Style analysis indicates that the total allocation to foreign assets is only 2.7% (1.8% MSCI Japan and 0.9% MSCI EMF).

The Putnam fund invests mainly in common stock of large US companies with a "focus on value stocks". This is confirmed by Figure 6. As the classification of Morningstar suggests, the Vanguard fund provides a blend of large value and growth stocks. The exposure of 95.6% to the two Russell 1000 indexes shows that the fund likely exceeds the lower bound of 65% invested in S&P 500 stocks as declared in the prospectus. Activity in the fixed-income segment that would be allowed to a limited extent cannot be detected.

Despite similar objectives, the strategy implementations differ substantially. Fund names together with the prospectus do not necessarily deliver a concise description of the investment style. The literature has addressed the problem of misclassification. During the period from 1972 to 1992, Brown and Goetzmann (1997) found 237 funds that switched their fund objective. They propose a classification algorithm that identifies funds that are either strategically or unintentionally assigned to an incorrect category. Using a different methodology, DiBartolomeo and Witkowski (1997) conclude that 9% of the 748 equity funds in their study are seriously misclassified and 31% somewhat misclassified; mostly funds within the categories small-cap and aggressive growth. They show that their reclassification is robust out-of-sample. From the switches in the Morningstar classification, Indro *et al.* (1998) infer that 57% of the 770 actively managed funds changed their investment orientation (value/growth/blend, large-/medium-/small-cap) over the 3-year period 1993–1995.

Kim *et al.* (2002) add fund characteristics similar to the ones outlined in portfolio-composition-based style analysis (see Section 3.6) to past returns and screen a sample of 1043 funds from December 1993 to December 1996. They find that more than half are not consistent with their self-declared objective and "over 33% of the funds depart severely from their stated objectives". Deviations occur most frequently in the categories income, growth, or growth and income—the category we used as an example. The empirical evidence in Michaud (1998) indicates that even categorizing stocks into value and growth using the price-to-book ratio may be problematic. He demonstrates that at least three distinct factors are required to identify value stocks, that is, the value style attribute itself is multidimensional.

3.5 Active versus passive portfolio management

The difference $(1 - R^2)$ is often used as a measure of the degree of active management of a fund. A passively managed fund performs no research and fundamental analysis and tracks a benchmark trying to keep transaction costs low and consequently has a high R^2. Depending on the composition of the benchmark, the passive manager thus provides a portfolio with a particular style.

Active management of mutual funds can take different forms: a manager can (i) hold different securities

within each asset class, or even outside any asset class, and (ii) deviate from the asset class weights for the style benchmark from time to time, depending on market conditions. The style is then no longer able to mimic the returns of the fund and the excess returns—whether positive or negative—become larger in conjunction with a lower R^2 statistic. If the deviations are the result of (i), these excess returns are called the *selection* component of the fund's return; (ii) is referred to as *timing*. The selection component can result from, for example, industry concentration, stock picking, or a different degree of diversification due to a limited number of assets.

The numbers for R^2 in Figure 7 indicate that Goldman Sachs employed the most active management strategy, whereas Putnam and Vanguard more closely tracked a passive asset mix.[15] This conclusion is consistent with the funds' fee structure (Appendix B). The *expense ratio* expresses the operating costs that are periodically deducted from the fund's assets as a percentage of total assets under management. Active management may explain the relatively high expense ratio of 1.19% for the Goldman Sachs Growth and Income fund when compared to the 0.38% of Vanguard.[16] With the exception of Vanguard, the other three funds charge a commission or sales charge, called front(-end) load, which is paid when the shares are purchased (4.25%–5.75%).[17]

3.6 Comparison with portfolio-composition-based style analysis

Instead of relying exclusively on past returns, portfolio-composition-based style analysis builds the characteristics of the managed portfolio from knowledge of the characteristics of individual securities that make up the portfolio. The following characteristics are typically used for stocks: market capitalization, book-to-market ratio, historic earnings growth rate, dividend yield, and industry or economic sector to which the stock belongs. Duration and credit rating are some of the commonly used characteristics for fixed-income securities. Aggregating the information explains the typical average characteristics of the portfolio. The return on the managed fund can be analyzed by examining how the manager deviated from the performance benchmark.

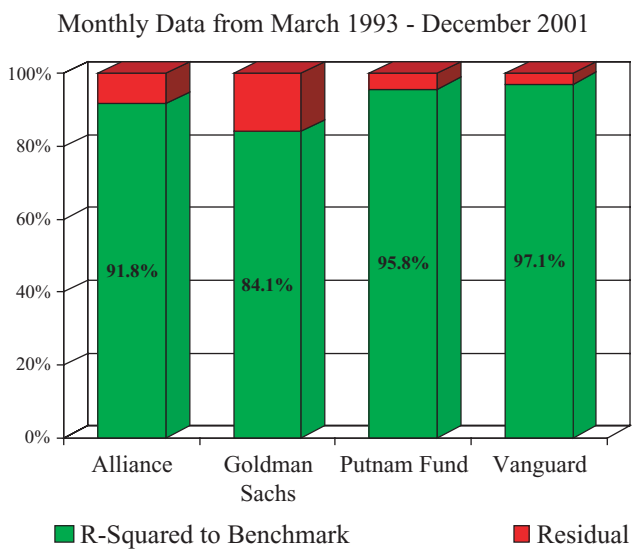

Figure 7 Performance attribution.

In what follows, we consider the Goldman Sachs Growth and Income Fund in order to illustrate the use of portfolio-composition-based style analysis. The reader who is interested in more examples is referred to the BARRA fundamental analysis for the AT&T Pension fund that is described in Sharpe (1992b).

Table 2 (Panel A) contains the characteristics of the fund when compared with the S&P 500. The fund holds 95 stocks with a median market capitalization of $27.8 billion, which is roughly half of the median market capitalization of the S&P 500. The price-to-earnings and price/cash flow ratios are lower than these for the S&P 500. The price-to-book ratio is higher as one would expect. This confirms the conclusion reached from return-based style analysis and the Morningstar classification that the Goldman Sachs Growth and Income Fund resembles a value/growth blend. Consistent with an income fund, the long-term earnings are higher than for the S&P 500. The fund is a pure equity fund with no bond holdings and a minor cash position. The results of return-based style analysis found a moderate exposure to foreign equity, which is confirmed by the portfolio weight for foreign holdings of 4.9% at the end of January 2002. Panel B of Table 2 shows the sector breakdown and Panel C the top 10 holdings. When compared to the S&P 500, the fund's weights are tilted towards financials and services and away from retail, technology, and health.

A limitation of return-based style analysis is that the style we calculate represents an average of the styles employed by the fund in the past. While portfolio-composition-based analysis has the advantage that it provides an estimate of the style going forward, it requires information that may be difficult to gather. Whereas asset class returns are easily available on a daily basis, updates of fundamentals may be delayed. Another advantage of return-based style analysis is that the conclusions are less sensitive to window dressing and, hence, less subject to manipulations by managers. In some situations, it is advisable to use a combination of the two methods.

4 Choosing style benchmarks

In this section, we discuss the importance of choosing the right style benchmark asset classes as well as some common pitfalls one should be aware of while implementing return-based style analysis in practice. An appropriate choice of the asset classes is important to obtain an informative style description, map a broad spectrum of portfolios, and draw correct conclusions about the degree of active management. We find that certain sector funds, like utilities, require the addition of sector indexes to the basic asset classes. Using Fidelity Magellan as an example, we illustrate how to interpret the results for an actively managed fund and compare the information content to peer evaluation.

4.1 Asset class misspecification

In this section, we demonstrate that an inadequate choice of indexes to represent asset classes can seriously distort the outcome of return-based style analysis. Buetow and Ratner (2000) combine the S&P 500 Barra Value and Growth with the Russell 2000 Value and Growth indexes to span the US equity universe. In one example, they apply return-based style analysis to the Vanguard Strategic Equity Fund and find that the results are inconsistent with the investment objectives and fundamentals of the fund. Atkinson *et al.* (2001) point out that by using these stock indexes the authors omit approximately 500 mid-cap companies—the ones accounted for by the Russell 1000 but not the S&P 500. They demonstrate that when the four Russell 3000 subindexes are used (and the adjusted R^2 as the optimization criterion), the outcome of the style analysis accurately matches the stated investment objectives of the fund.

Table 2 Portfolio-composition-based style analysis: Goldman Sachs Growth and Income Fund (GSGRX)

A: Fundamentals

	GSGRX	S&P 500
Number of stocks	95	500
Median market capitalization (billions)	$27.8	$58.0
Price/earnings ratio	25.1	30.3
Price/book ratio	4.2	3.7
Price/cash flow	13.2	18.9
Long-term earnings	16.2%	14.2%
Cash investments	0.1%	—
Bond holdings	0.0%	—
Foreign holdings	4.9%	—
Turnover ratio (fiscal year)	40.0%	—

B: Industry weightings

Sector breakdown (% of common stock)	GSGRX	S&P 500	Difference
Financials	36.2	17.8	18.4
Staples	11.0	8.9	2.1
Services	10.8	4.9	5.9
Industrials	10.4	11.0	–0.6
Energy	10.0	6.4	3.6
Technology	7.3	16.8	–9.5
Utilities	6.4	2.9	3.5
Health	6.3	14.9	–8.6
Retail	1.0	13.6	–12.6

C: Top 10 holdings

	Name	Sector	% Net assets	P/E	YTD return %
1	Exxon Mobil	Energy	3.35	17.64	–0.19
2	Citigroup	Financials	3.32	16.00	–13.50
3	Chevron Texaco	Energy	2.87	26.54	–8.00
4	Bank of America	Financials	2.70	12.36	–2.81
5	ConAgra	Staples	2.46	18.71	–0.66
6	Merck	Health	2.43	19.51	4.18
7	Philip Morris	Staples	2.26	13.43	13.35
8	Freddie Mac	Financials	2.18	11.18	–3.44
9	Heinz HJ	Staples	2.08	28.99	1.53
10	XL Capital	Financials	2.05	23.48	3.04

Informations based on the Morningstar website as of January 31, 2002.

While increasing the number of asset classes, it is important to keep in mind that some of the asset classes may be redundant. It may be possible to approximate the return on an asset class by the return on a portfolio of the other asset classes with sufficient degree of accuracy. Ignoring this introduces what is commonly known as multicollinearity among asset classes. The correlation pattern among

our 12 asset classes is shown in Table 3. The three longer-term bond indexes, the SSB Treasury 1–10 yr, SSB Treasury 10+ yr and the SSB Corporate Bond index, exhibit the highest cross-correlations. Within each of the two size subindexes—the Russell 1000 and Russell 2000—the value and growth indexes have correlation coefficients of 0.72 and 0.80, respectively. The value and growth indexes are also correlated across the size classes, namely 0.72 between the Russell 1000 Value and Russell 2000 Value and 0.78 for the growth subindexes. If asset classes are highly correlated, the optimization algorithm will have difficulty in finding the loadings for the asset classes. Attributions may oscillate over time between two highly correlated asset classes and make the exposures uninformative and interpretations difficult. One way to guard against this would be to leave out asset classes when including them does not lead to a significant increase in the adjusted R^2 or a significant decrease in the AIC. We discuss the "number of asset classes" further in Section 4.2.

It is also necessary to exercise caution while constructing style benchmark asset class portfolios by subdividing major stock indexes. The collection of assets representing an asset class can critically depend on the order in which major indexes are subdivided and grouped. The following stylized example provides an illustration. Assume the universe of securities consists of four stocks with the following size ($ billions) and P/E ratios—A: with size 40 and P/E ratio 10, B: 30/15, C: 20/20, and D: 10/25. The broad stock market index consists of the four stocks with weights equal to their relative

Table 3 Correlations

	Salomon 3-month T-bill	SSB Treasury 1—10 yr	SSB Treasury 10+ yr	SSB Corporate Bond	Russell 1000 Value	Russell 1000 Growth	Russell 2000 Value	Russell 2000 Growth	Lehman Global Ex US Bond	MSCI EASEA	MSCI Japan
Salomon 3-month T-bill	1.00										
SSB Treasury 1—10 yr	0.19	1.00									
SSB Treasury 10+ yr	0.11	0.90	1.00								
SSB Corporate Bond	0.13	0.91	0.91	1.00							
Russell 1000 Value	0.02	0.24	0.28	0.40	1.00						
Russell 1000 Growth	0.04	0.16	0.20	0.32	0.72	1.00					
Russell 2000 Value	−0.08	0.08	0.15	0.29	0.72	0.60	1.00				
Russell 2000 Growth	−0.04	−0.02	0.04	0.18	0.53	0.78	0.80	1.00			
Lehman Global Ex US Bond	0.01	0.36	0.25	0.24	0.04	0.07	−0.08	−0.02	1.00		
MSCI EASEA	0.02	0.11	0.12	0.21	0.58	0.65	0.50	0.55	0.40	1.00	
MSCI Japan	−0.07	0.07	0.04	0.08	0.29	0.37	0.20	0.31	0.41	0.52	1.00
MSCI EMF	−0.01	−0.09	20.10	0.08	0.49	0.55	0.55	0.60	0.00	0.56	0.37

The correlation matrix is based on monthly returns from January 1988 to December 2001. The 12 asset classes are described in Appendix A.

market capitalization. The total market capitalization is 100, the median market capitalization 25, and the P/E ratio 15.[18] Consider subdividing this index into value and growth. The value index will consist of A and B with a median capitalization of 35 and a P/E ratio of 12.1.[19] The characteristics of the growth index are 15/21.7. When we first divide the universe of the four securities into large and small stocks, we get the following characteristics: large (A and B) 35/12.1 and small (C and D) 15/21.7. The value and growth subindexes then have the following characteristics: large/value (consisting only of stock A) 40/10, large/growth (B) 30/15, small/value (C) 20/20, and small/growth (D) 10/25; that is, the P/E ratio of small/value is bigger compared to the large/growth subindex. Of course, this is an extremely simplified example. However, it illustrates that if value and growth stocks are not evenly distributed among size classes, subdividing an index may categorize a stock in a different style class.[20]

Specific sectors are dominated either by value or growth stocks. Typical value stock sectors are financials, energy, and, as we will see in Section 4.3, most utilities. Growth stocks are more widespread in high-tech industries like drugs, telecommunications, and computers. Siegel (1998) shows that at the end of 1996 the S&P 500 growth stocks outnumber value stocks, eight out of the largest 10 companies fall in the category growth, and the average market capitalization of value stocks is smaller.

Thus, it matters what universe is considered and what criteria are used to define the constituents of value and growth subindexes. Standard & Poor's divides the market capitalization of the S&P 500 equally into S&P 500/Barra Value and S&P 500/Barra Growth. After the rebalancing on November 6, 2002, the S&P 500/Barra Value covers approximately twice as many companies as the S&P 500/Barra Growth, more precisely 336 versus 164.[21] The style subindexes of the Russell 1000 and Russell 2000 are also subdivided such that approximately 50% of the market capitalization is assigned to value and 50% to growth. The breakpoints for the Russell 1000 in 2001 are a price-to-book ratio of 0.192 and the I/B/E/S long-term growth forecast of 14.4%. For the Russell 2000 both breakpoints are substantially higher, namely 0.418 and 18.0%.[22]

4.2 Number of asset classes

Our 12 asset classes include two size classes, large-cap and small-cap stocks, and a subdivision into value and growth.[23] Since 1997, Morningstar maps a fund in a style box by assigning stocks to one of three size classes and to one of three value/growth categories (value, growth, and a blend between value and growth).[24] The MSCI Emerging Market index could be further subdivided into Africa, Asia, Eastern Europe, and Latin America. An international investor who is seriously exposed to currency risk may consider adding currencies as additional asset classes.

While a larger number of assets automatically increases the explanatory power of the style benchmark, measured by R^2, it also introduces noise. An extensive set of asset classes contains more likely highly correlated asset classes and the optimization procedure may have difficulty to attribute exposures to asset classes. Even though the in-sample tracking improves, the interpretation of the results may become more difficult and the parameters less robust.

In some instances, an asset class that does not explicitly appear in the model can be closely represented by a combination of other asset classes. For example, Sharpe (1992a) pointed out that no additional, distinct asset class is needed when applying return-based style analysis to a fund with the focus on convertible securities. Convertible securities are

most often bonds that entitle the holder to exchange each bond for a number of shares of common stock. For valuation, a convertible bond can be separated into a straight bond and call options. A call option, on the other hand, is a derivative security and can be replicated by dynamically rebalancing a portfolio of riskfree assets and stocks. When the share price of common stock is relatively low (high), the value of the call option is low (high) and the convertible bond behaves more like a straight bond (stock).

We use the Fidelity Convertible Securities Fund (FCVSX) for illustrative purposes. The Fidelity Convertible Fund "normally invests at least 80% of assets in convertible securities, which are often lower-quality debt securities [. . .]". The issuers may be domestic or foreign.[25] The style analysis captures a large fraction of the monthly variation in the fund's returns, namely $R^2 = 86.9\%$. The most pervasive factors are domestic fixed-income securities, domestic growth stocks, and, to a smaller extent, foreign equity (Figure 8). The large attribution to the Russell 2000 Growth index may reflect the strategy to buy lower-quality debt securities that are typically bonds of smaller companies. Most remarkably, the fund is characterized as a combination of fixed-income and stock exposure.

4.3 Sector indexes

The Putnam Utilities Growth and Income Fund (ticker PUGIX) defines utilities as companies that "[. . .] derive at least 50% of their assets, revenues or profits from producing or distributing electric, gas, or other types of energy, supplying water, or providing telecommunications services such as telephone, microwave or other media (but not public broadcasting)".[26]

The column labeled "Basic model" in Panel B of Table 4 reports the results of return-based style analysis when using our 12 standard asset classes. The fact that the fund primarily invests in large

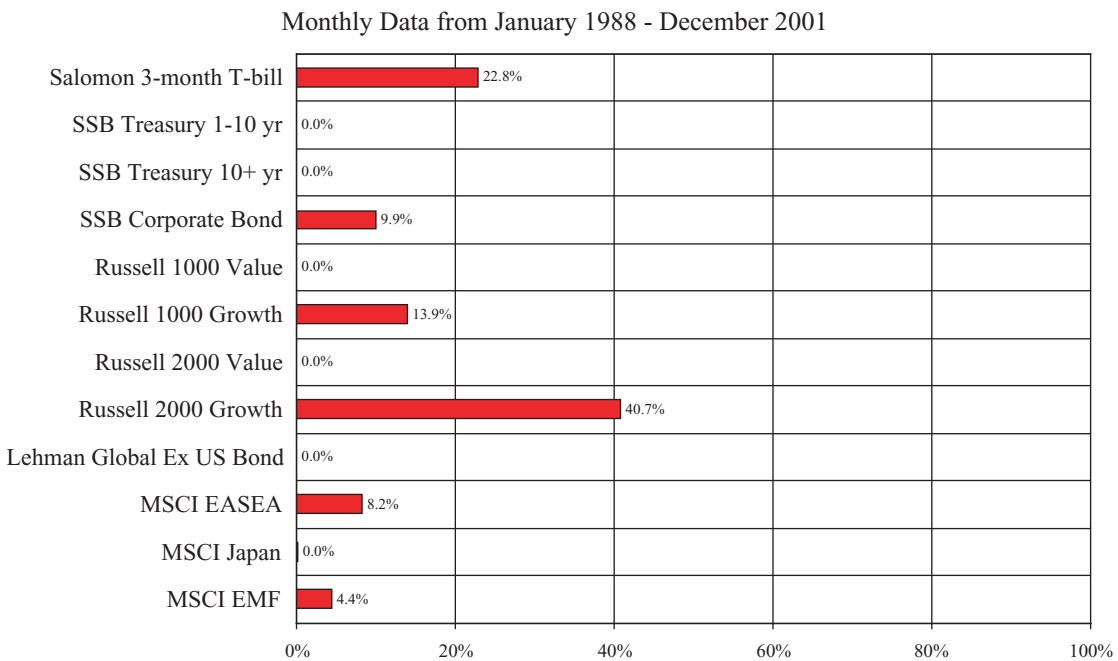

Figure 8 Fidelity Convertible Securities.

Table 4 Putnam Utilities Growth and Income Fund

A: Correlations

Asset class	Dow US Energy	Dow US Telecoms	Dow US Utilities
Salomon 3-month T-bill	−0.03	−0.08	0.06
SSB Treasury 1—10 yr	0.14	0.12	0.20
SSB Treasury 10+ yr	0.12	0.10	0.29
SSB Corporate Bond	0.19	0.20	0.24
Russell 1000 Value	0.53	0.47	0.38
Russell 1000 Growth	0.32	0.50	0.07
Russell 2000 Value	0.36	0.20	0.22
Russell 2000 Growth	0.29	0.30	0.01
Lehman Global Ex US Bond Index	0.18	0.06	0.03
MCSI EASEA	0.35	0.28	0.10
MSCI Japan	0.25	0.20	−0.06
MSCI EMF	0.29	0.22	−0.02
Dow United States Energy	1.00	0.17	0.49
Dow United States Telecommunications	0.17	1.00	0.10
Dow United States Utilities	0.49	0.10	1.00

B: Return-based style analysis

Asset class	Basic model		Extended model	
Optimization criterion	R^2 (%)	AIC (%)	R^2 (%)	AIC (%)
Salomon 3-month T-bill	4.0	—	4.7	—
SSB Treasury 1—10 yr	7.4	—	—	—
SSB Treasury 10+ yr	20.7	26.4	—	—
SSB Corporate Bond	—	—	—	—
Russell 1000 Value	56.5	57.9	14.1	14.6
Russell 1000 Growth	—	—	—	—
Russell 2000 Value	—	—	3.2	4.0
Russell 2000 Growth	—	—	—	—
Lehman Global Ex US Bond	11.4	15.7	10.8	14.0
MCSI EASEA	—	—	—	—
MSCI Japan	—	—	—	—
MSCI EMF	—	—	—	—
Dow United States Energy			6.1	5.5
Dow United States Telecommunications			16.9	17.0
Dow United States Utilities			44.2	44.8
R^2	60.4		92.4	
Adjusted R^2	56.4	59.5	91.4	92.0

Panel A of the table shows the correlations between the three Dow Jones sector indexes and the original 12 asset classes, plus the cross–correlations in the last three rows. Panel B contains the results of return-based style analysis with the basic 12 asset classes (Basic model) and when the three sector indexes are included (Extended model). Each version is estimated using the two optimization criteria standard R^2 and the Akaike information criterion (AIC). The data is monthly from January 1992 to December 2001.

companies is reflected by the large attribution to the Russell 1000 Value index. At first sight, the large exposure to Treasury bonds and the zero exposure to domestic corporate bonds might be surprising. However, many utility companies still operate in highly regulated markets or investors may assume that the government will back up these companies in distressed situations. Sharpe (1992a) remarks that utility stocks display features of bonds and stocks as "revenues are 'sticky' because of the regulatory process". The Californian energy crisis disclosed the complexity of the market environment. The attempt to deregulate the power industry in California peaked in financial difficulties of two of the state's largest electric utilities, Southern California Edison and Pacific Gas & Electric Co. (filed for bankruptcy in April 2001) and power outages. One of the reasons was the freely fluctuating wholesale prices that soared due to increasing demand while retail prices remained fixed and thus prohibited utility companies to pass the higher costs on to customers. The state of California eventually entered the energy market buying electricity.

The exposure to foreign bonds can either result from direct investments in foreign companies or American companies that are globally active. Examples are Verizon, a worldwide provider of communications services, or the UK based Vodafone Group PLC which rank among the top 10 equity holdings in October 2001. The fund targets investment-grade bonds; that is, bonds rated BBB and above or Baa and above, with intermediate- to long-term maturity. Most remarkably, the R^2 value for the analysis is very low with 60.4%.

In a second step, we perform style analysis by augmenting the asset classes by three sector indexes. We use the Dow Jones indexes for the sectors energy, telecommunications, and utilities. Panel A of Table 4 demonstrates that the correlations of the sector indexes with the other asset classes are, in general, moderate. The three cross-correlations are 0.10, 0.17, and 0.49, the latter between the Dow US Energy and Dow US Utilities. Adding the three indexes improves the adjusted R^2 dramatically from 56.4 to 91.4%. This confirms that the fund does not employ a highly active management strategy but the return pattern of utilities cannot be properly replicated by a mix of bonds and large-cap stocks. Note the exposure to bills, which results from occasionally large positions in short-term interest rate securities. As of October 2001, the fund reported holding 5.7% of its net assets in cash.[27] The cash position varies over time explaining why it is discarded when using the AIC criterion.

4.4 Low R^2 as an indicator of active management

The difference $(1 - R^2)$ is often used as an indicator of the level of active management. This is only true when the asset classes used for the style benchmark are correctly specified, as we have seen in the example of the Putnam Utilities Growth and Income Fund above. An incomplete or inadequate set of asset classes will lead to a low R^2 and could be misinterpreted as an indication of active management.

Going back to the initial Vanguard Windsor example illustrates this point. If in Figure 2 we use the S&P 500, a commonly used performance benchmark for large-cap funds, only 65.9% of the variation in the fund returns can be explained. The low R^2 in this case does not imply a high degree of active management. As the style box (Figure 1) indicates, the S&P 500 divides the 500 largest US companies in approximately 50% growth and 50% value. It is not the appropriate index to replicate the bias of Windsor towards value and medium-cap stocks. The asset class specification further determines what would be a low or high value for R^2. We replicate the R^2-table in Buetow, Johnson and Runkle (2000) and report the R^2s for

Table 5 R^2 by fund type

A: Bond and equity indexes

Bond indexes		Equity indexes	
Name	R^2	Name	R^2
Short-term government	96.6	Large value	97.9
Intermediate-term government	97.4	Large blend	99.2
Long-term government	97.9	Large growth	97.7
Muni short-term	62.7	Mid-cap value	94.3
Muni national intermediate-term	65.3	Mid-cap blend	97.2
Muni national long-term	64.7	Mid-cap growth	96.1
Ultrashort-term bond	69.3	Small value	94.2
Short-term bond	95.8	Small blend	97.0
Intermediate-term bond	98.7	Small growth	96.9
Long-term bond	96.6		
High-yield bond	46.0		

B: Hybrid, international and specialty indexes

Hybrid/international indexes		Specialty indexes	
Name	R^2	Name	R^2
Convertibles	91.8	Specialty-communications	83.1
Domestic hybrid	99.1	Specialty-financial	83.1
International hybrid	94.6	Specialty-gealth	65.7
World stock	96.4	Specialty-natural resources	48.4
Diversified Pacific/Asia	80.4	Specialty-precious metals	14.8
Foreign stock	94.8	Specialty-real estate	53.1
Japan stock	87.8	Specialty-technology	81.7
		Specialty-utilities	63.9

The R^2 values of return-based style analysis applied to 35 Morningstar indexes are given. The calculations are based on monthly returns from January 1988 to December 2001 and the 12 asset classes described in Appendix A.

Morningstar equity, fixed-income, hybrid, international and specialty equity indexes from January 1988 to December 2001. The values in Table 5 represent typical R^2s we would expect for a fund within a particular category. Overall, the results in the table indicate that our 12 asset classes are not suited to analyze municipal bonds and high-yield bonds.

As Fung and Hsieh (1997a) remark, we could include a municipal bond index to represent non-taxable bond returns. This is particularly relevant for individual investors holding 75% of the municipal bonds that are exempted from federal income tax (see Fabozzi, 1997, chapter 9). The set of asset classes is biased towards domestic US investments and should be adapted to study international funds with a substantial exposure to currency risks. This explains the relatively low R^2s for Diversified Pacific/Asia and Japan stock funds. As we already pointed out, for sector funds the basic 12 classes should be augmented by sector indexes. In particular, we do not account for commodities, like precious metals or natural resources, and the asset classes will perform poorly when examining the exposures of REITs (Real Estate Investment Trust) or any portfolio related to real estate. Sharpe (1992a) added a mortgage index to cover this fund category.

Another indicator of active management is the turnover ratio. A low turnover ratio combined with a low R^2 is likely the result of ill-specified benchmark asset classes. A high turnover ratio or expense ratio are indicators for an actively managed fund.[28] A turnover ratio of 100% means that on average assets stay in the portfolio for 1 year. High turnover ratios are linked to larger trading activity whereas low turnover ratios of 20–30% are typical for buy-and-hold strategies. The passive Vanguard 500 Index fund (VFINX), for example, has an extremely low turnover of 4%. According to the prospectus, the average annual turnover from 1996 to 2001 for Vanguard Windsor is 45%. The asset turnover if we would have invested in the style benchmark for this fund (Figure 4) is 4.31%.

4.5 Style consistency and changes in management

To review whether the fund has changed its style in the past, we roll a 60-month window through time. It has been previously stressed (see e.g. Sharpe, 1992a and Buetow *et al.*, 2000) that return-based style analysis always portrays the average style over the recent history. The Vanguard Balanced Index Fund (VBINX) targets a 60 : 40 allocation to two indexed portfolios of stocks and bonds. Figure 9 shows the analysis for the period from October 1992 to December 2001. The first 60 monthly returns are used to determine the style benchmark as of September 1997. Every month the analysis is repeated and the window of the past 60 monthly returns is shifted by 1 month.

Figure 9 portrays only minor changes in the exposures to the 12 asset classes. The style of the Vanguard Balanced Index Fund is truly balanced and consistent over time. The sums of the exposures to US stocks (54.8%) and bonds (43.8%) closely match the fund's self-declared investment objective. Even though Vanguard tracks different aggregates, namely the Wilshire 5000 Equity Index and the Lehman Brothers Aggregate Bond Index, the style mapping to our 12 asset classes is stable over time. The explanatory power of the style benchmark, R^2, is 99.3%, supporting the conclusion of Buetow *et al.* (2000) that return-based style analysis is especially successful where the fund strategy allocates assets to indexed asset classes.

Characterizing the style of an actively managed fund poses a serious challenge and reveals the limits of return-based style analysis. For example, consider the Fidelity Magellan Fund (FMAGX). It was launched in 1963 and named after the Portuguese explorer Ferdinand Magellan who was leading the first expedition to circumnavigate the globe in 1519–22. In the prospectus (May 2002), the investment objective is outlined as seeking capital appreciation. The fund is "not constrained by any particular investment style" and switching between value and growth strategies may occur at any time. Fidelity Magellan is the world's largest actively managed fund with six million investors and $80 billion assets under management as of December 2001.

Table 6 breaks the monthly observations from January 1988 to December 2001 into the different management periods. Panel A exhibits the exposures to the basic 12 asset classes identified by return-based style analysis. The table only covers the last 2.5 years of Peter Lynch's tenure that started in May 1979. His successor, Morris Smith, pursued a similar investment philosophy although he narrowed the number of stocks from 1300 in March 1990, when Lynch announced his resignation, to about 800. He added non-bank financial stocks like insurance and money management firms.[29] Financials are typically large-cap value stocks, which may explain the increased exposure to the Russell 1000 Value. The main shift occurred from small-cap value to small-cap growth stocks.

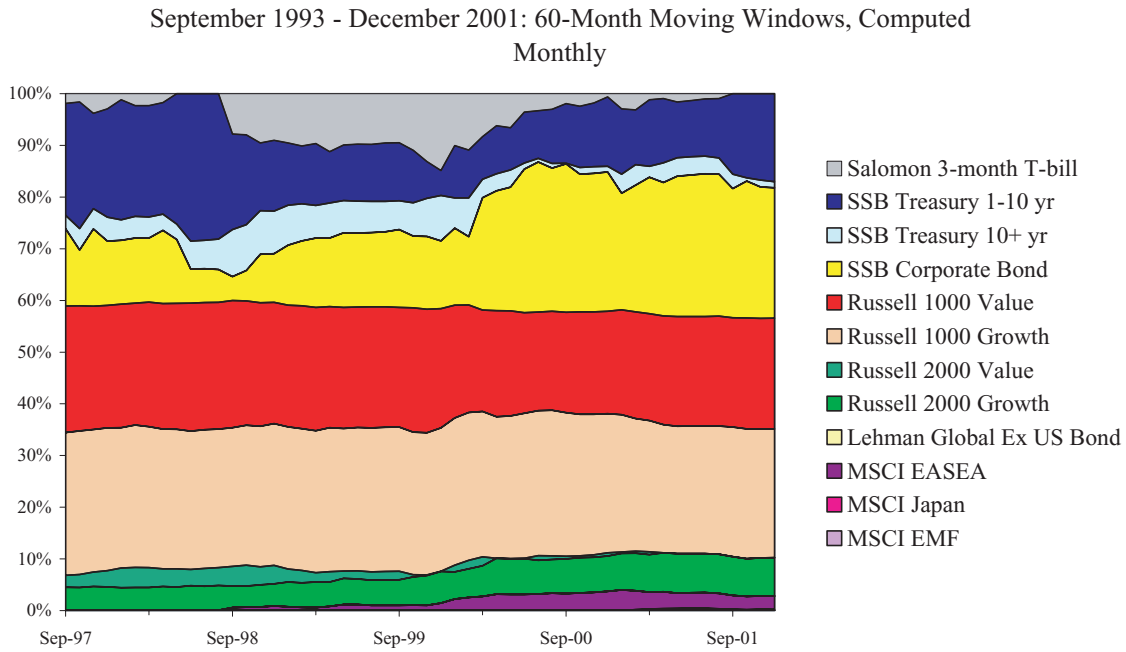

Figure 9 Style changes of Vanguard Balanced Index.

Jeffrey Vinik's portfolio management style has been described as making sweeping sector bets like technology, holding stocks of all market capitalization, trading frenetically, and trying to time the market. He completely eliminated the exposure to large-cap growth companies and instead developed a position in large-cap value stocks. The sector bet on technology shows up in the substantial exposure to the Russell 2000 Growth index. The comparatively low R^2 of 74.1% confirms the high turnover strategy. Robert Stansky, on the other hand, trimmed the number of stocks to 250–350 and reduced the annual turnover below 40%. He favors big companies and significantly increased the average market capitalization. The average exposure to the Russell 1000 until the end of 2001 was 90.7% (37.0% Russell 1000 Value and 53.7% Russell 1000 Growth).

Next, in Figure 10 we analyze the change in style under each management using a 36-month rolling window. There is no answer on theoretical grounds as to what is the optimal length of the trailing window. Similar to the choice of the optimization criterion the window length is based on judgment. An alternative to a shorter window size is to put more weight on most recent observations, for example, by using an exponential weighting scheme. Departure from equally weighted observations, however, adds noise to the optimization process.

The vertical lines in Figure 10 indicate management changes. The time line on the horizontal axis begins in December 1990, 7 months after Morris Smith assumed control of Fidelity Magellan. In analyzing the style history, it is important to keep in mind that from month to month 35 observations overlap. In December 1990, the exposures are calculated from the 7 months of Smith's management and the last 29 months of Peter Lynch's tenure. The switch from Smith to Jeffrey Vinik demonstrates the effect of the trailing window. During the reign of Vinik (July 1992 to May 1996), the shaded region denoting exposure to the Russell 1000 Growth index is large. However, 3 years—the length of the time

Table 6 Management changes of Fidelity Magellan

	Sample	Full	Lynch	Smith	Vinik	Stansky
	From	01/88	01/88	06/90	07/92	06/96
	To	12/01	05/90	06/92	05/96	12/01
A: Manager styles						
Asset class						
Salomon 3-month T-bill		—	—	—	—	—
SSB Treasury 1—10 yr		—	—	—	—	—
SSB Treasury 10+ yr		—	—	—	2.4%	—
SSB Corporate Bond		—	—	—	—	5.5%
Russell 1000 Value		38.4%	29.0%	37.0%	46.0%	37.0%
Russell 1000 Growth		44.3%	47.0%	45.6%	—	53.7%
Russell 2000 Value		2.3%	14.9%	—	—	—
Russell 2000 Growth		7.8%	7.7%	17.4%	29.9%	3.8%
Lehman Global Ex US Bond		—	—	—	2.8%	—
MCSI EASEA Index		4.2%	—	—	14.8%	—
MSCI Japan		3.1%	1.2%	—	3.2%	—
MSCI EMF		—	0.3%	—	0.9%	—
R-squared		93.1%	97.1%	98.3%	74.1%	96.9%
B: Excess returns						
Monthly average excess returns over 3-month T-bills						
Style benchmark		0.69	0.97	0.34	0.99	0.50
Selection		0.17	0.36	0.34	0.01	0.13
Fidelity Magellan		0.86	1.32	0.68	1.00	0.63
S&P 500		0.77	1.06	0.38	0.96	0.65
Standard deviation of excess returns over 3-month T-bills						
Style benchmark		4.13	3.59	4.50	2.21	5.18
Selection		1.15	0.77	0.82	1.67	0.94
Fidelity Magellan		4.39	3.74	5.04	2.92	5.24
S&P 500		4.08	3.76	4.36	2.23	5.05
Sharpe ratio						
Style benchmark		0.17	0.27	0.08	0.45	0.10
Selection		0.14	0.46	0.41	0.01	0.13
Fidelity Magellan		0.20	0.35	0.14	0.34	0.12
S&P 500		0.19	0.28	0.09	0.43	0.13

Panel A shows the results of return-based style analysis for the full sample and the subperiods for the four managers between January 1988 and December 2001: Peter Lynch (his tenure started in May 1979 and the table covers only the last 29 months), Morris Smith, Jeffrey Vinik, and Robert Stansky. Panel B compares the performance over the different subperiods. The mean, standard deviation, and Sharpe ratio of the monthly excess returns is divided into a style benchmark and selection component. The three statistics are also reported for the S&P 500.

window—after Vinik took over the management the attribution to the large-cap growth index vanishes. Thus, the gradually declining exposure to the Russell 1000 Growth index is a mere result of the periods overlapping with the Smith period (June 1990 to June 1992). The actual shift in the portfolio style is shown more drastically in Table 6. Considering only the observations of Vinik's period, the attribution to large-cap growth stocks is zero. During the last year of his tenure, Vinik invested in the bond market and put 19% of the fund into long-term US Treasury bonds, a bet that likely accelerated his exit as stock markets went up. The spike can be seen at the top of the graph. At the end of

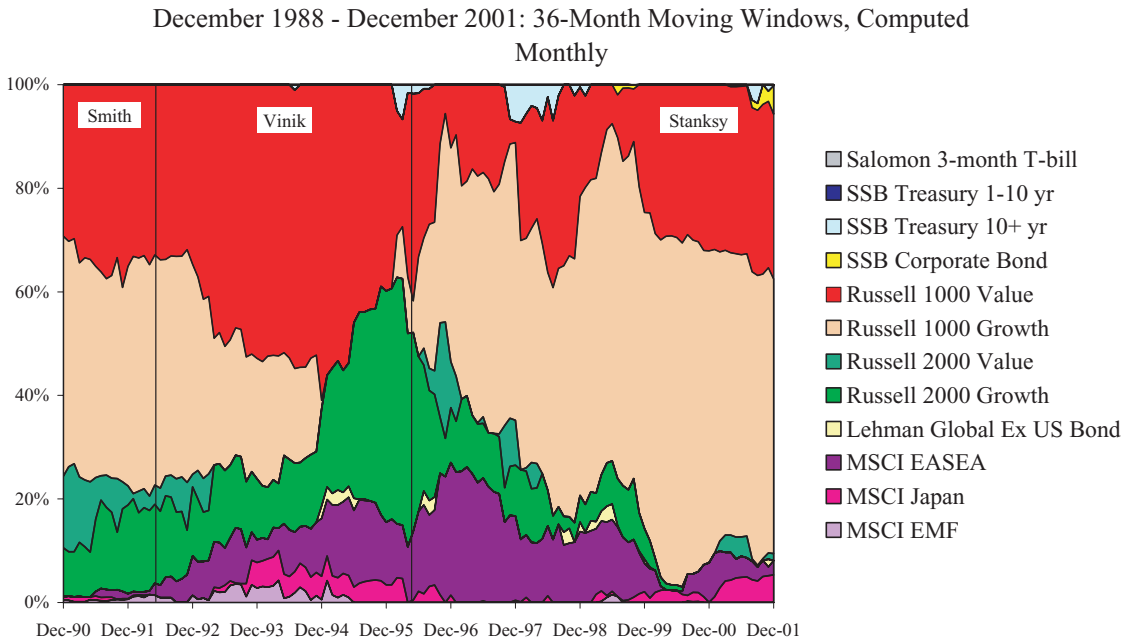

Figure 10 Style changes in Fidelity Magellan.

March 1996, the top three holdings were long-term (10 and 30-year) Treasury bonds.[30]

Robert Stansky quickly moved into large-growth stocks, computer companies like Cisco, Dell, and Oracle, health care, and retail.[31] His style is described as picking blue-chip companies and preferring growth stocks—before his engagement with Magellan he managed the Fidelity Growth Fund. Stansky made one of the biggest bets starting in August 1998. Technology stock prices were corrected downwards during the summer and "he went on a buying spree" as the succeeding sharp increase in the weight of the Russell 1000 Growth index shows. By the end of 1998, the position in tech stocks reached 25.8% of the assets.[32] The style history visualizes the large exposure to large-cap growth stocks. Consistent with the finding of Table 6, the attribution to the Russell 2000 Growth quickly passed out of the trailing window.

Panel B of Table 6 describes the risk-return tradeoff for Fidelity Magellan over the full sample and for each management period separately. The mean and standard deviation of the monthly excess returns are broken down into the fraction that can be explained by the style benchmark and the selection component. As a reference point, the last row reports the corresponding value for the S&P 500.

Besides average returns and standard deviations, the table contains the average Sharpe ratio over time. The Sharpe ratio of the selection component of Lynch (during the last 2.5 years) and Smith is better than for the other two. The market during Vinik's period is characterized by high average returns, low volatility, and a high Sharpe ratio of 0.43 for the S&P 500. However, his value for the selection component is the lowest among all four managers. The consistently positive Sharpe ratios for the selection components documents the success of Fidelity Magellan over the 13 years.

In his critique of return-based style analysis, Christopherson (1995) raises the point that the style based on historic data is misleading. It is correct that due to the rolling window there is a delay until a permanent shift in the style becomes apparent. As

Trzcinka (1995) replies, in this case the addition of portfolio data can be valuable to detect a shift earlier. However, data describing firm characteristics may become available later, whereas returns for the asset classes are easily available on a daily basis at low cost. Using weekly or daily data and comparing the deviations of the fund from what you would expect from the style can also indicate substantial departures from the style in a timely manner.

4.6 Manager universes and peer evaluation

Funds often reference their position within a manager universe. "Based on the portfolio statistics and compositions over the past 3 years", Morningstar assigns five stars if a fund is within the top 10% of similar funds. Lipper Index Service provides more than 85 indexes to classify and rank fund performance relative to their peers.[33]

The peer evaluation in the prospectus of Fidelity Magellan (May 22, 2002) raises some questions. The fund is compared to the Lipper Large-Cap Core Funds Average and the Lipper Large-Cap Supergroup Average over the past 1, 5, and 10-years. The Large-Cap Core Funds covers mutual funds with similar portfolio characteristics and capitalization and the Large-Cap Supergroup is only based on comparable capitalization. Given the big changes in Fidelity Magellan's investment style, a 10-year return comparison with the two manager universes is not informative. As we have seen in Table 6, during the tenure of Jeffrey Vinik from July 1992 to May 1996, the average exposure to the Russell 2000 Growth—measuring small-cap companies—was 29.9%. At the end of 2001, the Vanguard Growth & Income Fund we analyzed in Figure 6 also ranked among the 30 funds constituting the Lipper Large-Cap Core Funds Index. As we have seen, a balanced mix of Russell 1000 Value and Growth is a good proxy for this fund.

Bailey (1992) argues that peer evaluation violates key assumptions of a good benchmark and the median manager is only specifiable *ex post*. It is well documented that manager universe averages are upwardly biased due to survivorship bias. Poorly performing funds are eliminated from the database or cease operation. The results on the survivorship bias by Grinblatt and Titman (1989), Brown *et al.* (1995), and Malkiel (1995) indicate that mutual fund returns are overstated by 0.1–1.4%.

5 Style analysis of hedge funds

Hedge funds are less regulated than mutual funds. They are typically available only to institutional investors and individual investors who meet certain minimum wealth constraints.[34] Unlike mutual funds that follow a defined investment strategy and are limited to investing in specific asset classes, hedge funds have substantial amount of freedom to choose from among a variety of investment strategies. For example, hedge funds can take short positions in securities and trade in derivative assets whereas most mutual funds cannot do so. In order to align the incentives of hedge fund managers who have more flexibility in terms of what investment strategy to choose with that of investors, hedge fund managers are compensated with an incentive fee of 15–20% in addition to a 1–2% management fee (see Fung and Hsieh, 1999; Liang, 2000).[35] Hedge fund managers also have a substantial amount of their own wealth invested in the funds they manage.

The importance of hedge funds as an investment vehicle has increased in the recent past. TASS Management Limited (TASS), based on reports from 2722 funds, estimates that hedge funds as a group had between $450 and $500 billion under management in 2001.[36] For tax reasons many hedge funds are domiciled offshore. According to Brown *et al.* (1999), at the end of 1996, hedge funds reporting to

Managed Account Reports (MAR) had $68 billion assets under management and $31.7 billion managed by offshore entities. The variety of hedge funds is almost unlimited. TASS assigns hedge funds to nine major categories, with long/short equity hedge funds totaling 44%. The Hedge Fund Research Inc. (HFR) classifies hedge fund styles into 33 categories.

Performing return-based style analysis using traditional asset classes is unsuitable for determining the effective style of hedge funds due to their low correlations with returns on traditional asset classes. For example, using eight traditional asset classes, Fung and Hsieh (1997a) find that 48% of the hedge funds had R^2s of less than 25%, whereas more than half of the mutual funds had R^2s above 75%. Unlike mutual funds that have mainly positive exposures to asset classes and relatively large exposures to US stocks and bonds, hedge funds have significant exposure to most asset classes, with 25% of the exposures being negative.

Traditional mutual funds follow well-defined investment strategies. A typical mutual fund manager is mainly engaged in selection, that is, selects mispriced securities that belong to some pre-specified asset classes. In contrast, a hedge fund manager will often time the market, sectors, and countries by actively moving the money around, invest in derivative securities, and engage in dynamic trading strategies that exploit relative mispricing among securities. In that case, return-based style analysis will, in general, not be able to capture the manager's effective style. For example, consider a portfolio of short positions in puts and calls on the S&P 500 index. The return on the position will depend on the return on the S&P 500 in a nonlinear way. The position will result in losses for large changes in the index value and will result in gains otherwise. However, the position can be formed in such a way that its beta as well as its R^2 in return-based style analysis is zero. Clearly, return-based style analysis using standard asset classes is of little value in this case.

Even when a hedge fund does not directly invest in derivative securities, its returns may exhibit option-like features because of active changing of positions across asset classes.[37] Merger arbitrage, a commonly employed hedge fund investment strategy, would be an example that exhibits an option-like payoff structure even though the strategy does not involve derivative securities. When a merger or an acquisition is announced and there is no uncertainty regarding the deal going through, the target firm's stock price should trade at the price it is offered by the acquirer. This need not be the case when there is substantial deal uncertainty. Typically, target firms trade at a discount to their value based on the offer price. Merger arbitrage attempts to capture the spread between the target's price and the offering price by taking a long position in the target and a short position in the acquirer. Mitchell and Pulvino (2001) demonstrate that merger arbitrage strategy returns are "positively correlated with market returns in severely depreciating markets but uncorrelated with market returns in appreciating markets". They conclude that the return to merger arbitrage resembles the return on uncovered puts on the market index. Hence, return-based style analysis using traditional asset classes will not be able to capture the risk associated with the return on merger arbitrage strategies. In what follows, we discuss these issues further and show how return-based style analysis can be modified.

5.1 Additional asset classes for return-based style analysis of hedge funds

It would be difficult to capture the effective style of a hedge fund manager just by increasing the number of style benchmarks by additional standard asset classes. As Glosten and Jagannathan (1994) point out, the returns on portfolios managed using

active strategies—as is the case with hedge funds—would exhibit option-like features. Fung and Hsieh (2001) and Mitchell and Pulvino (2001) empirically demonstrate that returns generated by hedge fund strategies do indeed exhibit significant nonlinear, option-like patterns. The nonlinear return pattern results from the use of derivatives, either explicitly or implicitly through the use of dynamic trading.

When a manager's return is related to the benchmark returns in a nonlinear manner, it would be difficult to identify the selection component of the manager's return using linear factor models, of which return-based style analysis is a special case. For example, Jagannathan and Korajczyk (1986) and Grinblatt and Titman (1989) showed that if investors were to evaluate the performance of a manager by measures like Jensen's alpha or the Treynor–Black appraisal ratio, then a manager selling call options on a standard benchmark will appear to be falsely classified as a superior performer. Merton (1981) and Dybvig and Ross (1985) noted that portfolios managed with superior information would typically result in returns that exhibit option-like features even when the managers do not explicitly trade in options.

Glosten and Jagannathan (1994) suggested augmenting the return on style benchmark indexes with returns on selected options on the style benchmark indexes in order to capture the investment style of portfolio managers who employ dynamic trading strategies. Instead, we suggest following a two-step approach when analyzing hedge funds using return-based style analysis. In the first step, we augment the traditional asset classes with a set of selected hedge fund style benchmark indexes for characterizing the effective style of an individual fund. An example of such a style benchmark index would be the return on a portfolio of hedge funds that specialize in merger arbitrage.[38] One would need a collection of such benchmarks, one for every commonly used hedge fund strategy. In the second step, we analyze the nature of the risks in these benchmarks using return-based style analysis after augmenting traditional asset classes with a collection of options on those asset classes, as we demonstrate later on.

This two-step approach has the following advantage. On average, the hedge fund industry is young and the data history of hedge funds is short. Many hedge fund strategies are characterized by significant left-tail risk, that is, the fund's return becomes largely negative in the event of a sharp unexpected drop in asset class returns. These events are rare and may not appear often enough in the sample to be captured with sufficient accuracy using options on standard asset classes. Once we have identified the effective style of a hedge fund using the pure strategy benchmarks we discussed earlier, we can go back in history to evaluate the risk in those pure strategies using options on asset classes with a larger time series of data. The use of a longer time series will facilitate better appreciation of the risk in these pure strategies that arises due to excessive exposure to extreme events.

Suppose these additional, pure strategies so identified are investable. Then, we can augment our standard asset classes with these benchmark hedge fund strategies or styles. Denote the additional style benchmark returns that are necessary to capture the effective style of hedge funds by y_n and their loadings by c_n. Then, Eq. (2a) becomes:

$$r_{p,t} = [b_{p,1}x_{1,t} + \cdots + b_{p,N}x_{N,t}] + [c_{p,1}y_{1,t} + \cdots + c_{p,N}y_{N,t}] + e_{p,t} \quad \text{for } t = 1, 2, \ldots, T \tag{2a'}$$

As of now, a set of such benchmarks is not available. In its absence we will use the indexes constructed by the Hedge Fund Research Institute (HFR) for illustrative purposes. In what follows, we show that including HFR indexes as additional style benchmarks does improve the R^2 in style regressions when

analyzing individual hedge funds. For that purpose we use the Hudson Valley fund classified in TASS as a fund employing an event-driven strategy. Since hedge funds can take short positions, we do not restrict the coefficients in return-based style analysis to be positive when analyzing hedge funds.[39]

The results are given in Table 7. Style analysis using standard asset classes gives an R^2 of 21.8%. When AIC is used to screen out redundant asset classes we are left only with three asset classes: 83.0% weight on Salomon 3-month T-bills, 14.3% weight on the Russell 2000 Value index, and 2.7% weight on the MSCI Japanese stock index. The 18.4% adjusted R^2 for the style regression with these three asset classes is higher than the 15.3% adjusted R^2 when all 12 traditional asset classes are used, indicating that the other traditional asset classes are not required. The adjusted R^2 increases from 18.4 to 72.1% (with the AIC as the optimization criterion) when the HFR Merger Arbitrage index is included as a style benchmark. The substantial increase confirms the need to add additional style benchmarks when analyzing hedge funds. The merger arbitrage index gets a weight of 96.2%, indicating that the Hudson Valley hedge fund is primarily a one-strategy fund. We now go on to characterize the risk in the HFR Merger Arbitrage index we used to augment the traditional asset classes.

5.2 Characterizing the risk in two hedge fund strategies: merger arbitrage and market timing

Academic research has identified the payoff pattern for a few hedge fund strategies: market timing, equity non-hedge and short selling are directional strategies; merger arbitrage (at least in its pure form) and equity hedge aim to have low correlation

Table 7 Analysis of an individual event-driven hedge fund

Asset classes	Basic		Basic plus HFR Merger Arbitrage Index	
Optimization criterion	R^2 (%)	AIC (%)	R^2 (%)	AIC (%)
Salomon 3-month T-bill	108.6	83.0	18.3	8.9
SSB Treasury 1—10 yr	−31.8	—	−6.3	—
SSB Treasury 10+ yr	8.5	—	5.1	—
SSB Corporate Bond	0.7	—	−11.6	—
Russell 1000 Value	6.2	—	0.8	—
Russell 1000 Growth	−0.2	—	2.2	—
Russell 2000 Value	8.2	14.3	−2.7	—
Russell 2000 Growth	2.4	—	0.5	—
Lehman Global Ex US Bond	−3.2	—	−3.8	−6.0
MCSI EASEA	−1.8	—	−1.8	—
MSCI Japan	3.1	2.7	2.2	2.6
MSCI EMF	−0.6	—	−1.3	−1.7
HFR Merger Arbitrage			98.4	96.2
R^2	21.8		73.8	
Adjusted R^2	15.3	18.4	71.4	72.1

The results of return-based style analysis using different sets of asset classes are provided. The monthly returns for Hudson Valley Partners LP are from January 1990 to December 2001.

with the market and make non-directional bets by providing liquidity where it is needed and exploit relative mispricing of securities. In this section, we examine merger arbitrage and market timing. We will discuss the three equity-oriented strategies, equity non-hedge, equity hedge, and short selling, in Section 5.4.

We use monthly data from January 1990 to December 2001 of the HFR Merger Arbitrage and Market Timing indexes (for a description see Appendix C). Figures 11 and 12 show the returns of the two strategies against the S&P 500. We fit the payoff of a short put option and a straddle to these strategies.[40] The kinked line in the left scatter plot (Figure 11) shows a put option payoff diagram fitted to the data. Going short a put option on the S&P 500 will earn the premium if the market is above the exercise price. The kink (exercise price) is at −3.0% and the level to the right at 1.2%. The slope on the downside is 0.509. Fitting a straddle to the HFR Market Timing index in Figure 12 positions the kink at −4.5%. As expected, the slope to the right is positive 0.391 and negative −0.012 to the left. For a perfect market timer we would definitely expect a more symmetric pattern. There are many possible reasons why this is not the case: some hedge funds in the category "market timing" try only to time

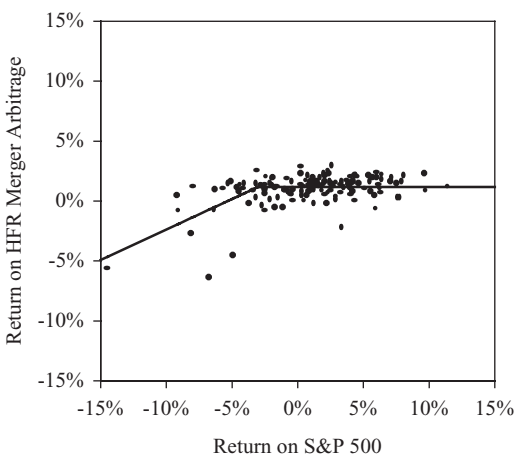

Figure 11 HFR Merger Arbitrage.

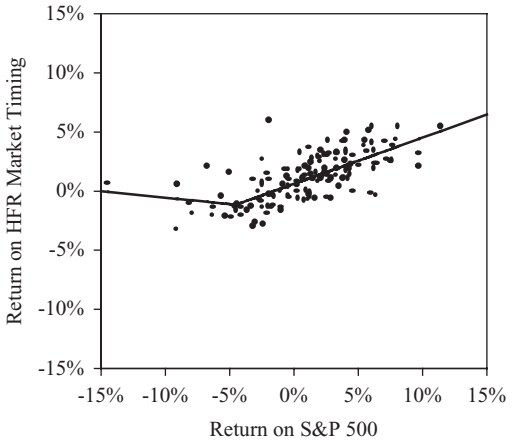

Figure 12 HFR Market Timing.

appreciating markets and otherwise hold positions in the money market (which agrees with the description of the HFR Market Timing index in Appendix C), shorting certain securities is more difficult than being long, and the funds in the index are after all not perfect market timers. However, both diagrams confirm the option-like payoff patterns.

In the next step, we incorporate traded options that mimic these payoffs into return-based style analysis. We use data on option returns calculated from at-the-money (ATM) and out-of-the-money (OTM) call and put options on the S&P 500 Composite Index provided by Agarwal and Naik (2002). In addition, we drop the restriction (2b) of the classic return-based style analysis and allow for short positions. The negative weights make it possible to create new artificial return series as linear combinations of the existing ones. For example, a combination of long and short positions in the three classes of Treasury securities will, in general, help capture the interest rate exposure of the hedge fund strategy using return-based style analysis more accurately. However, as can be seen from Figure 13, when we use the AIC that penalizes strongly additional variables the wildly fluctuating long and short positions in the three Treasury securities classes disappear, but the adjusted R^2 remains about the same.

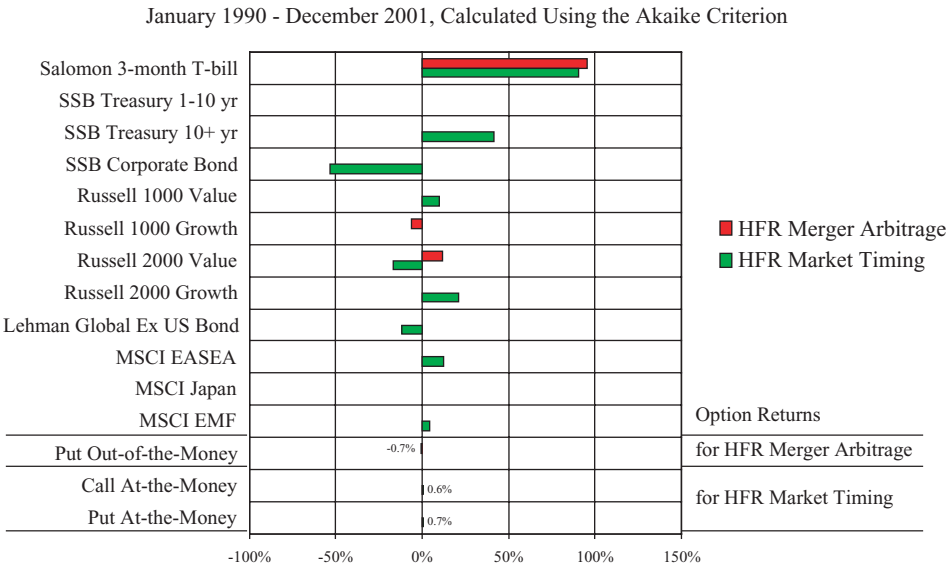

Figure 13 Style analysis with options.

Mitchell and Pulvino (2001) observe that in the sample of mergers and acquisitions that they examine the target firm is typically smaller than the acquirer. Agarwal and Naik (2002) find evidence that more often the acquirer is a large growth firm and the target is a smaller value firm. The results in Figure 13 are consistent with these findings. To exploit risk arbitrage an investor would on average go short the acquiring firm, that is, Russell 1000 Growth, and long the target firm, that is, Russell 2000 Value.

The weight of −0.7% on the put options for merger arbitrage appears to be small. However, we have to keep in mind that even when the weight attached to a written option position is small, it can have significant amount of sensitivity to tail events. For example, consider investing \$100 in cash and writing 1.2 index put options with an exercise price of \$90 and 3 months to maturity when the current index value is \$100. Suppose the interest rate is 5% per year and the index volatility is 20% per year. Then, the Black-Scholes put option value will be \$0.55. The portfolio will have \$100 in T-bills and −\$0.66 in index put options, that is, 100.7% of the funds invested in T-bills and −0.7% invested in out-of-the-money index put options. Suppose the index value drops steeply to \$80 right after forming the position, that is, a 20% drop. The position will lose \$12, that is, a 12% drop. Hence, the position can lose a significant amount in severely depreciating markets even though most of the money is in T-bills.

We have to be careful in interpreting R^2 values—even when the R^2 is relatively low, there can be significant tail event risk. For merger arbitrage and market timing the adjusted R^2 increases from 29.9 and 60.8%, respectively, to 38.8 and 64.6%, when option returns are included (Figure 13). Figure 14 shows the style changes for the HFR Merger Arbitrage index over time. The negative exposures are displayed below the horizontal axis. In order to make the OTM put option position visible, it is scaled up by a factor of 10, that is, the exposure to put options with 1/10 of the return are shown. Spikes represent drastic changes as each data point represents an average exposure over the past 36 observations. Taking into account that this figure plots the style shifts for an index, where

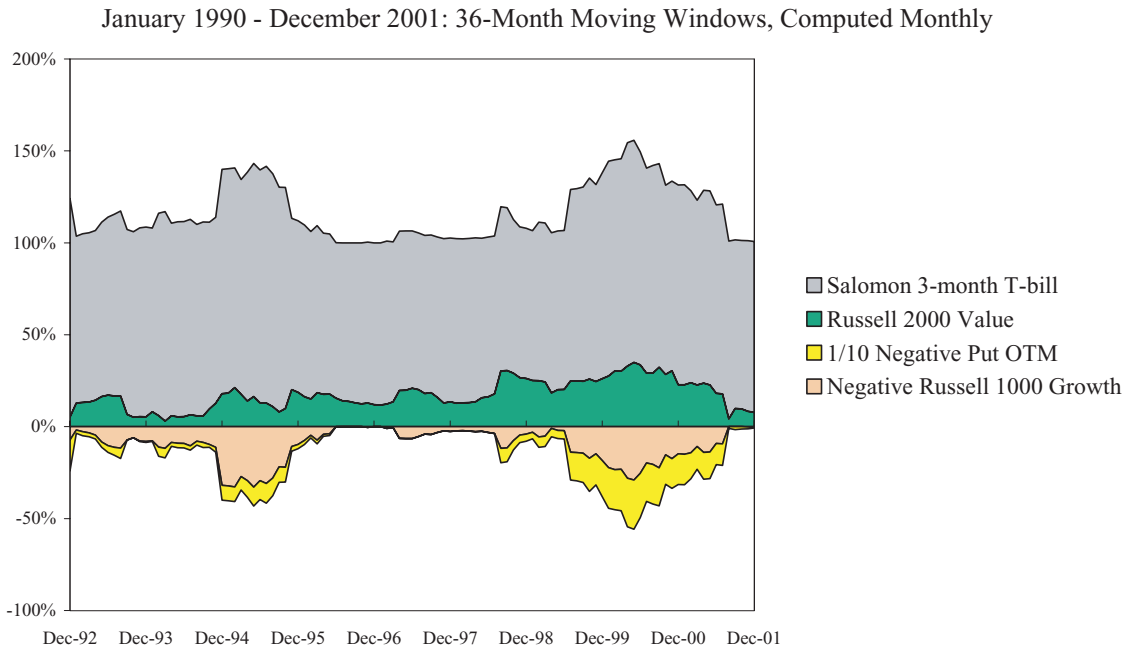

Figure 14 Style changes of HFR Merger Arbitrage.

idiosyncratic risk is averaged out, we get an idea of the dynamics of the strategies hedge funds implement.

5.3 Index choice and survivorship bias

There are three major providers for hedge fund indexes. (i) Credit Suisse First Boston/Tremont (CT) provides indexes that are value-weighted and based on the TASS database. Only funds with at least $10 million in assets and audited financial statements are included in the indexes. (ii) In contrast, Hedge Fund Research (HFR) indexes are equally-weighted without any minimum asset size requirements. Due to legal arrangements the constituents of the HFR indexes are not disclosed. (iii) Managed Account Reports (MAR) indexes correspond to the performance of the median manager within the investment style class and are available beginning January 1994.[41] Note that the correlations among the three indexes for some hedge fund strategies are low. For example, the correlations for the strategy named "market neutral" are between 0.26 and 0.37 among the three indexes. This is an indication that hedge funds most often follow a mixture of strategies. It is difficult to form a fixed-weight portfolio of these funds that accurately represents a particular pure hedge fund strategy. Hence, the conclusions reached using one set of indexes may be reversed when another set of indexes is used, highlighting the need for caution in interpreting the results from return-based style analysis.

When evaluating managers using indexes it is important to keep in mind that the way funds are included in the index may bias the conclusions. In many cases index providers include hedge funds after they already existed for some time. At the time of inclusion the history of returns is backfilled in the database. The average return on such funds will in general overstate what investors expected since these funds ended up successfully and survived. Fung and Hsieh (2000b) discuss the biases that arise due to this practice. The survivorship bias can be large. For example, in the sample of Brown, Goetzmann, and Ibbotson (1999), only 25 out of

108 hedge funds survived over the 7 years from 1989 to 1995. Survivorship rates also vary across databases. Ackerman, McEnally, and Ravenscraft (1999), Fung and Hsieh (2000b), and Liang (2000) report higher attrition rates in TASS than HFR. Fung and Hsieh (1997b) discuss the survivorship bias for CTAs and argue that it can substantially overstate the benchmark return. Based on a sample of offshore hedge funds Brown, Goetzmann, and Ibbotson (1999) find a survivorship bias of approximately 3% per year, similar to the bias found by Fung and Hsieh (2000b) for the hedge funds reporting to TASS. Due to the lack of data on defunct hedge funds the quality of the databases is low during the period prior to 1994 (see Fung and Hsieh, 2000b, 2002).

5.4 Equity-oriented strategies

We saw earlier that the hedge fund strategy "merger arbitrage", while in general uncorrelated with the market, loses money when the market sharply depreciates. In that sense, the payoff from the strategy resembles selling disaster insurance. The strategy rarely loses money, but when it does, the amount of the loss can be large and the associated risk is systematic and not diversifiable. Several hedge fund strategies involve this type of excessive sensitivity to tail events. In the history of returns available to the investor, such events may not have taken place with sufficient regularity to accurately assess the probability of their occurrence. In that case, the coefficients for index options included as additional asset classes when analyzing benchmark hedge fund strategies may not be significant; and the investor is left to analyze the risks associated with those strategies through introspection.

For example, consider equity-oriented strategies. According to TASS, 44% of the hedge funds can be classified as equity-oriented strategies. These hedge funds try to time the market and take short and long positions in overvalued and undervalued stocks, respectively. HFR differentiates between three equity-oriented strategies: equity non-hedge, equity hedge, and short selling (for a description see Appendix C). Equity non-hedge funds predominantly hold long positions in equities. Equity-hedge funds eliminate part of the systematic risk in the bets they take by using short positions, stock options, and index options, depending on market conditions. Hedge funds in the short selling category sell securities they do not own and consider to be overvalued. They anticipate a price decline and expect to buy the securities back at a future date at a lower price. These types of hedge funds still have substantial correlations with the standard asset classes. The correlation for equity non-hedge with the S&P 500 is 0.86, for equity hedge still 0.64, and for short selling −0.69.

Figure 15 shows the exposures for the three equity-oriented strategies using the AIC criterion. The estimated effective style for the HFR Short Selling index has a 167.2% long position in the Salomon 3-month T-bill index and a combined 90.8% short position in Russell 2000 Growth and MSCI Japan (plus a 24.8% long position in the Russell 2000 Value), with an associated adjusted R^2 of 81.3%. The finding that the short selling strategy has no negative exposure to the MSCI EMF confirms the observation that in many emerging markets short selling is prohibited. Even in the most advanced stock exchanges, like Hong Kong, restricted short selling was allowed only recently (see Frank and Jagannathan, 1998).

The effective style for HFR Equity Hedge consists of a portfolio of Salomon 3-month T-bills, SSB Treasury 10+ yr, Russell 2000 Growth, and MSCI EMF with an adjusted R^2 of 73.9%. The HFR Equity Non-Hedge exhibits a major exposure to the Russell 2000 Growth and also to the MSCI EMF with an associated adjusted R^2 in the style regression of 91.6%. The portfolio is tilted towards small and

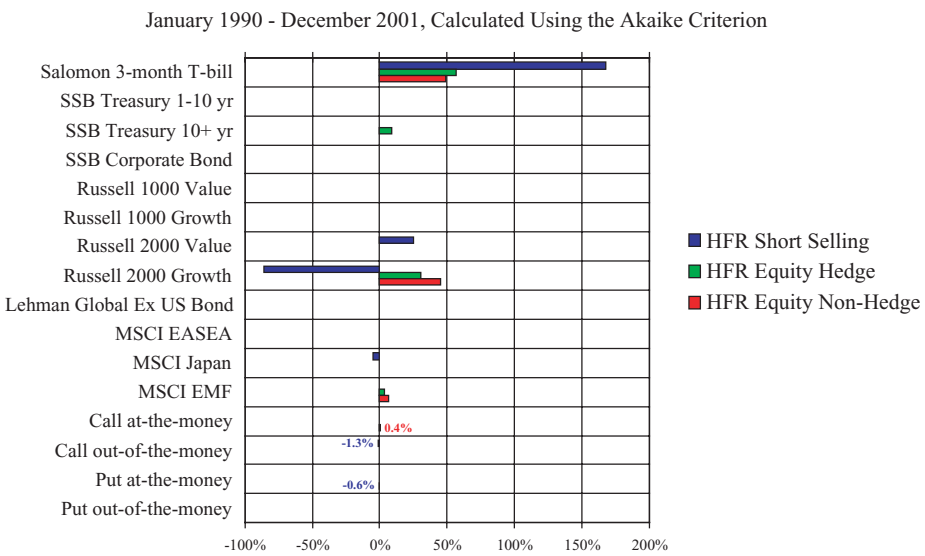

Figure 15 Style analysis for equity-oriented hedge fund strategies.

growth equities, which is consistent with the view that small growth companies are more likely to be mispriced. For example, Bogle (1998) finds that out of the nine style classes in the Morningstar style box only for the small-cap growth category the average actively managed funds outperformed a passive index. The exposure to the MSCI EMF is in line with Agarwal and Naik (2002) who use stepwise regression in their analysis.

The coefficients for index options are small for all three strategies (between −1.3 and +0.4%), even though one may suspect that index options may be relevant. For example, the equity hedge strategy may involve taking simultaneous long and short positions in two stocks in the Russell 1000 Value index resulting in zero exposure to Russell 1000 Value. While the two stocks may have similar sensitivity to small market moves, they may have different sensitivity to the market for large moves. If sharp moves in the market occur over a short period of time, the position may show large gains or losses similar to a portfolio of out-of-the-money options. In the data used for return-based style analysis there may be no such large sharp price movements but that does not mean that such a move may not occur in the future.

A word of caution is in order when using return-based style analysis, especially for hedge funds. Given the flexibility allowed to hedge fund managers, an individual hedge fund manager may choose strategies in the future that may be very different from the ones employed in the past. Hence, the risks and rewards from any given individual fund may be vastly different from that indicated by return-based style analysis. An investigation of individual hedge funds in the TASS database indicates that the R^2s can be low. This suggests that a given fund may be following strategies that are difficult to capture sufficiently accurately using the style benchmark asset classes we discussed. Therefore, an investor will have to obtain additional information regarding a fund's strategies through discussions with the hedge fund manager and arrive at the right collection of asset classes to use in return-based style analysis of that fund.

5.5 Stepwise regression to identify major exposures

In our examples we used the AIC to select which style benchmarks to leave out in return-based style analysis. Stepwise regression is another commonly

used technique that would be useful for that purpose. It has been applied in the hedge fund literature by Liang (1999), Fung and Hsieh (2000b), and Agarwal and Naik (2002), to determine pervasive factors. The forward stepwise regression starts with a constant term on the right hand side. At each step, the most significant term, that is, the one with the highest F-statistic, is added to the model. We use a 5% significance level as the threshold for the inclusion of an additional parameter. The model is re-estimated and it is tested whether any variable can be removed without loss of much explanatory power. Note that the R^2 values in stepwise regressions tend to be upwardly biased and the standard significance tests of the coefficients do not apply.

The results obtained using stepwise regression are given in Table 8. We did not impose the constraint that the coefficients sum to one in the stepwise regressions. Instead we normalize the coefficients by dividing by the absolute value of the sum of the coefficients. We compare the results of the stepwise regression in Table 8 to Figures 14 and 15. The striking result is that the adjusted R^2 values do not change much when the stepwise regression approach is used even though we did not impose the constraint that the coefficients sum to one. The coefficients for the different asset classes differ by a large amount, suggesting that there are several equivalent ways to describe the effective style using these asset classes. The set of coefficients we pick by imposing the constraint that they must sum to one in return-based style analysis appears more reasonable given the strategies implied by the style names. When the R^2 is low, this indeterminacy may indicate the difficulties associated with replicating the returns by any fixed-weight portfolio of the style benchmark asset classes.

Table 8 Stepwise regression analysis

Asset class	Merger Arbitrage	Market Timing	Short Selling	Equity Hedge	Equity Non-Hedge
Constant/Salomon 3-month T-Bill	13.3%	5.9%	1.4%	3.8%	1.7%
SSB Treasury 1—10 yr	—	—	—	—	—
SSB Treasury 10 +yr	—	—	—	—	—
SSB Corporate Bond	—	—	—	—	—
Russell 1000 Value	—	—	—	—	—
Russell 1000 Growth	❸ −99.8%	—	—	—	—
Russell 2000 Value	❶ 197.7%	❹ −62.7%	❸ 42.1%	—	—
Russell 2000 Growth	—	❷ 95.1%	❶ −141.3%	❶ 96.2%	❶ 85.8%
MCSI EASEA	—	—	—	—	—
MSCI Japan	—	❸ 57.8%	—	—	—
MSCI EMF	—	—	—	—	❸ 12.8%
Call ATM		❶ 3.9%	—	—	❹ 0.8%
Call OTM			❷ −2.2%	—	—
Put ATM		—	—	—	❷ −1.2%
Put OTM	❷ −11.2%		—	—	—
Adjusted R^2	37.4%	60.6%	82.0%	73.0%	91.7%

Estimation results for HFR Merger Arbitrage, Market Timing, and the three equity-oriented indexes Equity Non-Hedge, Equity Hedge and Short Selling. The corresponding columns contain the results of a forward-stepwise regression on the twelve asset classes and the additional options. The numbers indicate the order in which the variables are added. The threshold significance levels for adding and removing variables are 5% and 10%, respectively.

6 Conclusions

Return-based style analysis helps investors understand the effective style of funds in which they invest in, monitor and evaluate managers to whom they entrust their money, and ensure that their asset allocation is consistent with their investment objectives. Return-based analysis is easy to implement and interpret and is a useful precursor to more detailed analysis based on the actual portfolio holdings.

Proper use of the technique requires correct specification of the style benchmark asset classes. Inappropriate or inadequate choice of style benchmarks can lead to wrong characterization of the effective style of the portfolio manager and the level of active management. The use of the Akaike information criterion helps narrow down the number of asset classes required for capturing the effective style of a manager.

Return-based style analysis characterizes the average style of a manager over a period of time. While it is possible to detect style rotation to some extent using return-based style analysis, the procedure may not be able to detect short-lived style deviations even when they are large in magnitude. As is the case with all analysis that relies on historical data, it is necessary to exercise caution in making forecasts about the future based on past performance.

The method can be modified to examine the effective style of hedge fund managers by augmenting traditional asset classes with benchmark hedge fund style indexes, each of which represents the return on a particular pure hedge fund strategy. Return-based style analysis using traditional asset classes augmented by carefully chosen index options can then be used to characterize the risks in the pure hedge fund strategies that the hedge fund style indexes represent. Given that hedge fund managers are typically reluctant to disclose their holdings, portfolio-composition-based style analysis may not be feasible for hedge funds.

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Appendix A: Asset classes

Asset class	Description
Salomon 3-month T-bill	Salomon Brothers 3-month Treasury bill index
SSB Treasury 1—10 yr	Intermediate Treasury notes and bonds with maturities between 1 and 10 years
SSB Treasury 10+ yr	Long-term Treasury bonds with maturities over 10 years
SSB Corporate Bond	Corporate bonds with ratings of at least BB
Russell 1000 Value	The Russell 3000® Index measures the performance of the 3000 largest US companies based on total market capitalization, which represents approximately 98% of the investable US equity market
Russell 1000 Growth	
Russell 2000 Value	
Russell 2000 Growth	The Russell 1000® Index measures the performance of the 1000 largest companies in the Russell 3000 Index, which represents approximately 92% of the total market capitalization of the Russell 3000 Index. As of May 31, 2002, the average market capitalization was approximately $11 billion; the median market capitalization was approximately $3.5 billion. The index had a total market capitalization range of approximately $309 billion to $1.3 billion

Appendix A: *Continued*

Asset class	Description
	The Russell 2000® Index measures the performance of the 2000 smallest companies in the Russell 3000 Index. As of May 31, 2002, the average market capitalization was approximately $490 million; the median market capitalization was approximately $395 million. The index had a total market capitalization range of approximately $1.3 billion to $128 million Each stock in the Russell 1000 and Russell 2000 is ranked by two variables, the price-to-book ratio and the I/B/E/S forecast long-term growth mean. Variables are combined to create a composite value score for each stock. Stocks are ranked by the composite value score and a non-linear probability algorithm is applied to the distribution to determine style membership weights. 70% are classified as all value or all growth and 30% are weighted proportionally to both value and growth. *Source*: www.russell.com
Lehman Global Ex US Bond	All issues in the Lehman Global Index must be fixed rate, non-convertible debt and have at least 1 year remaining to maturity. Securities from countries classified as emerging markets are excluded. The country components are weighted according to market capitalization, except for Japan, which is weighted according to the market capitalization of the 40 largest Japanese government bonds. For accuracy in pricing, some illiquid issues are also excluded. *Source*: www.styleadvisor.com
MSCI EASEA	MSCI EASEA (MSCI EAFE excluding Japan). The MSCI EAFE® Index (Europe, Australasia, Far East) is a free float-adjusted market capitalization index that is designed to measure developed market equity performance, excluding the US and Canada. As of April 2002, the MSCI EAFE Index consisted of the following 21 developed market country indices: Australia, Austria, Belgium, Denmark, Finland, France, Germany, Greece, Hong Kong, Ireland, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, Switzerland, and the United Kingdom
MSCI Japan	Country composite index targets 60% coverage of the market capitalization. Selection criteria include: size, long- and short-term volume, cross-ownership and float
MSCI EMF	The MSCI EMF (Emerging Markets Free) Index^{SM} is a free float-adjusted market capitalization index that is designed to measure equity market performance in the global emerging markets. As of April 2002, the MSCI EMF Index consisted of the following 26 emerging market country indices: Argentina, Brazil, Chile, China, Colombia, Czech Republic, Egypt, Hungary, India, Indonesia, Israel, Jordan, Korea, Malaysia, Mexico, Morocco, Pakistan, Peru, Philippines, Poland, Russia, South Africa, Taiwan, Thailand, Turkey and Venezuela. *Source*: www.msci.com

Appendix B: Growth and income funds—objective and investment strategy

The information is based on the funds' prospectuses as of December 2001.

Alliance Capital Growth & Income
Objective: The fund seeks to provide income and capital appreciation
Primary investment strategies: The fund primarily invests in dividend-paying common stocks of good quality. It may also invest in fixed-income and convertible securities. The fund tries to maintain a defensive dividend yield and price-to-earnings ratio, a fully invested posture, and a high degree of sector and industry diversification. The fund invests in quality companies that trade at undeserved discounts to their peers. The fund does not make sector or market timing bets, but instead emphasizes intensive, bottom-up research and careful stock selection.
Size: $3.2 billions, Front load: 4.25%, Expense ratio: 0.91%

Appendix B: *Continued*

Goldman Sachs Growth & Income
Objective: This fund seeks long-term growth of capital and growth of income through investments in equity securities of well-established companies that are considered to have favorable prospects for capital appreciation and/or dividend-paying ability
Primary investment strategies: Based on a research-intensive approach, the fund employs a value investing strategy that emphasizes stocks they believe to be inexpensive relative to the fund's estimate of their actual worth. The fund maintains a long-term investment horizon with low turnover
Size: $335 millions, Front load: 5.50%, Expense ratio: 1.19%

Putnam Fund for Growth & Income
Objective: The fund seeks to provide capital growth and current income by investing primarily in common stocks that offer the potential for capital growth while also providing current income
Primary investment strategies: The fund invests mainly in common stocks of US companies, with a focus on value stocks that offer the potential for capital growth, current income, or both. Value stocks are those that we believe are currently undervalued by the market. We look for companies undergoing positive change. If we are correct and other investors recognize the value of the company, the price of the stock may rise. We invest mainly in large companies
Size: $18.6 billions, Front load: 5.75%, Expense ratio: 0.81%

Vanguard Growth & Income
Objective: The fund seeks to provide a total return (capital appreciation plus dividend income) greater than the return of the Standard & Poor's 500 Index
Primary investment strategies: The fund's adviser uses computer models to select a broadly diversified group of stocks that, as a whole, have investment characteristics similar to those of the S&P 500 index, but are expected to provide a higher total return than that of the index. At least 65% (and typically more than 90%) of the fund's assets will be invested in stocks that are included in the index. Most of the stocks held by the fund provide dividend income as well as the potential for capital appreciation
Size: $6.6 billions, Front load: –, Expense ratio: 0.38%

Appendix C: HFR hedge fund classes

Merger arbitrage	Sometimes called risk arbitrage, involves investment in event-driven situations such as leveraged buy-outs, mergers, and hostile takeovers. Normally, the stock of an acquisition target appreciates while the acquiring company's stock decreases in value. These strategies generate returns by purchasing stock of the company being acquired, and in some instances, selling short the stock of the acquiring company. Managers may employ the use of equity options as a low-risk alternative to the outright purchase or sale of common stock. Most merger arbitrage funds hedge against market risk by purchasing S&P put options or put option spreads
Market timing	Involves allocating assets among investments by switching into investments that appear to be beginning an uptrend, and switching out of investments that appear to be starting a downtrend. This primarily consists of switching between mutual funds and money markets. Typically, technical trend-following indicators are used to determine the direction of a fund and identify buy and sell signals. In an up move "buy signal," money is transferred from a money market fund into a mutual fund in an attempt to capture a capital gain. In a down move "sell signal," the assets in the mutual fund are sold and moved back into the money market for safe keeping until the next up move. The goal is to avoid being invested in mutual funds during a market decline
Equity non-hedge	Predominately long equities although they have the ability to hedge with short sales of stocks and/or stock index options. These funds are commonly known as "stock-pickers." Some funds employ leverage to enhance returns. When market conditions warrant, managers may implement a hedge in the portfolio. Funds may also opportunistically short individual stocks. The important distinction between equity non-hedge funds and equity hedge funds is equity non-hedge funds do not always have a hedge in place. In addition to equities, some funds may have limited assets invested in other types of securities.

Appendix C: *Continued*

Equity hedge	Investing consists of a core holding of long equities hedged at all times with short sales of stocks and/or stock index options. Some managers maintain a substantial portion of assets within a hedged structure and commonly employ leverage. Where short sales are used, hedged assets may be comprised of an equal dollar value of long and short stock positions. Other variations use short sales unrelated to long holdings and/or puts on the S&P 500 index and put spreads. Conservative funds mitigate market risk by maintaining market exposure from 0 to 100%. Aggressive funds may magnify market risk by exceeding 100% exposure and, in some instances, maintain a short exposure. In addition to equities, some funds may have limited assets invested in other types of securities
Short selling	Involves the sale of a security not owned by the seller; a technique used to take advantage of an anticipated price decline. To effect a short sale, the seller borrows securities from a third party in order to make delivery to the purchaser. The seller returns the borrowed securities to the lender by purchasing the securities in the open market. If the seller can buy that stock back at a lower price, a profit results. If the price rises, however, a loss results. A short seller must generally pledge other securities or cash with the lender in an amount equal to the market price of the borrowed securities. This deposit may be increased or decreased in response to changes in the market price of the borrowed securities. *Source*: www.hfr.com

Notes

[1] *Source:* Flow of Funds Accounts of the United States, Board of Governors of the Federal Reserve System.

[2] Equity funds had a market value of $3.4 trillion, followed by money market funds ($2.3 trillion), bond ($0.9 trillion), and hybrid funds ($0.3 trillion) that are invested in equity, bonds, and derivatives.

[3] *Source: Mutual Fund Fact Book*, Investment Company Institute, 2001 (www.ici.org, "About Mutual Funds").

[4] The reader is referred to Kim *et al.* (2000) for a discussion of the issues involved in calculating the standard errors.

[5] Fund managers are typically evaluated by comparing the return on their portfolio with that of a performance benchmark index. The standard deviation of the excess return of the fund over the performance benchmark is referred to as the *performance benchmark tracking error*.

[6] Since the style coefficients are estimated after imposing the constraints, the estimated value of $\text{var}(r_p)$ will not in general equal the estimated value of $\text{var}(b_{p,1}x_{1,t} + b_{p,2}x_{2,t} + \cdots + b_{p,N}x_{N,t})$ + the estimated value of $\text{var}(e_p)$. Hence the R^2 computed using Eq. (4a) will not in general equal R^2 computed using the standard formula given by $R^2 = \text{var}(b_{p,1}x_{1,t} + b_{p,2}x_{2,t} + \cdots + b_{p,N}x_{N,t})/\text{var}(e_p)$.

[7] A number of other criteria have been proposed in the literature to adjust for the loss of degrees of freedom due to the use of a larger number of explanatory variables. For a discussion and justification of these criteria, see, e.g. Amemiya (1985).

[8] StyleAdvisor is a registered trademark, Zephyr Associates Inc. For more information see www.styleadvisor.com.

[9] Salomon 3-month US Treasury bill index.

[10] The joint of price-to-book ratio and analysts' growth forecasts used by Russell allows to classify about 70% of the stocks as purely value or growth, the remaining 30% are "weighted proportionally to both value and growth" (see www.russell.com, "US Equity Indexes: Construction & Methodology"). The weights always sum to 100% to ensure mutual exclusivity. For example, 20% of a stock may be in the value index and 80% in the growth index.

[11] The style box was introduced by Sharpe (1988) and Tierney and Winston (1991).

[12] Morningstar separates funds into three size classes and value, blend, and growth stocks, totaling nine quadrants (see www.morningstar.com, "Style Box: Help"). Since June 2002, Morningstar's market overview is summarized by 16 indexes. The new methodology assigns stocks to the different style orientations based on 10 variables (www.morningstar.com, "Morningstar Market Indexes").

[13] The SEC requires a prospectus to include the fund's goal, fees, and expenses, and a description of the investment strategies and risks.

[14] We select investor shares, class A, for all funds.

[15] This observation is consistent with the style changes over time. We will address style changes in Section 4.5. The exposures to the different asset classes of the Goldman Sachs Growth and Income, and to a lesser extent the

Alliance Growth & Income fund, shift much more than for the comparable funds of Putnam and Vanguard.

[16] The expense ratio includes all operating expenses incurred by the fund. The ranking using management fees alone is: 0.70% Goldman Sachs, 0.48% Alliance, 0.42% Putnam, and 0.36% Vanguard (*Source*: Morningstar).

[17] For selling shares, none of the funds imposes a back(-end) load, or named formally "contingent deferred sales charge".

[18] $(40/100) \times 10 + (30/100) \times 15 + (20/100) \times 20 + (10/100) \times 25 = 15$.

[19] The total market capitalization of the value index is 70 and the P/E ratio is calculated as $(40/70) \times 10 + (30/70) \times 15 = 12.1$.

[20] Buetow *et al*. (2000) replace the Russell 2000 with the BGI Small Cap indexes and use them in conjunction with the S&P Mid Cap and S&P 500. The correlation between the Russell 2000 and the BGI Small Cap indexes is 0.98 for the data period from January 1988 to December 2001. Analyzing the Fidelity Select Technology fund, the authors find a large increase in the exposure to the S&P Midcap 400 and S&P/Barra 500 Growth index over time when the Russell 2000 Growth index is replaced with the BGI Small Cap index. Using our 12 asset classes and substituting the Russell 2000 with the BGI Small Cap indexes and setting the size of the trailing window to 3 months, we cannot confirm this result.

[21] *Source*: www.spglobal.com, "S&P U.S. Indexes: Constituents and Data".

[22] *Source*: www.russell.com, "Russell Indexes: Construction and Methodology Details".

[23] An alternative approach to span the US equity styles pursued by Agarwal and Naik (2002) is to add the Fama-French size and value factors to the Russell 3000.

[24] The Frank Russell Company, for example, offers the Russell Top 200 Value and Growth index and the Russell 800 Midcap Value and Growth that add up to the Russell 1000.

[25] Based on the prospectus from January 2002, p. 3.

[26] See prospectus dated February 2002, p. 2.

[27] Information on holdings is taken from the fund's annual report, October 31, 2001.

[28] Morningstar takes the lesser of purchases or sales (excluding all securities with maturities of less than 1 year) in the nominator and the average monthly net assets in the denominator.

[29] "Quarterly review of mutual funds: decade's star Magellan likes financial stocks", *The Wall Street Journal*, July 7, 1990.

[30] "Magellan: what to expect from Stansky", *Business Week*, June 14, 1996; "Vinik quits Magellan as Stansky steps aboard", *The Wall Street Journal*, June 24, 1996.

[31] "Fidelity Magellan shifts investments, as net redemption rate slows down", *The Wall Street Journal*, September 6, 1996.

[32] "Sailing past the S&P 500", *Business Week*, February 1, 1999; "Magellan sails into uncharted waters", *The Wall Street Journal*, July 15, 1999.

[33] Lipper's US Diversified Equity (USDE) classification system, introduced in September 1999, classifies funds by the stocks they hold rather than their stated objectives. For details, see "Lipper U.S. Diversified Equity Fund Classification Source Document", *Lipper*, 2002; www.lipperweb.com, "USA Client Services: Fund Definitions".

[34] Most hedge funds are organized as private limited partnerships. The minimum investment level is often $1 million, whereas for 83% of the mutual funds the minimum investment requirement is $5000 or lower. Source: *Mutual Fund Fact Book*, Investment Company Institute, 2001.

[35] Many hedge funds have the so-called high water mark provisions. For example, suppose a manager has an incentive fee of 20% and he incurs a loss of $100 000 in year 1 and gains $300 000 in year 2. The fund first has to cross the high water mark before the fund manager participates in the gains. In year 2, he will earn $20\% \times (300\,000 - 100\,000) = \$40\,000$. The asymmetric fee structure, where managers enjoy a percentage of the earnings but do not have to rebate fees when losses occur, is not allowed in mutual funds. Fung and Hsieh (1999) discuss the legal differences between mutual and hedge funds and the history of regulations in detail.

[36] "Asset flow report, fourth quarter", *Tremont TASS Research*, 2001; www.tremontadvisers.com, "Research Library: Reports".

[37] Several papers have pointed out that returns on actively managed portfolios will have option-like features. The interested reader is referred to Merton (1981), Dybvig and Ross (1985), Jagannathan and Korajczyk (1986), and Glosten and Jagannathan (1994).

[38] Another approach to identify common factors in hedge fund returns is through principal component analysis of the returns on a large collection of hedge funds as in Fung and Hsieh (1997a). From a data set of 320 hedge funds and 89 commodity trading advisor pools (CTA) they extract five principal components, that is, five common investment styles. Two of the investment styles have high correlations with traditional asset classes. The R^2 is 70% for the style that involves buying undervalued

stocks and 56% for the style that involves investments in distressed companies. The style "distressed" can be captured by returns on high-yield corporate bonds, reducing the set of relevant, additional style factors to three. Using a distinct data set of 901 CTAs, Fung and Hsieh (1997b) find one dominant style factor, a strategy described as "trend-following". Note that the styles identified this way correspond to returns on some portfolios of hedge funds used in the principal component analysis.

[39] Agarwal and Naik (2000) allow for negative weights and investigate the impact of constraining the weights to add up to one. For a sample of eight HFR indexes from January 1994 to September 1998, they conclude that the R^2 increases by 1–16% if the constraint is dropped, with a bigger effect on non-directional strategies than directional strategies.

[40] We choose the slope, the kink, and the level of the horizontal right leg of the payoff diagram such that the squared deviations are minimized. An alternative is to run a linear spline regression [see e.g. Greene (1999) for an introduction] and choose a threshold value that maximizes the R^2. For merger arbitrage, the spline regression allows the segment to the right of the kink to have a nonzero slope. Using data from 1963 to 1998, Mitchell and Pulvino (2001) find a slightly positive slope coefficient to the right of the kink, but not significant at the 1% level.

[41] *Source*: www.marhedge.com.

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