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# Active Share, Tracking Error and Manager Style


## Abstract

Active Share is a relatively new portfolio risk metric which complements, and in some cases substitutes for, the traditional measure of tracking error. Investors, portfolio managers, and consultants are grappling with how to utilize this new statistic to better understand the sources of risk in active portfolios. Using simulations, we estimate expected Active Share metrics for typical domestic and international equity managers. We derive an analytical expression for the relationship between Active Share and tracking error and show that for unconstrained active managers, Active Share only directly affects the idiosyncratic component of active risk. Using simulated investment styles, we measure Active Share and tracking error relationships for four types of equity managers using real-world constraints. We show that manager style and market volatility significantly affect the relationship between these two metrics of benchmark-relative risk. Finally, we conduct an empirical study using a sample of managers benchmarked to selected domestic and international benchmarks to show that the data broadly supports our theoretical and simulation-based findings.



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## Introduction

The concept of tracking error – a portfolio's expected or realized statistical deviation from a benchmark return – is ubiquitous throughout the investment management industry. From the beginnings of Modern Portfolio Theory (Markowitz, 1952), to the advent of practitioner systems such as Barra in the 1980s (Rudd, 1988), to modern-day measures such as Conditional Value at Risk

(cVAR) (Ait-Sahalia and Lo, 1998) and extreme value theory (Novak, 2011), investors and investment managers are continually devising methods for determining how closely aligned their portfolios are to their respective benchmarks. Although tracking error is still considered the industry standard, the measure known as Active Share (Cremers and Petajisto, 2009) has garnered considerable interest in the investment community in recent years. Unlike the tracking error calculation, which relies on the covariance matrix of asset returns, Active Share is significantly easier to measure, requiring only two basic inputs: benchmark and portfolio weights. Today, many consultants are producing Active Share measures in the evaluation of their managers, and investment managers themselves are increasingly utilizing Active Share in their communications with investors.[3] Both Morningstar and Lipper have plans to make Active Share available to their users in 2013.[4] As a result, the use of Active Share is becoming much more commonplace in the investment management industry.

In part, the gravitation toward Active Share has been a function of its simplicity. The formula's lack of reliance on variances and covariances, which can be challenging to measure (Ledoit and Wolf, 2003), makes Active Share a particularly convenient tool for measuring the "activeness" of managers. Beyond its ease-of-use, however, Active Share is often cited as a measure quantifying the "desirable" component of tracking error. This interpretation follows from the original findings on Active Share, which showed that high Active Share mutual funds have shown historically positive and persistent alpha, whereas no direct link was found for tracking error.[5] Hence, at least empirically, managers who assume both high tracking error and high Active Share have on average outperformed their respective benchmarks.

Still, despite the well-documented findings in the historical performance data, the jury remains out on precisely what Active Share measures. What does it mean for a portfolio to have a "high" Active Share? What are the properties which determine a manager's Active Share and what is the role of the benchmark? Can we compare the Active Shares of managers benchmarked to different indices? In this paper, we attempt to take the Active Share debate beyond just its usefulness as a predictor of performance. Using a mathematical model and simulation to motivate intuition, as well as empirical data to confirm the model results, we add to the dialogue by formally linking together Active Share, manager style, and tracking error.

Our paper is organized as follows. In Section 2, we use simulation-based portfolios to show how the interpretation of Active Share is conditional upon the nature of the benchmark and manager style. Section 3 utilizes a set of simplifying assumptions to show that mathematically Active Share can be considered as an alternative measure of a portfolio's idiosyncratic risk. In Section 4, we use the Fama-French 3-factor model to build style portfolios and show that the relationship between Active Share and tracking error is highly dependent on both manager style and the level of risk in the marketplace. Finally, we present empirical evidence on Active Share and tracking error using a sample of some of the largest mutual funds benchmarked to domestic and international indices.

## Active share and benchmarks

Active Share measures the deviation in portfolio weights from a benchmark as follows:

$$AS = \frac{1}{2}\sum_{i=1}^{N}|w_i - w_{bi}| \qquad (1)$$

where $w_i$ is the weight of asset $i$ in the portfolio, $w_{bi}$ is the weight of asset $i$ in the benchmark, and $N$ is the number of names in the superset of the benchmark and investment portfolio.[6] For long-only, unleveraged portfolios, Active Share is bounded between 0 and 100%, with zero representing an index fund and 100% representing a portfolio holding all of its names outside of the benchmark.

The characteristics of a benchmark, such as the number of securities, can have a significant influence on the Active Share potential of a manager. Thus, in attempting to understand the relationship between manager style and Active Share, it

is important to examine not just the manager's weighting methodology, but the nature of the benchmark as well. To motivate intuition, we consider two distinct manager weighting schemes: cap-weighted and equally-weighted. In our framework, equally-weighted portfolios are intended to capture an investment style which is completely agnostic to a cap-weighted benchmark. For example, managers who focus solely on holding assets which they deem attractively valued, irrespective of the benchmark characteristics, would fall into this category. Conversely, capitalization-weighted portfolios are designed to capture the investment approach of managers who are more benchmark-centric, often focusing on broad investment themes or styles. Examples might include a manager who focuses on taking tilts to various economic sectors as well as many ETF-based investment strategies.

In our study, we created six sets of equally-weighted and capitalization-weighted portfolios, each holding 25, 50, 100, 200, 300, 400 and 500 names, respectively. To create our portfolios, we generated a series of random sequences without replacement from a uniform distribution, ranging from 25 to 500 draws. Each draw represented an assignment to a weight in a capitalization-weighted benchmark. For example, a draw of 1 would be assigned to the largest stock in the index. Once assigned to a benchmark weight, equally-weighted portfolios were weighted by $\frac{1}{N}$. Capitalization-weighted portfolios were assigned weights proportional to the benchmark weight. For example, a two-stock portfolio, randomly assigned to benchmark weights of 3% and 1%, would be weighted as 75% and 25%, on the first and second assets, respectively. Active weights were then measured using Equation 1. Simulations were run 100,000 times for each portfolio relative to the S&P 500 and the MSCI All Country World ex-US indices. Table 1 shows average, standard deviation, minimum, and maximum Active Share for each portfolio vs. their respective benchmark. We have also measured Active Share for each of the portfolios relative to an equally-weighted index in order to show the effect of benchmark concentration.

Unsurprisingly, cap-weighted active portfolios have systematically lower Active Share than their equally-weighted counterparts vs. cap-weighted benchmarks. This distinction becomes particularly pronounced as the level of diversification increases. As the number of names in the portfolio increase, cap-weighted active portfolios more closely resemble the underlying index, approaching a pure index fund as $N$ grows larger. Conversely, equally-weighted portfolios retain more of their "activeness," as their position weights are independent of their assigned benchmark weights. As a result, even with 500 positions, equally-weighted portfolios are characterized by Active Share of 46.6% and 72.8% vs. the S&P 500 and MSCI ACWI ex-US benchmarks, respectively. The very active nature of concentrated managers – those holding 50 or fewer names – is noted by Active Share measures exceeding 90% vs. both benchmarks. Cremers et al. (2009) characterizes managers with Active Share in the 20%-60% range as "low." In the context of Table 1, we would generally agree – at least for domestic portfolios – since S&P 500-benchmarked portfolios don't fall within this range until they reach 300 names.

We find that Active Share metrics are materially higher for global portfolios compared to domestic portfolios. This is due to the fact that the MSCI ACWI ex-US index holds in excess of three times the number of names as the S&P 500.[8] As a result, each respective active global portfolio represents a smaller fraction of the benchmark compared to the domestic-only portfolios, resulting in higher levels of Active Share for international managers. Active Share, therefore, must be placed within the context of the diversification of a manager's benchmark. The fact that a seemingly well-diversified 500-stock international portfolio can have a relatively high Active Share of 76%, highlights the importance that the benchmark plays in the Active Share calculation.

While conventional wisdom is that top-heavy, cap-weighted indices represent more difficult benchmarks with which to achieve a high Active Share, Table 1 shows that the relationship between benchmark skewness and Active Share is ambiguous at best. We can isolate the impact of benchmark concentration by comparing the Active Share for cap-weighted vs. equally-weighted benchmarks (i.e. reading the rows of Table 1). First, for very concentrated managers, there is virtually no difference in Active Share for portfolios benchmarked against cap vs. equal-weighted indices; for domestic portfolios with fewer

### TABLE 1: ACTIVE SHARE FOR DOMESTIC AND INTERNATIONAL PORTFOLIOS[7]

Table 1 shows Active Share for equally and capitalization-weighted active portfolios, holding between 25 and 500 assets. We generated 100,000 simulations for each type of portfolio vs. the S&P 500 and the MSCI All Country World ex-US indices. The data show that Active Share is higher for equally-weighted managers relative to capitalization-weighted managers and for managers whose benchmarks hold larger numbers of names. As the level of diversification increases, the contrast between equally and capitalization-weighted portfolios becomes particularly pronounced.

| | | vs. S&P 500 | | | | vs. EqW S&P 500 | | | |
|---|---|---|---|---|---|---|---|---|---|
| Names | Weighting | Mean | Std | Min | Max | Mean | Std | Min | Max |
| 25 | Equal-Weighted | 95% | 2% | 84% | 99% | 95% | 0% | 95% | 95% |
| | Cap-Weighted | 95% | 2% | 83% | 99% | 95% | 0% | 95% | 95% |
| 50 | Equal-Weighted | 90% | 2% | 78% | 96% | 90% | 0% | 90% | 90% |
| | Cap-Weighted | 90% | 3% | 74% | 96% | 90% | 0% | 90% | 91% |
| 100 | Equal-Weighted | 83% | 2% | 73% | 90% | 80% | 0% | 80% | 80% |
| | Cap-Weighted | 80% | 3% | 64% | 90% | 81% | 0% | 80% | 84% |
| 200 | Equal-Weighted | 71% | 2% | 65% | 77% | 60% | 0% | 60% | 60% |
| | Cap-Weighted | 60% | 4% | 43% | 74% | 67% | 1% | 64% | 71% |
| 300 | Equal-Weighted | 61% | 1% | 56% | 66% | 40% | 0% | 40% | 40% |
| | Cap-Weighted | 40% | 4% | 26% | 56% | 58% | 1% | 53% | 62% |
| 400 | Equal-Weighted | 53% | 1% | 50% | 56% | 20% | 0% | 20% | 20% |
| | Cap-Weighted | 20% | 3% | 9% | 36% | 52% | 1% | 47% | 54% |
| 500 | Equal-Weighted | 47% | 0% | 47% | 47% | 0% | 0% | 0% | 0% |
| | Cap-Weighted | 0% | 0% | 0% | 0% | 47% | 0% | 47% | 47% |

| | | vs. MSCI ACWI-ex US | | | | vs. EqW ACWI-ex US | | | |
|---|---|---|---|---|---|---|---|---|---|
| Names | Weighting | Mean | Std | Min | Max | Mean | Std | Min | Max |
| 25 | Equal-Weighted | 99% | 1% | 95% | 100% | 99% | 0% | 99% | 99% |
| | Cap-Weighted | 99% | 1% | 95% | 100% | 99% | 0% | 99% | 99% |
| 50 | Equal-Weighted | 97% | 1% | 92% | 99% | 97% | 0% | 97% | 97% |
| | Cap-Weighted | 97% | 1% | 92% | 99% | 97% | 0% | 97% | 97% |
| 100 | Equal-Weighted | 95% | 1% | 89% | 97% | 95% | 0% | 95% | 95% |
| | Cap-Weighted | 95% | 1% | 89% | 97% | 95% | 0% | 95% | 95% |
| 200 | Equal-Weighted | 90% | 1% | 85% | 94% | 89% | 0% | 89% | 89% |
| | Cap-Weighted | 89% | 1% | 82% | 94% | 89% | 0% | 89% | 90% |
| 300 | Equal-Weighted | 85% | 1% | 80% | 90% | 84% | 0% | 84% | 84% |
| | Cap-Weighted | 84% | 2% | 76% | 90% | 84% | 0% | 84% | 86% |
| 400 | Equal-Weighted | 82% | 1% | 76% | 86% | 78% | 0% | 78% | 78% |
| | Cap-Weighted | 78% | 2% | 70% | 85% | 80% | 0% | 79% | 82% |
| 500 | Equal-Weighted | 78% | 1% | 74% | 82% | 73% | 0% | 73% | 73% |
| | Cap-Weighted | 73% | 2% | 64% | 80% | 76% | 0% | 75% | 78% |

than 100 names, Active Share measures are largely the same, while for international portfolios, benchmark skew makes almost no difference at all levels of portfolio concentration. For more diversified managers, equally-weighted portfolios have materially higher Active Share vs. a cap-weighted index than vs. an equally-weighted index. Hence, a concentrated benchmark, rather than acting as a hindrance, can actually assist a manager in achieving high Active Share.

### The general relationship between active share and tracking error

In its simplest form, active management entails taking active exposures to systematic factors and idiosyncratic security-specific risk, with the expectation of outperforming a market benchmark. Typical systematic tilts for an equity manager might be active exposures to size, value, or beta, while for a fixed income manager, the most significant active exposure is usually duration. Stock-specific exposures are tilts toward specific assets, irrespective of an asset's systematic risk. Examples would include exposures to unexpected earnings news, regulatory issues involving a specific company, or bets on corporate mergers.

Consider an active manager who takes active exposure to a single risk factor, in addition to incurring active stock specific risk. We assume that the returns of assets are governed by the basic single-factor model $r_{i,t} = \beta_i f_t + e_{i,t}$ where $r_{i,t}$ is the return to asset $i$ in period $t$, $\beta_i$ represents asset $i$'s exposure to the risk factor, $f_t$ represents the return to the risk factor over period $t$, and $e_{i,t}$ is a random noise term specific to asset $i$. We show in the Appendix that for an unconstrained active manager taking exposures over $N$ assets, the relationship between tracking error $(TE)$ and Active Share $(AS)$ can be expressed as:

$$TE = \left[\beta_a^2 Var(f) + AS^2 \frac{2\pi}{N} \overline{\sigma_e^2}\right]^{0.5} \quad (2)$$

where $\beta_a^2$ is the portfolio's active exposure to the risk factor, $Var(f)$ is the factor variance, and $\overline{\sigma_e^2}$ is the average idiosyncratic variance of all assets in the investable universe.[9,10]

The first term in Equation 2, $\beta_a^2 Var(f)$, is the component of tracking error coming from a manager's exposure to the systematic risk factor. To the extent a manager specifically neutralizes systematic exposure relative to their market benchmark, her portfolio would be characterized by $\beta_a^2 = 0$ and thus any tracking error risk would come solely from the Active Share decision. Importantly, Equation 2 shows that, for an unconstrained portfolio, Active Share only directly affects the idiosyncratic component of tracking error. This occurs because, while a high Active Share portfolio may produce high systematic risk, it need not do so; portfolios can contain a high or low degree of systematic risk irrespective of the level of Active Share. In other words, the systematic risk decision is independent of the Active Share decision. As a result, Active Share is absent from the systematic component of tracking error in Equation 2.

Equation 2 also shows that the relationship between Active Share and tracking error need not be constant. Although we have removed the time subscripts in Equation 2 for notational simplicity, the variables $Var(f)$ and $\overline{\sigma_e^2}$ will vary with the level of systematic and idiosyncratic risk in the market. For example, for a given level of Active Share, the tracking error of managers at the height of the Credit Crisis in 2008 would be much higher than, say, in 2005 - the heart of what has commonly become known as "The Great Moderation". Thus, we must consider the relationship between tracking error and Active Share as *conditional*, in the sense that the level of market volatility will affect the relationship between the two variables.

In order to provide intuition around Equation 2, in Table 2 below we show expected manager tracking errors by varying the levels of Active Share and $N$. Assuming a volatility of 15% for the market factor (roughly the long-run volatility of the S&P 500) and 30% average idiosyncratic volatility for an asset, we use Equation 2 to show expected tracking error levels for each level of Active Share. Consistent with Equation 2, tracking error is positively related to the level of Active Share and inversely related to $N$. Further, the marginal impact to tracking error of increasing Active Share is much higher for concentrated investment portfolios, a finding which we confirm in the next section.

**TABLE 2: TRACKING ERROR FOR VARIOUS LEVELS OF ACTIVE SHARE**

Table 2 shows the predicted tracking errors for various levels of Active Share from Equation 2. Tracking errors are based on assumed values of 15% for the volatility of the market factor 30% for the average level of idiosyncratic volatility, and 0.1 active exposure to the risk factor.

| | Active Share | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1 |
| 50 | 1.8% | 2.6% | 3.5% | 4.5% | 5.5% | 6.6% | 7.6% | 8.6% | 9.7% | 10.7% |
| 100 | 1.7% | 2.1% | 2.7% | 3.4% | 4.0% | 4.8% | 5.5% | 6.2% | 6.9% | 7.7% |
| 250 | 1.6% | 1.8% | 2.1% | 2.4% | 2.8% | 3.2% | 3.7% | 4.1% | 4.5% | 5.0% |
| 500 | 1.5% | 1.6% | 1.8% | 2.0% | 2.3% | 2.5% | 2.8% | 3.1% | 3.4% | 3.7% |

## Manager style, active share and tracking error

In the prior section, we derived the general relationship between Active Share and tracking error for the unconstrained active manager who holds all assets in the benchmark. While clearly not indicative of the manner in which active managers invest in the real world, Equation 2 is useful because it provides intuition for the drivers of tracking error and how they relate to Active Share. Arguably, what is of more interest to investors is the relationship between these variables for real-world long-only, unleveraged investment portfolios. In this section, we use the insights from the prior section's theoretical results to define broad categories of active management and then test how the relationship between Active Share and tracking error relate to manager style, using real-world constraints.

We consider four types of equity managers: Pure Stock Pickers (PSP), Pure Style Managers (PSM), Factor-Neutral Stock Pickers (FNSP), and Quasi-Indexers (QI). Table 3 summarizes each of our manager categories. For each manager style, we generate simulated portfolios to characteristically match the descriptions in Table 3, while varying the level of concentration (Active Share). For example, for the Pure Stock Pickers (PSP), we created equally-weighted portfolios by maximizing the portfolio's expected return subject to a maximum position size and maximum number-of-names constraint. FNSP portfolios are generated similarly to the PSPs, except we add an additional constraint that each portfolio must be neutral to the benchmark with respect to the Fama-French 3-factor model. We provide a detailed description of the methodology for each style in the Appendix.

**TABLE 3 : MANAGER STYLES AND DESCRIPTIONS[11]**

Table 3 describes general categories for four distinct types of investment managers. Each manager style is designed to reflect varying degrees of systematic risk and Active Share. These manager definitions are subsequently utilized by simulating each style and assessing the relationship between Active Share and ex-ante tracking error.

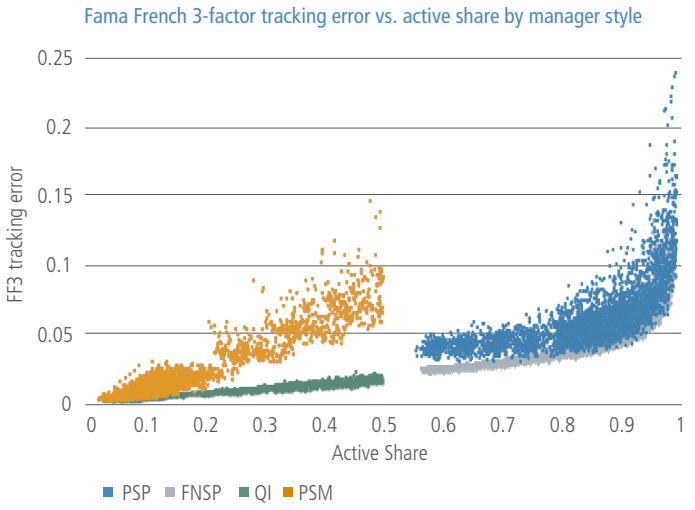
| Style category | Description |
|---|---|
| Pure Stock Picker (PSP) | Pure bottoms-up stock selection in the spirit of Graham and Dodd (1934). Do not consider the benchmark in their investment decisions. Portfolios are concentrated in a small number of names and may contain large systematic tilts. |
| Pure Style Manager (PSM) | Only invests in broad systematic factors such as value stocks or economic sectors. Factor tilts may be static or dynamic. Portfolios are typically diversified at the asset level. |
| Factor-Neutral Stock Picker (FNSP) | Bottoms-up stock selection within styles or factors. Example would be a sector neutral manager who focuses on his best ideas within a sector, but remains sector neutral at the portfolio level. |
| Quasi-Indexer (QI) | Explicitly or implicitly eliminates active factor bets. Well-diversified at the asset level. Holds large numbers positions and looks like the benchmark in nearly all respects. |

Once portfolios were generated for each style, we measured the ex-ante tracking error of the portfolio using the 3-factor model. Because the relationship between Active Share and tracking error is conditional upon the level of market volatility, we measured the relationship over three distinct market regimes. We define a market regime as being a 'low', 'moderate', or 'high-risk' market, based on the three-year trailing average level of the CBOE VIX index.[12] A 3-year

estimation window was chosen to match the estimation window for our risk model. The highest and lowest 3-year VIX levels were for the years ended 2010 and 2006, respectively. For our "moderate" VIX year we chose 2004, which was elevated due to the recessionary years in the early part of the decade but did not reach levels associated with the 2008 Credit Crisis. In Figure 1 below, we plot the relationship between Active Share and ex-ante tracking error for each manager style for the high volatility market regime.

**FIGURE 1: ACTIVE SHARE VS. TRACKING ERROR BY MANAGER STYLE (2010:12)**

Figure 1 shows the relationship between Active Share and tracking error conditional on manager style. The ex-ante tracking error is measured using the Fama-French 3-factor risk model as of 2010:12, the most volatile year-end period in our sample. The four types of manager styles are: Pure Stock Pickers (PSP), Factor-Neutral Stock Pickers (FNSP), Pure Style Managers (PSM), and Quasi-Indexers (QI). PSMs have the highest tracking errors per unit of Active Share, followed by PSPs, FNSPs, and QIs.




Consistent with Equation 2, Figure 1 shows that the Pure Style Managers (PSMs) have the highest ex-ante tracking error per unit of Active Share (Equation 2 shows that holding Active Share fixed, portfolios with higher active systematic risk will have higher tracking errors). Unlike stock pickers, who tend to focus on the idiosyncratic component of return, PSMs intentionally take large active bets on systematic risk factors, thus increasing tracking error at all levels of Active Share.[13]

Simply by virtue of their concentrated investment styles, both PSPs and FNSPs have high overall Active Share, varying between 0.5 and 1. However, while PSPs and FNSPs are characterized by similar levels of stock-specific concentration, they differ with regard to the level of systematic risk each incurs. Specifically, unlike PSPs who are willing to incur incidental systematic risk, FNSPs consciously neutralize their exposure with respect to the benchmark.[14] As a result, and consistent with Equation 2, FNSPs have systematically lower tracking error per unit of Active Share relative to their PSP counterparts. Closet Indexers (QIs), who simply attempt to track the benchmark, have systematically lower tracking error than the other three manager styles at all levels of Active Share.

We repeat our simulation analysis for low (2006:12) and moderate (2004:12) market regimes and show the average results in Table 4. As expected, Table 4 shows tracking error monotonically increasing with Active Share for all manager styles. Pure Style Managers have the highest level of tracking error per unit of Active Share, followed by Pure Stock Pickers, and Factor-Neutral stock pickers. Additionally, we see that at each level of Active Share, tracking error increases as we migrate from a low volatility regime (2006:12) to a high volatility regime (2010:12).[15]

## Empirical methodology and results

Thus far, the discussion has focused on using both a theoretical and simulation-based framework to develop a broader understanding of the relationship between Active Share and tracking error. We have shown in our controlled setting that the link between these metrics of active risk is conditional on factors such as the nature of the manager's benchmark, investment style, and market volatility. In this section, we conduct an empirical analysis to explore whether real-world data supports our findings in the prior sections. Using a sample of some of the largest U.S. mutual funds benchmarked to a representative list of domestic and international benchmarks, we measure the empirical relationship between Active Share, manager style, and tracking error.

We obtained the names of mutual funds sorted by assets-under-management (AUM) from the EFPR Fund-of-Flows Database as of 12/31/2012. Using the Factset Ownership Database, we extracted monthly returns and quarterly holdings for our set of mutual funds benchmarked against the S&P 500, Russell 2000, and MSCI ACWI ex-US. Indices.[16] Typically, large investment firms offer several mutual funds with differing investment styles benchmarked to the same index. For example, the list of top 20 mutual funds benchmarked to the S&P 500 includes three mutual funds managed by Fidelity: The Fidelity Contrafund Fund, The Fidelity Magellan Fund, and The Fidelity Dividend Growth Fund. For our study, we selected just the mutual fund with the highest AUM within each fund family.[17] We selected the top-10 mutual funds benchmarked to the Russell 2000, all mutual funds benchmarked to ACWI ex – US (there are just 7 active mutual funds with this benchmark) and 29 S&P 500 managers. As of 12/31/2012, our sample of mutual funds represented $438bn in total AUM.[18]

We then computed Active Share using Equation 1 for each manager relative to their benchmark. We also calculated the historical 3-year tracking error using monthly returns for year-ends 2004, 2006, 2010 and 2012, for each fund. Tables 5a-c show Active Share and tracking error for mutual funds grouped by each fund's relevant benchmark.[19]

Tables 5a-c show that tracking error is positively influenced by Active Share and is higher in elevated volatility regimes. Consistent with our earlier results, we see that Active Share is

**TABLE 4: AVERAGE TRACKING ERROR BY VOLATILITY REGIME AND MANAGER STYLE**

Table 4 shows the average level of ex-ante tracking error for various Active Share bins from our simulation data. Because tracking error is conditional on the level of market volatility, we condition our data on three specific volatility regimes. We show that Pure Style Managers have the highest level of tracking error per unit of Active Share, followed by Pure Stock Pickers and Factor-Neutral Style Managers. As expected, tracking error increases for each manager style moving from a low to a high volatility regime.

| PSP | 0–0.10 | 0.10–0.20 | 0.20–0.30 | 0.30–0.40 | 0.40–0.50 | 0.50–0.60 | 0.60–0.70 | 0.70–0.80 | 0.80–0.90 | 0.90–1 |
|---|---|---|---|---|---|---|---|---|---|---|
| Low (2006) | – | – | – | – | – | 2.5% | 2.6% | 2.9% | 3.5% | 5.4% |
| Mod (2004) | – | – | – | – | – | 4.3% | 4.5% | 4.7% | 5.5% | 8.1% |
| High (2010) | – | – | – | – | – | 3.9% | 4.1% | 4.6% | 5.5% | 8.6% |

| PSM | 0–0.10 | 0.10–0.20 | 0.20–0.30 | 0.30–0.40 | 0.40–0.50 | 0.50–0.60 | 0.60–0.70 | 0.70–0.80 | 0.80–0.90 | 0.90–1 |
|---|---|---|---|---|---|---|---|---|---|---|
| Low (2006) | 0.3% | 0.8% | 1.7% | 2.9% | 4.1% | – | – | – | – | – |
| Mod (2004) | 0.6% | 1.3% | 2.5% | 5.0% | 6.9% | – | – | – | – | – |
| High (2010) | 0.6% | 1.4% | 3.4% | 5.3% | 7.2% | – | – | – | – | – |

| FNSP | 0–0.10 | 0.10–0.20 | 0.20–0.30 | 0.30–0.40 | 0.40–0.50 | 0.50–0.60 | 0.60–0.70 | 0.70–0.80 | 0.80–0.90 | 0.90–1 |
|---|---|---|---|---|---|---|---|---|---|---|
| Low (2006) | – | – | – | – | – | 1.6% | 1.7% | 2.0% | 2.7% | 4.5% |
| Mod (2004) | – | – | – | – | – | 2.0% | 2.2% | 2.7% | 3.6% | 5.9% |
| High (2010) | – | – | – | – | – | 2.3% | 2.6% | 3.2% | 4.2% | 6.9% |

| QI | 0–0.10 | 0.10–0.20 | 0.20–0.30 | 0.30–0.40 | 0.40–0.50 | 0.50–0.60 | 0.60–0.70 | 0.70–0.80 | 0.80–0.90 | 0.90–1 |
|---|---|---|---|---|---|---|---|---|---|---|
| Low (2006) | 0.1% | 0.3% | 0.6% | 0.9% | 1.1% | – | – | – | – | – |
| Mod (2004) | 0.2% | 0.4% | 0.8% | 1.1% | 1.5% | – | – | – | – | – |
| High (2010) | 0.3% | 0.4% | 0.8% | 1.1% | 1.4% | – | – | – | – | – |

materially higher for Russell 2000 managers compared to S&P 500 managers. To further emphasize the role the benchmark plays in the determination of Active Share, Figure 3 shows average Active Share for each group of managers at the four time snapshots presented in Table 5. Consistent with the simulated data in Table 1, Figure 2 shows that managers benchmarked to more diversified indexes (in terms of number of securities) have higher Active Share. For example, as of 12/31/2012, the average Active Share for S&P 500 managers was 75.4 vs. 93.2 for managers benchmarked to the Russell 2000. While it's conceivable that managers may diversify their portfolios in the presence of elevated market volatility (thus resulting in an inverse relation between Active Share and volatility), Figure 2 shows no such relationship; manager diversification appears largely unaffected by the level of market risk.

**FIGURE 2: AVERAGE ACTIVE SHARES FOR MUTUAL FUNDS BY BENCHMARK**

Figure 2 shows the average Active Share by manager benchmark, by volatility regime. The data is taken directly from Table 5. Consistent with the results in Table 1, we find that Active Share is materially higher for managers benchmarked against more diversified benchmarks. Active Share does not appear to be conditional upon volatility regime.

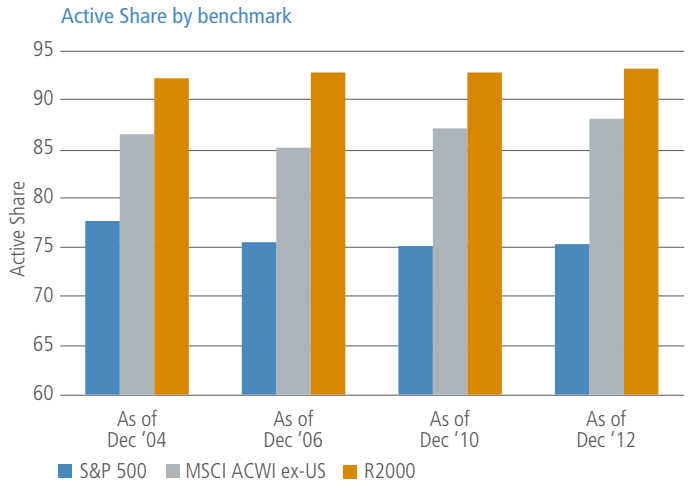
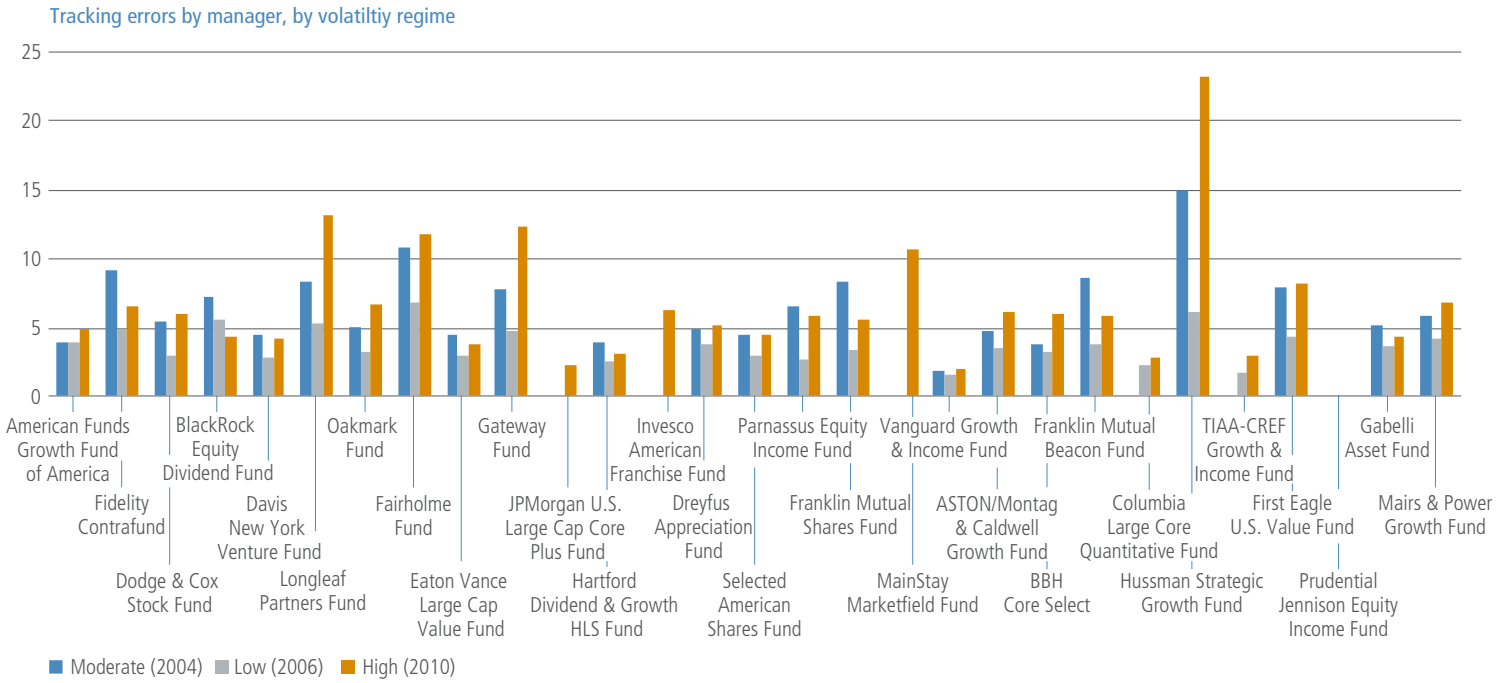



**FIGURE 3: TRACKING ERROR FOR MUTUAL FUNDS BENCHMARKED TO S&P 500 BY VOLATILITY REGIME**

Figure 3 shows the three-year realized tracking errors for managers benchmarked to the S&P 500 index. Consistent with the theoretical results in prior sections, Figure 5 shows that manager tracking errors are positively related to the level of market volatility



### TABLE 5A: ACTIVE SHARES AND TRACKING ERROR FOR SELECTED LARGE MUTUAL FUNDS: S&P 500

Tables 5a-c shows Active Share and tracking error for mutual funds in our sample benchmarked to the S&P 500, MSCI All World ex-US and Russell 2000 indices, respectively. Consistent with our prior results, tracking error is positively related to Active Share and is higher in periods associated with higher volatility. Additionally, we see that Active Shares are higher when compared to more diversified benchmarks.

| | 31 Dec 2004 | | 31 Dec 2006 | | 31 Dec 2010 | | 31 Dec 2012 | |
|---|---|---|---|---|---|---|---|---|
| Mutual Fund | Active Share | Tracking Error | Active Share | Tracking Error | Active Share | Tracking Error | Active Share | Tracking Error |
| American Funds Growth Fund of America | 70% | 4.0% | 66% | 3.9% | 56% | 4.8% | 69% | 3.1% |
| Fidelity Contrafund | 79% | 9.2% | 71% | 4.9% | 73% | 6.5% | 67% | 4.1% |
| Dodge & Cox Stock Fund | 84% | 5.4% | 79% | 3.0% | 81% | 6.0% | 81% | 3.6% |
| BlackRock Equity Dividend Fund | 69% | 7.2% | 66% | 5.6% | 60% | 4.4% | 61% | 3.3% |
| Davis New York Venture Fund | 85% | 4.5% | 79% | 2.8% | 80% | 4.2% | 84% | 2.8% |
| Longleaf Partners Fund | 98% | 8.3% | 97% | 5.3% | 97% | 13.1% | 96% | 6.8% |
| Oakmark Fund | 86% | 5.0% | 83% | 3.2% | 76% | 6.6% | 75% | 3.0% |
| Fairholme Fund | 98% | 10.8% | 99% | 6.7% | 94% | 11.7% | 99% | 14.7% |
| Eaton Vance Large Cap Value Fund | 73% | 4.5% | 67% | 2.9% | 63% | 3.8% | 62% | 2.2% |
| Gateway Fund | 50% | 7.8% | 47% | 4.7% | 39% | 12.3% | 35% | 9.7% |
| JPMorgan US Large Cap Core Plus Fund | – | – | 65% | – | 64% | 2.2% | 76% | 3.0% |
| Hartford Dividend & Growth HLS Fund | 66% | 4.0% | 63% | 2.6% | 61% | 3.1% | 61% | 2.1% |
| Invesco American Franchise Fund | – | – | 95% | – | 80% | 6.2% | 71% | 5.7% |
| Dreyfus Appreciation Fund | 64% | 4.8% | 66% | 3.7% | 69% | 5.2% | 68% | 3.7% |
| Selected American Shares Fund | 85% | 4.5% | 80% | 2.9% | 82% | 4.4% | 84% | 2.6% |
| Parnassus Equity Income Fund | 88% | 6.5% | 85% | 2.7% | 87% | 5.8% | 91% | 3.9% |
| Franklin Mutual Shares Fund | 97% | 8.3% | 88% | 3.4% | 85% | 5.6% | 83% | 3.7% |
| MainStay Marketfield Fund | – | – | – | – | 88% | 10.7% | 91% | 9.9% |
| Vanguard Growth & Income Fund | 60% | 1.9% | 63% | 1.6% | 55% | 2.0% | 26% | 1.2% |
| ASTON/Montag & Caldwell Growth Fund | 78% | 4.7% | 81% | 3.5% | 79% | 6.2% | 77% | 3.7% |
| BBH Core Select | 78% | 3.7% | 89% | 3.2% | 89% | 6.0% | 87% | 4.3% |
| Franklin Mutual Beacon Fund | 97% | 8.5% | 88% | 3.8% | 89% | 5.9% | 86% | 3.7% |
| Columbia Large Core Quantitative Fund | 69% | – | 55% | 2.3% | 62% | 2.8% | 67% | 1.9% |
| Hussman Strategic Growth Fund | 80% | 15.0% | 77% | 6.2% | 81% | 23.1% | 101% | 21.8% |
| TIAA-CREF Growth – & Income Fund | 38% | – | 57% | 1.7% | 50% | 2.9% | 53% | 1.8% |
| First Eagle U.S. Value Fund | 95% | 7.9% | 89% | 4.3% | 88% | 8.2% | 87% | 5.2% |
| Prudential Jennison Equity Income Fund | 68% | – | 54% | – | 84% | – | 87% | 4.0% |
| Gabelli Asset Fund | 81% | 5.2% | 78% | 3.6% | 76% | 4.3% | 76% | 3.2% |
| Mairs & Power Growth Fund | 86% | 5.9% | 88% | 4.2% | 88% | 6.8% | 88% | 4.8% |
| Average | 78% | 6.4% | 76% | 3.7% | 75% | 6.6% | 75% | 4.9% |

**TABLE 5B: ACTIVE SHARES AND TRACKING ERROR FOR SELECTED LARGE MUTUAL FUNDS: MSCI ACWI**

| | 31 Dec 2004 | | 31 Dec 2006 | | 31 Dec 2010 | | 31 Dec 2012 | |
|---|---|---|---|---|---|---|---|---|
| Mutual Fund | Active Share | Tracking Error | Active Share | Tracking Error | Active Share | Tracking Error | Active Share | Tracking Error |
| Hansberger International Fund | 76% | 3.3% | 76% | 2.7% | 79% | 5.2% | 91% | 4.5% |
| Manning & Napier Overseas Fund | 99% | – | 95% | 4.4% | 94% | 6.7% | 92% | 4.5% |
| Manning & Napier International Fund | 85% | 6.5% | 84% | 4.0% | 88% | 6.8% | 89% | 4.2% |
| Rainier International Discovery Fund | – | – | – | – | – | – | 99% | – |
| GMO International Intrinsic Value Extended Markets Fund | – | – | – | – | – | – | 71% | – |
| BNY Mellon International Equity Income Fund | – | – | – | – | – | – | 89% | – |
| Transamerica International Value Opportunities Fund | – | – | – | – | – | – | 85% | – |
| Average | 87% | 4.9% | 85% | 3.7% | 87% | 6.2% | 88% | 4.4% |

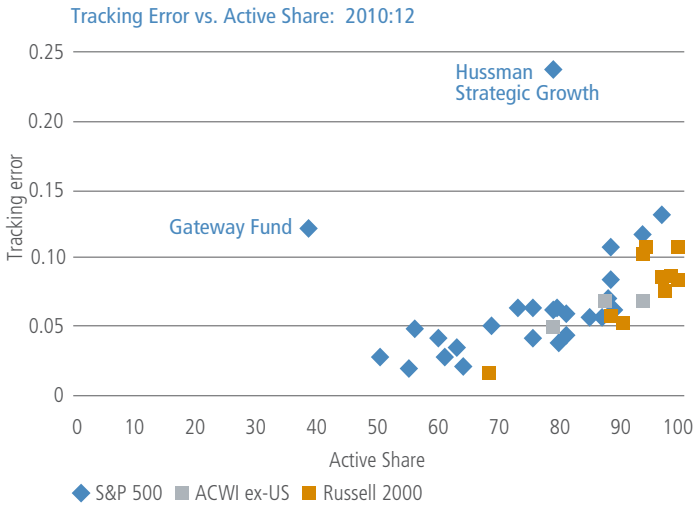
**TABLE 5C: ACTIVE SHARES AND TRACKING ERROR FOR SELECTED LARGE MUTUAL FUNDS: RUSSELL 2000**

| | 31 Dec 2004 | | 31 Dec 2006 | | 31 Dec 2010 | | 31 Dec 2012 | |
|---|---|---|---|---|---|---|---|---|
| Mutual Fund | Active Share | Tracking Error | Active Share | Tracking Error | Active Share | Tracking Error | Active Share | Tracking Error |
| Neuberger Berman Genesis Fund | 96% | 9.5% | 96% | 7.5% | 94% | 10.6% | 91% | 6.8% |
| Royce Premier Fund | 98% | – | 98% | 6.0% | 97% | 8.1% | 97% | 5.6% |
| Longleaf Partners Small Cap Fund | 100% | 11.6% | 99% | 7.6% | 99% | 10.9% | 99% | 8.3% |
| Keeley Small Cap Value Fund | 96% | 8.6% | 93% | 7.5% | 93% | 10.5% | 92% | 4.4% |
| Gabelli Small Cap Growth Fund | 92% | 6.5% | 92% | 4.6% | 89% | 6.1% | 86% | 4.6% |
| TIAA-CREF Small Cap Equity Fund | 52% | – | 65% | 1.4% | 68% | 1.9% | 78% | 1.7% |
| Brown Capital Management-Small Company Fund | 99% | 9.5% | 99% | 6.8% | 98% | 8.8% | 98% | 7.1% |
| Tocqueville Delafield Fund | – | 7.0% | – | 5.8% | 99% | 8.7% | 98% | 5.5% |
| Columbia Acorn USA Fund | 97% | 4.2% | 94% | 5.1% | 90% | 5.5% | 93% | 3.9% |
| Invesco Select Companies Fund | 99% | – | 99% | 7.5% | 100% | 8.7% | 99% | 6.4% |
| Average | 92% | 8.1% | 93% | 6.0% | 93% | 8.0% | 93% | 5.4% |

In the prior section, we conditioned our sample based on average 3-year VIX levels in order to partition our dataset into a moderate volatility regime (2004), a low volatility regime (2006) and a high volatility regime (2010). In Figure 3, we plot realized tracking errors for the group of managers benchmarked to S&P 500 for these 3 volatility regimes. We see that for most mutual funds in our sample, tracking error levels were indeed elevated in the high volatility regime (2010) and depressed in low volatility regime (2006).

**FIGURE 4: ACTIVE SHARE VS. TRACKING ERROR FOR SAMPLE OF MUTUAL FUNDS: 2010:12**

Figure 4 shows tracking errors for the 3-years ended 12/31/2010 for our sample of mutual funds vs. each fund's Active Share. We have differentiated our sample by each fund's benchmark. We see that the majority of our sample classifies as Pure Stock Pickers (PSPs) given their relatively high Active Share. The Gateway fund is an outlier in the sample as the fund is broadly diversified (low Active Share), but uses derivatives to hedge away much of the Fund's systematic risk (high tracking error).




Finally, we posited a conditional relationship between Active Share and tracking error based on manager style. We showed that managers which focus on broad investment themes or styles had the highest tracking errors per unit of Active Share. While it is difficult to ascertain each manager's distinct style based on just holdings and returns, we can still confirm the overall effect of Active Share and tracking error using our manager data. Figure 4 shows the scatterplot between Active Share and tracking error for all of the managers in our study. We see a similar overall effect as in Figure 1. Tracking error increases with the level of Active Share, with the ranges being very much in-line with the simulated data in the prior section.

For our sample of the largest mutual funds, low Active Share managers are notably absent. In fact the only fund in our sample with an Active Share less than 50 as of 12/31/2010 is the Gateway Fund, which is characterized by a very high ratio of tracking error to Active Share. Interestingly, upon further examination, we find that the Gateway Fund "invests in a broadly diversified portfolio of common stocks, while also selling index call options and purchasing index put options." Thus, although the nature of the Gateway Fund's tracking error is quite distinct from the way we've modeled PSMs in the prior section (it comes largely through the use of derivatives), the parallel is clear: the Fund holds a diversified portfolio (low Active Share), while hedging away much of the portfolio beta (large systematic tilts). We also note another outlier in our data – the Hussman Strategic Growth Fund. Like the Gateway Fund, the Hussman Fund invests in a relatively diversified portfolio of common stocks and uses derivatives to hedge market risk. However, because the portfolio holds several names outside of the benchmark – as of 12/31/10, 28% of the Fund's holdings were non-benchmark positions – it has a relatively high Active Share, placing it to the right of the Galaxy Fund, but with a similar ratio of tracking error to Active Share.

## Conclusion

While in recent years much attention has been paid to the relationship between Active Share and manager alpha, there has been considerably less focus on how Active Share affects portfolio tracking error. By utilizing simulation methods, we showed that Active Share must be placed within the context of a manager's benchmark, since the number of benchmark positions has a material impact on Active Share metrics. We next showed that in a fully unconstrained framework, Active Share only directly affects the idiosyncratic component of portfolio active risk. Because a high Active Share portfolio can be designed to have either a low or high level of active

systematic risk, there is no direct link between systematic risk and Active Share. Continuing with our simulation-based framework, we utilized a well-defined set of manager styles to generate portfolios of varying degrees of Active Share, and measured the resultant tracking errors. We found that Pure Style Managers are characterized by higher levels of tracking error per unit of Active Share and we provided estimates of the tracking error levels for each manager style. Finally, using actual mutual fund data for some of the largest U.S. managers, we replicated many of the analyses in prior sections, and found that the empirical data are largely consistent with our theoretical and simulation-based results.

# Appendix

### Derivation of Equation 2

As in Equation 2, Active Share is defined mathematically as $AS = \frac{1}{2}\sum_{i}^{N} = 1|w_i - w_{bi}|$. Let active weights be defined as $w_{ai} = w_i - w_{bi}$. In the spirit of Grinold & Khan (2000), we assume $w_a \sim N(0, \overline{\sigma_e^2})$. Thus, we can express Active Share $AS = \frac{1}{2}\sum_{i}^{N} = {}_1|\sigma_a z_i|$, where $z \sim N(0,1)$. Since $E[|z|] = \sqrt{2/\pi}$, expressing $AS$ as an expectation, we have $E[AS] = \frac{N\sigma_a}{\sqrt{2\pi}}$. We further assume that a manager targets a specific vector of systematic exposure, $b$. Thus, $b = \beta' w_a$, where $\beta$ is an $Nxk$ matrix of factor loadings. Therefore, for a general $k$-factor risk model, the tracking error of a portfolio can be written as $TE^2 = b'Vb + \sum_{i}^{N} = {}_1 w_{ai}^2 Var(e_i)$, where $b$ is a $kx1$ vector of portfolio factor loadings, $V$ is the $kxk$ risk factor covariance matrix, and $Var(e_i)$ is the idiosyncratic variance of asset $i$. Using the normally distributed property for active weights, expected tracking error variance can be expressed as $E[TE^2] = b'Vb + \sigma_a^2 \sum_{i=1}^{N} Var(e_i)$. Substituting out $\sigma_a^2$ from both the Active Share and tracking error equations and dropping the expectations for notational simplicity, we have $TE^2 = b'Vb + AS^2 \frac{2\pi}{N^2}\sum_{i=1}^{N} Var(ei)$. Finally, for a single-factor risk model we have $TE = [b_p^2 Var(f) + AS^2 \frac{2\pi}{N}\overline{\sigma_e^2}]^{0.5}$, where $b_p$ is the portfolio's exposure to the single risk factor, $Var(f)$ is the variance of the risk factor, and $\overline{\sigma_e^2}$ is the average idiosyncratic variance in the asset universe. We impose the boundary condition $TE(AS = 0) = 0$, so that an index fund must have zero tracking error.

### Description of manager style portfolios

All optimizations are subject to zero-leverage (no shorting) and full-investment constraints. Optimizations were implemented in Matlab. For PSPs and FNSPs, we utilized the function solvesdp(), which is contained in the YALMIP modeling language. PSMs and QIs were generated using the function quadprog(). We generated expected returns for PSPs, FNSPs, and QIs by generating random normal zero-mean vectors with a standard deviation of 5%. The solution results are invariant to the particular standard deviation we chose. For PSMs, we generated three standard normal random variables, reflecting expected returns for each of the three FF factors. The standard deviation of each factor draw was designed to be equal to the standard deviation of the respective risk factor. Expected returns at the asset level were generated simply by multiplying each asset's exposure by its expected factor return and adding them up. We forced the standard deviation of the overall expected return vectors for PSMs to be equal to that of expected return vector for the other style portfolios, but this is a scaling choice which did not affect the resultant optimization.

Pure Stock Pickers (PSPs) – We maximized the portfolio's expected return by varying the number of allotted names from 10 to 300. Each portfolio was approximately equally weighted by $1/n$.

Factor-Neutral Stock Pickers (FNSPs) – We used the same constraints and objective function as for PSPs, but we add an additional constraint that the three Fama-French risk factor exposures must be within 0.05 standard deviations of the benchmark exposures. Like PSPs, portfolio weights were approximately equally weighted by $1/n$.

Pure Style Managers (PSMs) – We minimized portfolio tracking error subject to constraints on varying degrees of expected return, where the expected return vectors were generated from the underlying factor exposures of the assets in the universe. Expected return constraints ranged from 0.10% to 12.0%.

Quasi-Indexers (QIs) – We used the same constraints and objective function as for PSMs, but expected returns were replaced with the expected returns utilized for PSPs and FNSPs.

**Description of risk model**

We utilized the Fama-French 3-factor risk model. FF factors were downloaded from Ken French's website (http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html). For every asset in the S&P 500 we measured factor loadings by regressing monthly excess returns on each of the FF3 factors. Regressions were run over the prior 36 months. Idiosyncratic risk was measured as the trailing 36-month standard deviation of each asset's idiosyncratic return. S&P 500 constituent and return data was obtained from Factset.

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[3] Examples include, Mercer Consulting, "Perspectives on Equity Investment", September 2012 and Vanguard, "The Search for Outperformance: Evaluating 'Active Share', May 2012.

[4] Barrons, "Is Your Fund Manager Active Enough?", January 2013.

[5] See for example Cremers and Petajisto (2009) Table 4, which shows that the average alpha for high-minus-low Active Share managers is 2.55% vs. 0.58% for high-minus -low tracking error managers.

[6] Assets which are held in the managed portfolio but not in the benchmark, are simply assigned $w_{bi} = 0$ in the calculation of Active Share.

[7] Data as of 30 September 2012.

[8] As of 30 September 2012 the S&P 500 Index had 500 names vs. 1837 for the MSCI All-Country ex-US Index.

[9] Equation 2 has the boundary condition $TE(AS = 0) = 0$. The relationship between tracking error and Active Share is continuous except for the point at which Active Share is exactly equal to zero.

[10] The term "unconstrained manager" means that the manager is not subject to a long-only or leverage constraint. These assumptions are necessary to obtain an analytic solution for the relationship between Active Share and tracking error and are not intended to be indicative of real-world investment constraints.

[11] The manager style definitions in Table 3 are similar to those detailed in Cremers and Petajisto (2009). The authors categorize each manager style as 'diversified stock picks', 'concentrated stock picks', 'factor bets' and 'closet indexing'. We have redefined the style definitions here in order to better describe the nature of each manager style and to be consistent with our methodology for portfolio construction.

[12] For a detailed discussion of the relationship between VIX and tracking error see Gorman, Sapra, and Weigand (2010).

[13] Index funds and style portfolios are typically well-diversified in practice. Therefore, we assume that PSP and QIs don't hold portfolios with Active Share greater than 0.5.

[14] We use the term 'incidental' because any systematic risk incurred by a PSP is assumed to be a side effect of their stock selection methodology as opposed to an objective. FNSPs optimizations use the same expected returns as the PSPs, but all factor risk is neutralized by constraint.

[15] We note some non-monotinicity with respect to volatility regime for Pure Style Managers at Active Share levels in excess of 90%. As shown in Figure 3, this cohort is characterized by very wide ranges of tracking error as Active Share rises. Thus, we attribute this to sampling error in the data. There is also a similar effect for PSPs between the moderate and high regimes. In our estimates of risk factor betas, there was a much wider disparity in betas in 2004 compared to 2010. This had the effect of making the tracking error ranges wider in 2004 for portfolios exposed to the systematic component of risk. Because FNSPs are factor neutral, the tracking errors of this group are unaffected by the disparity in betas.

[16] We used manager-stated benchmark in this analysis.

[17] The only exception we make is that in the group of managers benchmarked to MSCI ACWI ex-US, we select two mutual funds offered by Manning and Napier to increase the sample size of this group.

[18] AUM is broken out as $398.7bn, $3.7bn and $36.1bn for mutual funds managed to the S&P 500, MSCI ACWI ex-US and Russell 2000 benchmarks, respectively.

[19] Periods for which we have insufficient history to calculate a three-year tracking error number are set to missing.

[20] Gateway Fund prospectus, 21 February 2013.

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