Tilt Nickels to Diamonds

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Abstract

We propose a simple two-stage portfolio tilting strategy to address the long-standing "risk factors eating alpha" problem. Fundamental factors are projected onto risk factors to obtain a set of risk-adjusted fundamental factors. Then we tilt portfolio weights of any selected index based on the risk-adjusted fundamental factors to construct more efficient index portfolios. We illustrate the efficiency of the strategy using a hypothetical index anchored to Russell 1000. The new index outperforms Russell 1000 in raw and risk-adjusted returns. It has greater information and Sharpe ratios while maintaining a lower tracking error than other alternative indices. Further, the index fares better in bearish and turbulent markets than in bull markets.

Key words: Indexing; Alternative Index; Smart Beta; Tilting; Portfolio Efficiency

JEL Classifications: G11, G12

1 Introduction

Index mutual funds, exchange traded index funds (ETFs), and other index oriented products grew substantially in the past two decades (e.g., French 2008; Wurgler, 2010; Stambaugh 2014). According to the 2014 Investment Company Institute Fact book, index equity mutual funds share, measured by a percentage of equity mutual funds' total net assets, increased from 9.5 percent in 2000 to 18.4 percent in 2013. As of year-end 2013, U.S. index funds and ETFs managed total net assets of $3.4 trillion as opposed to $15 trillion assets managed by U.S. mutual funds. Conventional index products are linked to the market capitalization weighted indices (i.e., cap-weighted indices). Due largely to the controversy on the efficiency of conventional cap-weighted indices, alternative index products, not cap weighted, were developed. Indexes associated with fundamental factors are an important sector of alternative indexes. While some of these fundamental indices deliver better performance than cap-weighted indexes (Arnott, Hsu, and Moore, 2005; Clare, Motson, and Thomas, 2013), it is also well noted that fundamental factors are potentially correlated with risk factors. The lack of control for risks expose the these alternative index products to greater risks than cap-weighted indices (Amenc, Martellini, Goltz, and Ye, 2011).[1]

In this study, we propose a simple two-stage portfolio tilting strategy to address portfolio bias to risk factors. The essential idea is to identify an optimal way to adjust portfolio weights of a selected cap-weighted index based on risk-adjusted fundamental factors. Specifically, in the first-stage regression, we purge the influence of risk factors from fundamental factors by regressing fundamental factors on risk factors and obtain a set of "clean" fundamental factors. Then in the second-stage regression we estimate the sensitivities of portfolio weights of the benchmark index to the risk-adjusted fundamental factors estimated from the first stage. We subsequently tilt the sensitivities to fundamental factors to construct a new index. Because tilts are on fundamental factors after risk adjustments, at least in theory, our approach would not pick up extra risks when we adjust the exposure to fundamental

[1] In an interview with the *Journal of indices* in 2007, Fama, arguably, pointed out that the fundamental index simply captures the "value effect". See http://www.bloomberg.com/news/2011-06-02/arnott-index-derided-by-bogle-as-witchcraft-beats-vanguard-fund.html.

factors. Furthermore, this strategy controls for the tracking error by anchoring the new index *directly* to the selected cap-weighted index.

We demonstrate the efficiency of the portfolio tilting methodology using a hypothetical equity index, the fundamental factor tilt index (FIX). The benchmark portfolio is the Russell 1000 index (R1000). Three fundamental factors of individual firms are considered: returns on assets (ROA), net sales (NS), and long-term debt (D). Intuitively, ROA reflect a firm's operating efficiency thus high ROA firms (i.e., firms with productive assets) tend to outperform in bad economies (Novy-Marx, 2013). On the other hand, corporate sales co-move with the economy thus high sales stocks are less persistent in performance given the cyclical nature of the economy. The performance of high-debt stocks is cyclical as well – leverage acts like a magnifying glass, expanding small profit opportunities into larger ones, but also expanding small losses into larger ones (e.g., Billio, Getmansky, Lo, and Pelizzon, 2012). With these considerations, an index potentially yields superior long-term stock performance when the portfolio is highly sensitive to asset productivity while it has a low sensitivity to net sales and long-term debt potentially. Note that we tilt the portfolio based on net sales and long term debts, not the scaled sales and leverage ratios. This is because both level factors are correlated with market capitalization. Tilting portfolio weights based on the level factors results in relatively low tracking error of the new index.

To insulate risks from selected fundamental factors, we project these fundamental factors onto various risk factors, including four factors developed in Fama and French (1993) and Carhart (1997) and indicator variables for industrial sectors of individual R1000 stocks. We subsequently regress stock weights of the Russell 1000 (the benchmark index we select, abbreviated as R1000 hereafter), on the orthogonalized fundamental factors (residuals from the first-step regressions) to estimate the elasticity of portfolio weights to the factors. The so-called tilting is to inflate the portfolio elasticity to the asset productivity factor (ROA) while to decrease the elasticities to net sales and long-term debt. As a result, the performance index portfolio becomes more sensitive to asset productivity while less sensitive to business cycles.

We show that FIX significantly outperforms R1000 during the period from 1990 to 2011. The average annual return for FIX is 11.40 percent while the average annual performance for R1000 is 9.76 percent in the sample period. The difference in performance of these two portfolios, 1.64 percent per year, is significant at the 1 percent level. The outperformance of FIX relative to R1000 is substantial after controlling for portfolio standard deviations – the annual Sharpe ratio for FIX is 0.50, higher than 0.39 for the Sharpe ratio of R1000. Over the 22 year period, FIX outperforms R1000 for 15 years in terms of raw returns and for 19 years in terms of the four-factor adjusted performance.

An impressive feature of FIX is its counter-cyclical nature in performance. FIX outperforms R1000 by 60 basis points per annum in the first half of the sample period, from 1990 to 2000, while the outperformance is enlarged to 267 basis points per annum in the second half of the sample. Note that the first subsample period is largely a bull market while the second period (2001-2011), covering the recent credit crisis, is turbulent and bearish. The better stock performance in the second half of the sample is aligned with a key design of FIX – by underweighting stocks with high net sales and long-term debt factors. The relatively lower operating and financial leverages help FIX hedge against the market risk. Thus, it fares better in more turbulent market conditions.

We further evaluate the relative efficiency of FIX based on the information ratio, the difference in the returns of FIX and R1000 scaled by the tracking error of FIX. FIX's information ratio is 1.01 over the full sample period, suggesting a clear dominance of FIX relative to its benchmark. To our knowledge, FIX has a higher information ratio than other alternative indices reported by prior studies. Note that the relatively higher efficiency of FIX is not due to its large deviation from R1000. In fact, the tracking error of FIX is much lower than other alternative indices.[2] Moreover, it appears that FIX is more efficient in bearish and turbulent markets than in bull markets. The information ratio of FIX is 1.71 in the second subsample from 2001 to 2011 as opposed to 0.42 from 1990 to 2000.

[2]Tracking errors are considered as an important feature of the alternative index products. Clare, Motson and Thomas (2013), for instance, examine tracking errors of alternative indices using cap-weighted market indices (such as S&P 500 or Russell 1000 indices) as their benchmarks.

Finally, we attribute performance of FIX to the tilts on three fundamental factors and on the idiosyncratic risk. The finding indicates that all these factors have positive return contributions to FIX when R1000 had small positive returns or negative returns, which suggests such a tilting strategy is effective in improving the index performance. Also, the result shows that the four factors performed well in high volatility periods, which makes the strategy particularly appealing to investors as it helps to stabilize index performance.

To summarize, we introduce a portfolio tilting strategy better controlling for risk and tracking errors than other alternative indices. The primary contribution of the paper is that it addresses the long-standing "risk factors eating alpha" problem. Going beyond, the improved portfolio strategy has a positive effect on the efficiency of capital allocations. Wurgler (2012) suggests that poor investments made by index-linked products could distort stock prices and risk-return tradeoffs, resulting in distorted corporate investment and financing decisions as well investor portfolio allocation decisions. Therefore, through proposing a methodology to deliver more efficient index portfolios, this study helps to improve the efficiency of the capital market.

In the remainder of the paper, we first discuss the potential issues associated with alternative indices in Section 2. In Section 3 we discuss the new portfolio tilting strategy, followed by Sections 4 and 5 where we discuss the data and the performance and portfolio formation details of FIX. Section 6 concludes.

2 Alternative indices: Background and Issues

A conventional index is constructed based on the market capitalization of individual securities.[3] A cap-weighted index is optimal in an efficient capital market where securities are appropriately priced and no stock can persistently have an abnormal performance. However, numerous works cast doubts on the efficiency of the market portfolio (e.g., Shanken,

[3]The most popular cap-weighted indices are the S&P 500 index and Russell 1000. By offering investors a convenient way to invest in the broad equity market, cap-weighted indices have the advantage in low maintenance as they require little trading. Besides, market capitalization weighting tends to emphasize the stocks with greater investment capacities, thus allowing the use by large pension funds and institutions.

1985; Kandel and Stambaugh, 1987; and Hansen and Jagannathan, 1991, 1997). Alternative non-cap based indices emerge to exploit the potential inefficiency of the capital market.

There is a wide array of non-cap based indices in the practice. Namely heuristic indices, a large group of alternative indices, like the equal-weighted indices, are constructed based upon a "rule of thumb". Among them, Arnott, Hsu, and Moore (2005) introduce the fundamental indices that tie the portfolio weights to corporate fundamentals, known as fundamental factors, such as book value, cash flow, sales, and aggregate dividends. A key limitation of the fundamental factor based indices is a lack of control for risk, which is elaborated below. Alternatively, a different group of alternative indices, such as minimum variance index and risk efficient index, are constructed using portfolio optimization (see, e.g., Clare, Motson and Thomas, 2013). While optimization based indices can be designed to control for portfolio risk, they are sensitive to model inputs and the choice of utility functions (Michaud and Michaud, 2004).[4]

Assume that we construct a hypothetical alternative index using fundamental factors. To carry this task, we first identify a set of fundamental factors, **F**. We average the fundamental factors to obtain a composite fundamental factor. We rank all stocks in a stock universe using the composite factor and select N stocks having the largest ranks. Stocks weights, **W**, are a function of individual fundamental factors, **F** (in the way that weights are positively correlated with the rank of fundamental factors):

$$\mathbf{W} = \underline{\mathbf{F}}\boldsymbol{\zeta} + \boldsymbol{\epsilon} \tag{1}$$

where $\boldsymbol{\zeta}(= \zeta_1, \zeta_2, ..., \zeta_k)$ is the portfolio sensitivities to the selected fundamental factors, $\underline{\boldsymbol{f_1}}, \underline{\boldsymbol{f_2}}, \cdots, \underline{\boldsymbol{f_k}}$.

Fundamental factors may be corrected with risk factors (i.e., individual firm characteristics driving systematic risk of an individual stock). As a result, the correlation between **W** and $\underline{\mathbf{F}}$ would be partially attributed to the interplay between **W** and **K**. In other words, an

[4]For reviews of cap-weighted and alternative indices, see Chow, Hsu, Kalesnik, Little (2011) and Clare, Motson and Thomas (2013a, b).

increase in $\boldsymbol{\zeta}$ will not only increase portfolio returns but also raise the portfolio sensitivity to $\mathbf{K}$. For example, Amenc, Martellini, Goltz, and Ye (2011) report that the fundamental index has a positive bias to the value factor, which is an important risk factor in conventional multifactor asset pricing models (Fama and French, 1993; Carhart, 1997). Consequently, the portfolio strategy does not increase the risk-adjusted return. In the practice, this issue is known as the problem of "risk factors eating alphas" (e.g., Lee and Stefek, 2008).

3 Portfolio Tilting Methodology

3.1 The Methodology

We introduce the two-stage regression based portfolio tilting strategy designed to address the issues discussed in Section 2.

In the first-stage regression, we project fundamental factors on the risk factors. In each month, for example, we regress individual fundamental factors on risk factors to obtain risk-adjusted factors.

$$\underline{\boldsymbol{F}} = \boldsymbol{K}\boldsymbol{\Gamma} + \boldsymbol{\eta} \tag{2}$$

where $\boldsymbol{\Gamma}$ measures the sensitivity of fundamental factors to the risk factors. $\boldsymbol{\eta}$ is a vector of regression residuals. We use $\boldsymbol{F}$ to denote $\boldsymbol{\epsilon}$, the orthogonalized fundamental factors.

In the second-stage regression, weights of individual stocks included the benchmark index, $\boldsymbol{W}$, are regressed onto the *orthogonalized* fundamental factors $\boldsymbol{F}$, estimated from Eq (2) and a set of risk factors, $\boldsymbol{K}$.

$$\boldsymbol{W} = \boldsymbol{F}\boldsymbol{\delta} + \boldsymbol{K}\boldsymbol{\gamma} + \boldsymbol{\upsilon} \tag{3}$$

In Eq (3), $\boldsymbol{\delta}$, termed as the fundamental beta, measures the sensitivities of stock weights to the orthogonalized fundamental factors. $\boldsymbol{\gamma}$, termed as the risk beta, measures the sensitivities of stock weights to risk factors. $\boldsymbol{\upsilon}$ represents the idiosyncratic component.

The next step of the tilting strategy is straightforward – that is to adjust the three sets of parameters ($\boldsymbol{\delta}$, $\boldsymbol{\gamma}$, and $\boldsymbol{\upsilon}$) estimated from Eq. (3) tailoring investor needs, e.g., their constraints (e.g., limits of investments in a specific sector), required performance, and risk preferences.

$$\boldsymbol{W} = \boldsymbol{F}\boldsymbol{\delta}^{*} + \boldsymbol{K}\boldsymbol{\gamma}^{*} + \boldsymbol{\upsilon}^{*} \tag{4}$$

For example, if the investor's objective is the minimize the volatility of an index product, then she may obtain the optimal "betas" by minimizing the variance of portfolio (inserting eq (4) in the variance function). Alternatively, if the investor's goal is to maximize the efficiency of a portfolio given a specific tracking error, she would maximize the information ratio of the index portfolio. In the illustration below, we construct an index portfolio with linear tilts of the fundamental betas, $\boldsymbol{\delta}$ and the idiosyncratic component, υ. We keep risk betas constant to hold the new portfolio's exposure to risk factors identical to the benchmark's.

3.2 An Illustration of Portfolio Tilting Methodology

In this section, we demonstrate the use of the portfolio tilting strategy with a specific index portfolio, namely, the fundamental factor tilt index, abbreviated as FIX. To form the new index, we choose the Russell 1000 index (R1000) as the benchmark index.

We pick up three fundamental factors, return on assets (hereafter ROA), net sales (NS), and long-term debt (D) for the following reasons. Following Novy-Marx (2013), asset productivity positively predicts stock performance, which justifies the use of ROA as a fundamental factor.[5] On the other hand, firm sales are positively associated with a firm's exposure to the macro-economy. Therefore, a firm with less sensitivity to sales could shun away from the business cycle risk. Moreover, financial leverage negatively predicts future stock performance as leverage drives up firm insolvency (see, e.g., Hamada, 1972, Dimitrov and Jain, 2006; George and Hwang, 2009; Korteweg, 2010). Under this consideration, portfolios with

[5]ROA is highly correlated with gross profits-to-assets, the measure of asset productivity used in Novy-Marx (2013). In addition, Fama and French (2014) and Hou, Xue and Zhang (2012) examine the return predictability of operating performance, proxied by firm ROE, as well.

a low weight in leverage firms could outperform in economic downturns. Essentially, the choice of fundamental variables makes the portfolio less sensitive the economic fluctuations – at the cost giving up superior performance in extremely good years, the new index gains from the loss reduction in bad years. Such a risk management strategy potentially creates value to the index portfolio.

Note that we use the level of firm sales and long-term debt, rather than sale and leverage ratios, in the analysis. The levels of firm sales and debt are more correlated with firm market capitalization than are the ratios. This helps to reduce the tracking error of the portfolio.[6]

We normalize the selected fundamental factors within their industrial sectors. The normalization procedure includes three steps:

- In each month, we compute sector adjusted factors by deducting the median of each factor for an individual sector and then scaling difference with the standard deviation for an individual sector.
- Get the rank of standardized values and scale them within 0 and 1.
- The values are converted to percentage terms within the R1000.

Denoting the normalized variables as ROA, NS, and D, we have $\underline{\boldsymbol{F}} = (\boldsymbol{ROA}, \boldsymbol{NS}, \boldsymbol{D})$. In each month, $\underline{\boldsymbol{F}}$ is a $1,000 * 3$ matrix as R1000 holds 1,000 stocks.

Risk factors, $\boldsymbol{K}$, include i) loadings to Carhart's (1997) four factors (i.e., beta, size, book-to-market ratio, and momentum) and ii) 10 indicators for industry sectors. Loadings to Carhart's four factors are estimated as follows:

$$\boldsymbol{R_i} = \alpha_i + \beta_i \boldsymbol{MKT} + s_i \boldsymbol{SMB} + h_i \boldsymbol{HML} + \mu_i \boldsymbol{UMD} + \boldsymbol{\varepsilon_i} \qquad (5)$$

$\boldsymbol{R_i}$ is the monthly return of an individual stock in excess of the risk-free rate (the 1-month Treasury bill rate) in the month after portfolio rebalancing. $\boldsymbol{MKT}$ is the market

[6] The level factors are positively correlated with the corresponding ratios. Specifically, the correlation between sales and sale-to-assets ratio is 0.11 while the correlation between debt and the firm debt-to-assets (i.e., leverage ratio) is 0.31.

risk premium in a month t, calculated as the market return in month t minus the risk free rate of return. $\boldsymbol{SMB}$ (small minus big) is the difference each month between the return on small-cap stocks and large-cap stocks. $\boldsymbol{HML}$ (high minus low) is the difference each month between the return on a portfolio of high book-to-market stocks and the return on a portfolio of low book-to-market stocks. $\boldsymbol{UMD}$ is each month between the return on a portfolio of high momentum stocks and the return on a portfolio of low momentum stocks. In each month, using the recent 10 year data, we estimate β, s, h, and u for stock i. A minimum of 2-year data is required to be included in the estimation.[7]

Moreover, we use the first two-digits of the Global Industry Classification Standard (GICS) to obtain the 10 industry sectors and define an indicator for each of the ten industries, d^j (d^j=1 if a firm is in sector j and 0 otherwise).[8] We have $\boldsymbol{K} = (\boldsymbol{\beta}, \boldsymbol{s}, \boldsymbol{h}, \boldsymbol{u}, \boldsymbol{d^1}, \cdots, \boldsymbol{d^{10}})$. In each month, $\boldsymbol{K}$ is a $1,000 * 14$ matrix.

In each month end, we perform the following contemporaneous regression to obtain a set of orthogonalized fundamental factors:

$$(\boldsymbol{ROA}, \boldsymbol{NS}, \boldsymbol{D}) = (\boldsymbol{\beta}, \boldsymbol{s}, \boldsymbol{h}, \boldsymbol{u}, \boldsymbol{d^1}, \cdots, \boldsymbol{d^{10}})\boldsymbol{\Gamma} + \boldsymbol{\eta} \tag{6}$$

where $\boldsymbol{\Gamma}$ is a $14 * 3$ matrix and $\boldsymbol{\eta}$ is a $1000 * 3$ matrix.

The residual from Eq (6) is a vector of the orthogonalized fundamental factors.

We then regress stock weights, $\boldsymbol{W}$, of Russell 1000 onto orthogonalized fundamental factors and risk factors. This gives us the sensitivity of R1000 stock weights to each of the factors included in the study, expressed below:

$$\boldsymbol{W} = \boldsymbol{F\delta} + \boldsymbol{K\gamma} + \boldsymbol{\upsilon} \tag{7}$$

The purpose of the exercise is to adjust portfolio exposures to fundamental factors but holding the portfolio sensitivity to risk factors constant. We tilt fundamental betas and

[7]We alternatively use the 5-year window to estimate risk factors and obtain consistent results. The reason for us to use the 10-year estimation window is this horizon covers a full length of an economic cycle.

[8]For information on sector breakdown, see http://en.wikipedia.org/wiki/Global_Industry_Classification_Standard.

idiosyncratic risk as below:

$$\boldsymbol{W}^* = \boldsymbol{F}\boldsymbol{\delta}^* + \boldsymbol{K}\boldsymbol{\gamma} + d\boldsymbol{\upsilon}, \tag{8}$$

where

$$\boldsymbol{\delta}^* = \begin{bmatrix} 2 & 0 & 0 \\ 0 & 2/3 & 0 \\ 0 & 0 & 2/3 \end{bmatrix} \boldsymbol{\delta} \tag{9}$$

$$d = 2/3$$

In other words, the new index portfolio doubles the factor loading to adjusted ROA, while lower factor loadings to adjusted net sales, long-term-debt and idiosyncratic risk by one-third. These tilts are chosen to inflate the portfolio weight sensitivity to the fundamental factor potentially positively correlated stocks' future returns (ROA) and to decrease the weight sensitivities to factors potentially negatively correlated with stocks' future returns during bearish or turbulent market (net sales and long-term debt). Moreover, the reduction of the residual from the weight regression (the idiosyncratic component of a stock's weight in the cap-weighted index) helps better align the index with various fundamental and risk factors.

FIX is rebalanced at the beginning of each month. It is worthwhile to point out that our analysis is not subject to the look-ahead bias since data used to construct fundamental and risk factors lag portfolio performance. The analysis is immune from data snooping bias of any kind as we follow the standard literature to identify fundamental and risk factors, rather than selecting factors through data mining.

4 Data

We obtain stock weights of R1000 in each month from the Thomson Reuter's DataStream from January 1990 to June 2011. Monthly performance of FIX and the benchmark index (R1000) based on their respective portfolio holding in the beginning of each month, then annualize it (multiplying it by 12) to obtain the annual performance. Monthly stock return data is obtained from the CRSP database.

Quarterly financial statement data is obtained from the Compustat database. *ROA* is the ratio of operating income after depreciation and amortization to total assets. A firm's net sales are evaluated as gross sales generated by a company after the deduction of returns, allowances for damaged or missing goods and any discounts allowed. Long-term debt is the amount of debt whose maturity exceeds 1 year. In order to reduce seasonality in the data, fundamental factors are calculated as the rolling 4-quarter moving averages.

We assess the four-factor adjusted stock performance. The data for four factors, $\boldsymbol{MKT}$, $\boldsymbol{SMB}$, $\boldsymbol{HML}$, and $\boldsymbol{UMD}$, are obtained from Kenneth French's website.[9]

5 Results

5.1 Performance

Table 1 reports annual performance of FIX (rebalanced monthly) and R1000. Over the 22 year period, FIX outperforms R1000 for 15 years. Throughout the sample years from 1990 to 2011, the average annual return for FIX (monthly return of the rebalanced portfolio * 12) is 11.40 percent while the average annual return for R1000 is 9.76 percent. The difference in performance of FIX and R1000, 1.64 percent, significant at the 1 percent level, is economically significant as well. Also reported in Table 1, interestingly, the overperformance of FIX to R1000 is 0.60 percent in 1990s (a boom market) while it is over 2.67 percent after year 2000 (a more turbulent market). The countercyclical nature of FIX (to R1000) indicates that new index typically performs well in bad states of the stock market.[10] To better understand FIX, we further estimate the Pearson correlation between monthly return differences in FIX and R1000 and returns of R1000. The correlation is -0.58 – the outperformance of FIX is negatively associated with the market index. To be specific, FIX underperforms R1000 in

[9] http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html.

[10] Under the classical asset pricing paradigm, a security staying profitable in bad states is more valuable feature for securities because payoffs delivered in bad states yield greater utility.

1995, 1996, 1998, and 1999, years of the bullish market while FIX outperforms R1000 in 2001 through 2005, 2008 through 2011, commonly viewed as bearish or turbulent years.[11]

We then compare the risk-reward ratios of FIX and R1000 by assessing their respective Sharpe ratios. The 1-month T-bill rate is used to measure the risk free rate. The result shows that the Sharpe ratio for FIX, 0.50, is greater than the Sharpe ratio of R1000, 0.39 - FIX continues to outperform R1000 in terms of risk adjusted total return.

Next, we compare the volatilities of FIX and R1000. The volatilities are computed based on monthly returns in a 36-month rolling window. For example, the volatility of July 2010 is calculated using portfolio returns from August 2007 through July 2010. As revealed in Figure 1, the volatilities of these two portfolios move closely. As a matter of fact, the average volatility of FIX during the full sample period is 15.05%, slightly lower than that of R1000, 15.35%.

Further, we perform the four-factor regression following Carhart (1997) to see the underlying drivers for FIX's outperformance: compensations to extra risks or alphas? We estimate the Carhart's (1997) four-factor alpha for FIX and R1000. The analysis is similar to Eq. (5).

$$\boldsymbol{R_t} = \alpha + \beta \boldsymbol{MKT_t} + s\boldsymbol{SMB_t} + h\boldsymbol{HML_t} + \mu \boldsymbol{UMD_t} + \boldsymbol{\varepsilon_t} \tag{10}$$

Different from Eq. (5) where we applied the four-factor model on the returns of individual stocks held by R1000, here $\boldsymbol{R_t}$ are the monthly returns of FIX in excess of the risk-free rate (the 1-month Treasury bill rate). We first estimate the monthly alpha in a specific year by pooling monthly returns of the portfolio within that year, then multiplying monthly alpha by 12 to obtain the simple annualized alphas. We perform the four-factor regression using all the monthly returns of FIX during the sample period to estimate the "all years" annual alpha. The annualized alphas in individual years and during the full-sample period, together with the loadings (i.e., the coefficients) on the four factors and regression R-squareds, are reported

[11]A significant number of major credit events took place after year 2001, including Enron debacle and the subsequent accounting scandals, the World Trade Center attack, GM downgrades and default, and the financial crisis.

in Table 2. The table also reports the annualized alphas, loadings on the four factors, and regression R-squareds for R1000. The result shows that alphas of FIX is clearly greater than that of R1000. Based on the result of alphas from individual years, FIX outperform R1000 in 19 out of the 22 sample years. During the entire sample period, the annual alpha of FIX is 1.703%. This is greater than the four-factor adjusted portfolio alpha of R1000. The reported alpha for R1000 is merely 0.28%. In the 1990s (2000s), the annual alpha for FIX is 1.39% (1.76%) while it is 0.24% (0.19%) for R1000.[12]

The loadings from the four-factor regressions ($\boldsymbol{\beta}$, $\boldsymbol{s}$, $\boldsymbol{h}$, $\boldsymbol{u}$), reported in Table 2, reflect risk exposures of an index portfolio. The estimated beta of FIX (the coefficient on $RMRF$) is slightly less than 1 (0.97). The SMB loading of FIX is -0.015, with a much smaller magnitude than that of R1000 (-0.09). The MOM loading is insignificant while the only significant loading (at the 1% level) is the one on HML, which is 0.03. Even so, the magnitude of the value loading is much lower than that of the fundamental index – reported in Amenc et al. (2011), the loading on the value factor exceeds 0.30 for the fundamental index – it is not economically significant. The finding confirms that FIX is generally free of bias of any conventional risk factors.

5.2 Turnover and Tracking Error

In this subsection, we first evaluate portfolio turnover of FIX. The turnover rate is defined as the minimum of the total amount of new securities purchased or the amount of securities sold - whichever is less - over a 12-month period, divided by the total asset value of the fund. Reported in Table 3, the annual turnover rates are 3.4% for R1000 and 25.6% for FIX. In other words, FIX shuffles one quarter of its holdings in each year.

Further, we assess the tracking error of FIX as below.

[12] Besides the four-factor model, we try other risk factors. For example, Frazzini and Pedersen (2013) find that the betting-against-beta (BAB) factor that longs leveraged low-beta assets and shorts high-beta assets produces significant positive risk-adjusted returns. Asness, Frazzini and Pedersen (2013) find that a quality-minus-junk (QMJ) factor that goes long high-quality stocks and shorts low-quality stocks (stocks that are safe, profitable, growing, and well managed) earns significant risk-adjusted returns in the U.S. and globally across 24 countries. We include BAB and QMJ as additional factors and still find that FIX has an significant annual alpha of 0.84%.

$$TR = \sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(R_t^* - \overline{R_t^*} - R_t + \overline{R_t}\right)^2} \tag{11}$$

where $\overline{R_t^*}$ and $\overline{R_t}$ are the average performance of FIX and R1000 from month 1 to T. In other words, TR is the standard deviation of portfolio excess returns over the sample period.

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As reported in Panel A of Table 4, the annualized tracking error of FIX, $\sqrt{12} * TR$, is 1.56% (1.25% in 1990-2000 and 1.58% in 2001-2011). This is much lower than the tracking error of other alternative indices. For example, Amenc et al (2011) show that the annual tracking error for the fundamental index is 6.2% and that of the risk efficient index is 5.5% for the sample period from 1999 to 2011.

5.3 Information Ratio

Reported in Panel A, Table 4 (FIX with a monthly rebalance), the information ratio of FIX, measured as the difference in the annual performance of FIX and R1000 scaled by the tracking error of FIX (relative to R1000), is 1.01 during the full sample period. A positive information ratio suggests a dominance of FIX's performance relative to the performance of its benchmark.

It is interesting to note that the average information ratios of FIX are substantially different in the two subsample periods; It is 0.42 up to year 2000 while rises up to 1.71 in the period after 2000. Considering the earlier finding that tracking errors over the sample period remain constant, a higher information ratio in the second period (post year 2000) indicates that FIX delivers much higher performance relative to its benchmark when the stock market performs poorly, which is considered as a major advantage of the new index.

Reported in Amenc et al. (2011), the information ratios of the fundamental index and the risk efficient index (relative to the value-weighted S&P500 index) are respectively 0.64 and 0.99 over the period from 08/1999 to 08/2011.[13] We estimate the information ratio of

[13] The risk efficient index aims to improve the Sharpe ratio compared to cap-weighted indices by weighting stocks by their impact on portfolio and rewards. For details on the efficiency index, see Amenc et al. (2011).

FIX relative to R1000 over the corresponding period as 1.61. Amenc et al. (2011) report a positive information ratio of R1000 relative to the value-weighted S&P500 index. As a result, we conclude that FIX outperforms these alternative indices in terms of the information ratio.

5.4 Index Attributes under Alternative Rebalancing Schedules

Noting that FIX is rebalanced monthly, one may attribute FIX's efficiency to its high rebalancing frequency. Therefore, we examine the performance of alternative FIX products with a lower frequency of rebalancing. In Table 4, except for the 1 month full rebalancing frequency (the same portfolio as the original FIX), we report portfolio attributes under alternative full rebalance frequency[14]: 3 months, 6 months, and 12 months. The result suggests that the performance of FIX is largely insensitive to rebalance frequency. During entire sample period (reported in Panel A Table 4), the raw return is 11.30% with monthly rebalance while it is 11.02% for the annually rebalance. The analyses using the subsamples before and after year 2000 present consistent results (reported in Panels B and C of Table 4). Moreover, the information ratio for the annually rebalanced portfolio is 0.91 over the entire sample period (relative to 1.01 for the original FIX portfolio). The difference of the information ratios between the monthly and annually full rebalanced portfolios is modest.

We also examine how rebalance frequency affects tracking errors of alternative index portfolios. Based on the finding in Table 4, less frequent rebalance reduces the tracking errors in a modest way. With an annual full rebalance, the annualized tracking error is 1.44% (as opposed to 1.56% for the annualized tracking error of a monthly rebalanced portfolio).

We study the turnover rates of the alternative FIX products as well. In the full sample period, the turnover rate is reduced to 17.1% when the portfolio full rebalance is set at every six months (25.6% for the original FIX with a monthly rebalance). The turnover rate is further lowered to 13.8% when the portfolio is fully rebalanced at the annual frequency. Consistent results are obtained in the two sub-samples. With an annual rebalance, the average

[14] A full rebalance is one to rebalance the portfolio based on the 2-stage tilting strategy. Alternatively, a partial rebalance is conducted when there is an adjustment to R1000, such as a dividend payment and a stock addition or deletion.

turnover rate is 13.36% in the second sub-sample period from 2001 to 2011. Compared to the results reported in Amenc et al. (2011), FIX (with an annual full rebalance) has a turnover rate is lower than the risk efficient index (17.25%) and lower than the minimum volatility index (20.6%), while FIX's turnover rate is slightly higher than that of the fundamental index (10.12%).

5.5 Index Attributes under Alternative Tilts

Is our finding sensitive to tilting parameters? In this subsection, we address this issue by varying "tilts" on three fundamental betas and the residual from Eq (7). Panel A of Table 5 shows the result when the tilt on the residual is set at 2/3, which is the same the FIX; The sensitivity to ROA varies from 2, 3, and 4 while the sensitivities to sales and to debt are adjusted by 1/3, 2/3, and 1. This results in 3*3*3 (=27) variations including FIX. The included portfolio performance measures are i) total return, ii) alpha, iii) volatility, iv) Sharpe ratio, v) relative return between FIX and R1000, and vi) information ratio (IR). It also covers the tracking error (TR) and turnover rate (TURN).

The first row of Panel A reports the result for R1000. The subsequent rows show the result for tilted portfolios (X13 is identical to FIX). Based on our finding, when ROA's adjustment becomes larger (changing from 2 to 4), sales' adjustment becomes smaller (changing from 1 to 1/3), or debt's adjustment becomes smaller(changing from 1 to 1/3), Carhart alpha, total return, and excess return become larger. As a cost, tracking error and portfolio turnover of the original FIX are larger. Nevertheless, all the portfolios have similar information ratios. In other words, the original FIX is as efficient as alternative tilting indices.

In the appendix, we derive the portfolio weights of the optimal portfolio. As a matter of fact, the tilts based on the optimal weights differ substantially from the tilts applied for FIX. We nevertheless show that information ratio of the optimal portfolio is just slightly higher than FIX. Note that deriving the optimal portfolio is not without cost – we use the full-sample information to derive the optimal weights, which is clearly subject to look-ahead bias. To avoid such a bias (and un-necessary complexity), we choose the tilting parameters without conducting optimizations.

Panel B of Table 5 further reports the results for the tilted portfolio when we reduce the parameter on the residual to 1/3. Relative to the results reported in Panel A, the raw return, Carhart alpha, and Sharpe ratios are greater. Again, information ratios of the two sets of results are similar.

In summary, the results reported in Table 5 indicate that the index performance increases when the ROA adjustment (the sales adjustment or debt adjustment) becomes larger (smaller), or the residual adjustment becomes smaller. The tracking error and turnover rate of the index portfolio go higher when an adjustment is further away from 1.

5.6 Decomposing Portfolio Performance

5.6.1 Performance Decomposition across Factors

We perform an attribution analysis to see the contributions of fundamental factors on the performance of FIX.

According to Eq (8), we express the stock weights of FIX in each snapshot (suppressing the subscript denoting time) as follows:

$$\boldsymbol{W}^* = \boldsymbol{W} + \boldsymbol{F}\left(\boldsymbol{\delta}^* - \boldsymbol{\delta}\right) - 1/3\boldsymbol{\upsilon} \tag{12}$$

Pre-multiplying a row vector of returns of individual securities in FIX in both sides of Eq (12), we transform the expression of portfolio weights to the expression for performance attributions for FIX:

$$R^* = R + \boldsymbol{r}'\boldsymbol{F}\left(\boldsymbol{\delta}^* - \boldsymbol{\delta}\right) - 1/3\boldsymbol{r}'\boldsymbol{\upsilon} \tag{13}$$

Note that, based on Eq (12) and Eq (13), the excess turnover over R1000 results from $\boldsymbol{F}\left(\boldsymbol{\delta}^* - \boldsymbol{\delta}\right) - 1/3\boldsymbol{\upsilon}$, which is used to generate excess returns over the R1000, $\boldsymbol{r}'\boldsymbol{F}\left(\boldsymbol{\delta}^* - \boldsymbol{\delta}\right) - 1/3\boldsymbol{r}'\boldsymbol{\upsilon}$.

Based on Eq (13), the performance of FIX can be broken down to three components: i) performance of R1000, ii) performance due to tilts on fundamental betas, and iii) performance due to the reduction of the residual from R1000 weight regression.

Subtracting R in both sides of Eq (13), we have

$$R^* - R = \boldsymbol{r}'\boldsymbol{F}\left(\boldsymbol{\delta}^* - \boldsymbol{\delta}\right) - 1/3\boldsymbol{r}'\boldsymbol{v} \tag{14}$$

The left-hand side of the above expression is outperformance of FIX with respect to R1000. The right-hand side is the performance adjustments due to the *tilts* (i.e., $\boldsymbol{\delta}^* - \boldsymbol{\delta}$) on fundamental betas and the residual beta.

We further express the middle term in the left-hand side of $\boldsymbol{r}'\boldsymbol{F}\left(\boldsymbol{\delta}^* - \boldsymbol{\delta}\right)$ in Eq (13) as the total of performance contributions from the tilts of portfolio sensitivities to ROA, net sales, and long-term debt.

$$\begin{aligned}\mathbf{r}'\mathbf{F}\left(\boldsymbol{\delta}^* - \boldsymbol{\delta}\right) &= \boldsymbol{r}'\boldsymbol{F}\begin{bmatrix}1 & 0 & 0\\ 0 & -1/3 & 0\\ 0 & 0 & -1/3\end{bmatrix}\boldsymbol{\delta}\\ &= \boldsymbol{r}'\boldsymbol{F}\begin{bmatrix}1 & 0 & 0\\ 0 & 0 & 0\\ 0 & 0 & 0\end{bmatrix}\boldsymbol{\delta} + \boldsymbol{r}'\boldsymbol{F}\begin{bmatrix}0 & 0 & 0\\ 0 & -1/3 & 0\\ 0 & 0 & 0\end{bmatrix}\boldsymbol{\delta} + \boldsymbol{r}'\boldsymbol{F}\begin{bmatrix}0 & 0 & 0\\ 0 & 0 & 0\\ 0 & 0 & -1/3\end{bmatrix}\boldsymbol{\delta}\end{aligned} \tag{15}$$

The three items in Eq (15) represent the contribution of individual fundamental factors of the FIX strategy. Table 6 attributes FIX performance to various factors in each year and the entire sample period based Eq (14) and Eq (15). The findings suggest that the performance of FIX is countercyclical; all four factors had positive return contributions to FIX when the R1000 had small position returns or negative returns in 1990, 1994, 2000, 2001, 2002, and 2008 except the residual factor has a negative return in 1990. Moreover, the result shows that the four factors had slight negative return contributions of FIX when R1000 had favorable performance in 1992, 1993, 1995, 1996, 1998, 1999, 2006, and 2009. The negative return contributions were -0.6% in 1995 and -0.85% in 1998 while other contributions had returns of less than -0.30%. Recall that the core of FIX is a tilt of the sensitivities of stock weights of the benchmark index to fundamental factors and the residual factor. The result reinforces the effectiveness of the tilting strategy.[15]

In Figure 2, we plot the attributed relative returns between FIX and R1000 to three fundamental factors: ROA, sales, and debt over time. It is discernable that the contributions of the factors are much greater in the post-2000 period than the period before year 2000. This is consistent with the finding for subsample periods reported in Table 6 where we find the contributions of tilts is much greater in the second period. Specifically, over the period from 1990-2000, the average contributions are respectively 4.1 basis points for the ROA tilt, 6 basis points for the net sales tilt, 9.3 basis points for the long-term debt tilt, and 23 basis points for the residual tilt. By contrast, over the period from 2001-2011, the average contributions are respectively 16.5 basis points for the ROA tilt, 65 basis points for the net sales tilt, 45 basis points for the long-term debt tilt, and 113 basis points for the residual tilt. Simply put, tilts on the portfolio sensitivities to various factors have positive contributions to the performance of the new index.

5.6.2 Performance Decomposition across Industry Sectors

Finally, we examine the performance of FIX across different industry sectors and compare the sector performance with that of R1000. The following ten industry sectors are considered: i) energy, ii) materials, iii) industrials, iv) consumer discretionary goods, v) consumer stable goods, vi) health care, vii) financial sector, viii) information technology, ix) telecom service, and x) utilities.[16] We identify the sector of a stock with the industry classification offered

[15]There are differences between the sum of return components and the return of FIX in Table 5, potentially attributable to two reasons. First, some stocks are in R1000, but they are not in FIX due to their short historic data. Second, stock weights may become negative after they are adjusted by our procedure. We need to get rid of stocks with negative weights from FIX. The sum of the negative weights is about 3%.

[16]As we analyze strategies of index portfolio, we take a different approach from most other studies, by retaining the stocks from the financial sector. Owing to the concern that leverage of stocks from the financial sectors potentially plays a different role on firm operation from that of other industries, we look at the correlation of long-term debt of financial firms on stock performance. We find that long-term debt negatively affects stock returns in the subsequent year, a relation consistent with the general finding of this study.

by the database for the holdings of R1000. The calculation of sector performance involves two steps. First, we compute an average monthly return of each sector for FIX and R1000 based on respective portfolio holding within a given sector. Then we annualize the average monthly returns of FIX and R1000 to obtain their sector returns.

We present the results in Figure 3. It is clear that the sector performance of FIX exceeds the performance of R1000 in all industry sectors. The outperformance of FIX is not from few specific industry sectors.

6 Conclusions

Despite the merits of cap-weighted indices such as low turnover, high capacity, and a simple construction, the efficiency of the cap-weighted indices is under debate. Alternative indices emerged in response to the criticism on cap-weighted indices. Yet, a potential issue disturbing extant alternative indices, particularly those using fundamental factors, is that the indices may not be independent of risk factors. Recent work shows that the alternative indices are biased towards value stocks or small-cap stocks, leading to relatively low risk-adjusted returns.

In this study, we improve from alternative indices by proposing a two-stage regression based methodology that controls for portfolio biases to risk factors and develops efficient indices by tilting stock weights of a market index. First, we purge risk from fundamental factors by orthogonizing fundamental factors on risk factors. Second, the index is adjusted to be more or less sensitive to fundamental factors through tilting the sensitivities of portfolio weights of a cap-weighted index to risk-adjusted fundamental factors. This approach facilitates an "optimal" index under the targeted tracking error and portfolio turnover. Also, it addresses the so-called "risk factors eating alphas" problem which is a long-standing issue perplexing the investment industry. Our method isolates risk from the desirable fundamental factors potentially generating alpha.

We demonstrate the performance of the tilting method through a new stock index based on the Russell 1000. The new index is tilted to be more elastic to the profit factor, while less elastic to business cycle factor and financial leverage factor and less responsive to idiosyncratic factor. Tests show that the new index generates superior raw performance relative to the conventional cap-weighted index and the Carhart's four-factor portfolio. The new index has a high Sharpe ratio while unbiased to conventional risks such as beta, book-to-market ratios, size, and momentum. It also has a high information ratio while the tracking error and turnover rates are relatively low.

Our study contributes to the investment practice by introducing a methodology to control for risk and tracking errors while delivering superior performance. By introducing a methodology to construct more efficient index portfolios, we identify a way to improve the capital market efficiency, thereby resulting in more efficient corporate investment and financing decisions. Moreover, our work demonstrates a venue to apply active portfolio management techniques in passive portfolio managements. Prior studies show that financial leverage and operating leverage expose firms to great economic shocks (Billio, Getmansky, Lo, and Pelizzon, 2012) while corporates operating with high asset efficiency is less subject to economic shocks. With FIX, we show that underweighting factors associated with operating and financial leverages while over-weighting the asset efficiency factor generates superior performance.

Appendix: Optimal Index Weights

Multiplying stock returns in both sides of Eq (12), we have

$$\boldsymbol{r}'\boldsymbol{W^*} = \boldsymbol{r}'W + \boldsymbol{r}'\boldsymbol{F(D-I)\delta} + (d-1)\boldsymbol{r}'\boldsymbol{\upsilon}$$

Denoting that $\boldsymbol{\delta} = [\boldsymbol{\delta}_1, \boldsymbol{\delta}_2, \boldsymbol{\delta}_3]'$, $\boldsymbol{D} = diag(d_1, d_2, d_3)$, and $d_4 = d$,

$$\boldsymbol{r}'\boldsymbol{W^*} = \boldsymbol{r}'\boldsymbol{W} + \boldsymbol{r}'\boldsymbol{F}[\boldsymbol{\delta}_1(d_1-1), \boldsymbol{\delta}_2(d_2-1), \boldsymbol{\delta}_3(d_3-1)]' + (d_4-1)\boldsymbol{r}'\boldsymbol{\upsilon}$$

Therefore,

$$R^* = R + \boldsymbol{r}'\boldsymbol{F_1}\boldsymbol{\delta}_1(d_1-1) + \boldsymbol{r}'\boldsymbol{F_2}\boldsymbol{\delta}_2(d_2-1) + \boldsymbol{r}'\boldsymbol{F_3}\boldsymbol{\delta}_3(d_3-1) + (d_4-1)\boldsymbol{r}'\boldsymbol{\upsilon} \qquad (b1)$$

The excess return of FIX over the Russell 1000 is

$$R^* - R = R_1x_1 + R_2x_2 + R_3x_3 + R_4x_4,$$

where $R_i = \boldsymbol{r}'\boldsymbol{F_i}\boldsymbol{\delta}_i$ $(i = 1, 2, 3)$ is the return associated with the risk-adjusted fundamental factor F_i, $R_4 = \boldsymbol{r}'\boldsymbol{\upsilon}$ is the residual return, and $x_i = d_i - 1$, $i = 1, 2, 3, 4$. So, the average excess return of FIX is

$$\overline{R^*} - \overline{R} = \overline{R_1}x_1 + \overline{R_2}x_2 + \overline{R_3}x_3 + \overline{R_4}x_4 = \overline{A}x, \qquad (b2)$$

In the above expression, $A = [R_1, R_2, R_3, R_4]$ and $x = [x_1, x_2, x_3, x_4]'$. The tracking error of FIX to the Russell 1000 is

$$Vol(R^* - R) = \sqrt{\boldsymbol{x}'\sum\boldsymbol{x}},$$

where $\sum$ is the covariance matrix among R_i, $i = 1, 2, 3, 4$.

We optimize the information ratio of FIX over the Russell 1000. The optimization for a given tracking error, TR, is

$$maximize : IR = \frac{\overline{\boldsymbol{A}}\boldsymbol{x}}{\sqrt{\boldsymbol{x}'\sum\boldsymbol{x}}}, \sqrt{\boldsymbol{x}'\sum\boldsymbol{x}} \leq TR \qquad (b3)$$

for all $\boldsymbol{x}$. The solution to the optimization problem is

$$\boldsymbol{x} = TR\frac{\sum^{-1}\overline{\boldsymbol{A}'}}{\sqrt{\overline{\boldsymbol{A}}\sum^{-1}\overline{\boldsymbol{A}'}}} \qquad (b4)$$

The optimal sensitivities to the fundamental factors and residual factor are

$$[d_1, d_2, d_3, d_4]' = 1 + TR\frac{\sum^{-1}\overline{\boldsymbol{A}'}}{\sqrt{\overline{\boldsymbol{A}}\sum^{-1}\overline{\boldsymbol{A}'}}}$$

When we apply the optimization to FIX, the optimal solution is

$$\boldsymbol{x} = [1.00, -0.20, -0.55, -0.26]'$$

As a result, $[d_1, d_2, d_3, d_4] = [2.00, 0.80, 0.45, 0.73]$ are the optimal sensitivities to the fundamental factors and the residual factor. Under the optimal sensitivities, the information ratio of FIX is 1.05.

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Table 1: Returns of Fundamental Factor Tilt Index (FIX) and Russell 1000

This table reports the annualized stock performance and their differences for the Fundamental Factor Tilt Index (FIX) and the Russell 1000 (R1000) over the sample period. All the reported numbers are in percentage. The last three rows report the averages of sub-sample periods (1990-2000 and 2001-2011) and the entire sample period (1990-2011). The t-statistic for the return difference over the full sample period is reported in the parenthesis. *** represents the 1 percent significance level.

Year	FIX	R1000	DIFFERENCE (= R1000 - FIX)
1990	-2.658	-3.393	0.735
1991	31.287	30.625	0.662
1992	9.729	9.245	0.485
1993	9.423	9.867	-0.444
1994	1.716	0.881	0.835
1995	30.847	32.435	-1.587
1996	20.547	20.810	-0.263
1997	29.856	28.847	1.008
1998	23.772	26.644	-2.871
1999	21.545	22.561	-1.016
2000	0.013	-9.047	9.060
2001	-4.625	-11.491	6.866
2002	-17.494	-21.775	4.281
2003	28.855	26.825	2.030
2004	12.708	11.179	1.529
2005	7.456	6.515	0.941
2006	14.227	14.649	-0.422
2007	5.831	6.246	-0.415
2008	-38.980	-43.739	4.759
2009	31.488	28.250	3.238
2010	20.867	16.985	3.883
2011	14.356	11.646	2.710
1990-2000	16.007	15.407	0.600
2001-2011	6.790	4.117	2.673
All Year	11.398	9.762	1.636/(2.653)***

Table 2: Carhart's Four-Factor Regressions

This table reports the results when monthly excess returns (over 1-month Treasury bill rates) of FIX and Russell 1000 onto Carhart four factors. Annual alpha (ALPHA = 12 * intercept), the loading on the respective factors (RMRF, SMB, HML, and MOM), and the regression r-squared (RSQ) are reported. All the numbers are reported in percentage. The last three rows report the regressions of sub-sample periods (1990-2000 and 2001-2011) and those of the entire sample period (1990-2011). ***, **, and * represent the 1, 5 and 10 percent significance levels.

	FIX						R1000					
Year	ALPHA	RMRF	SMB	HML	MOM	RSQ	ALPHA	RMRF	SMB	HML	MOM	RSQ
1990	0.75	99.87***	-3.16	-3.90	-0.46	99.86	-0.13	99.57***	-7.02***	-0.97	-0.47	100.00
1991	1.00	98.85***	0.01	2.83	2.35	99.85	0.29	100.37***	-7.38***	-0.25	0.04	99.99
1992	1.65	93.02***	-3.25	-5.67*	0.58	99.36	0.23	99.35***	-8.21***	-0.73*	-0.14	99.99
1993	-0.53	97.79***	-11.95**	-4.05	3.60	99.20	0.09	100.96***	-9.50***	0.07	-1.42*	99.96
1994	0.98	94.76***	-1.82	-1.78	-3.19	99.53	0.42	100.42***	-8.52***	-1.12	-4.17**	99.98
1995	4.11	85.86***	-3.44	-4.51	-10.53*	98.59	0.56	98.77***	-11.51***	-1.17	-1.32	99.88
1996	1.11	94.81***	-8.35	-4.45	-2.72	99.50	0.77	98.36***	-13.61***	-3.21**	-0.91	99.98
1997	1.89	98.10***	-4.22	6.23	-0.47	99.83	1.06	99.55***	-12.64***	-4.46	-2.33	99.97
1998	-0.93	96.89***	-9.00	-7.80	-10.90*	99.75	1.22	98.22***	-7.01*	-3.18	-2.56	99.96
1999	0.77	97.34***	1.55	9.30	6.23	98.29	0.05	97.85***	-6.74***	-2.98	-0.61	99.91
2000	5.23	89.12***	-22.68	-4.29	2.82	98.62	-0.78	99.74***	-10.05	-2.34	-3.36	99.69
2001	2.45	103.55***	6.27*	7.74*	6.39*	99.80	0.91	99.17***	-7.19***	-1.30	-2.01	99.97
2002	3.53	97.93***	-3.00	3.03	-0.02	99.85	0.92	99.38***	-8.11***	-2.54**	-2.06***	99.99
2003	0.12	95.15***	8.56*	3.11	0.77	99.58	0.63*	99.16***	-8.19***	0.18	-0.34	99.99
2004	2.96***	94.04***	0.15	-14.87***	-2.14	99.90	-0.07	99.90***	-6.90***	-1.71	-3.05***	99.98
2005	0.64	101.11***	0.08	10.31	-1.53	99.55	-0.05	99.95***	-10.08***	-0.40	-0.37	99.99
2006	-0.12	90.78***	6.13	-0.64	-4.44	99.51	-0.20	99.11***	-9.29***	0.08	-2.14***	99.98
2007	2.59	93.32***	-10.02*	17.86**	3.40	99.58	-0.12	98.98***	-14.12***	3.44	1.55	99.97
2008	2.99	98.13***	3.09	2.25	2.49	99.64	-0.51	99.56***	-8.05***	-1.48	-0.93	99.98
2009	1.71	92.98***	10.73***	-2.60	-3.07	99.88	0.30	98.73***	-7.24***	-1.54	-2.11**	99.99
2010	2.10	97.43***	8.05**	-0.84	-0.11	99.94	-0.55	100.01***	-7.07**	1.08	1.01	99.97
2011	3.74	95.56**	12.74	-1.29	-6.42	99.73	0.34	98.61***	-9.20	3.53	-0.94	99.99
1990-2000	1.39	97.98	-4.69	2.38	-2.46	99.01	0.24	100.13	-9.75	-1.25	-1.35	99.87
2001-2011	1.76	95.85	4.14	1.29	-0.27	99.60	0.19	99.46	-7.64	-1.14	-1.59	99.96
All years	1.70***	96.77***	-1.51*	3.07***	-0.92	99.23	0.28*	99.94***	-8.85***	-1.00***	-1.48***	99.92

Table 3: Turnover rates of FIX and Russell 1000 over Time

This table reports the annual turnover rates of FIX and R1000. A turnover rate is the minimum of the total amount of new securities purchased or the amount of securities sold - whichever is less - over a 12-month period, divided by the total asset value of the fund. The last three rows report the average turnover rates of both portfolios during sub-sample periods (1990-2000 and 2001-2011), and in the full sample period (1990-2011).

Year	FIX	R1000
1990	18.688	1.661
1991	21.716	1.565
1992	24.008	1.502
1993	22.323	3.984
1994	24.432	2.347
1995	20.661	3.607
1996	30.799	4.675
1997	24.212	4.059
1998	21.433	4.619
1999	32.646	7.373
2000	37.968	10.404
2001	33.497	3.075
2002	29.379	2.024
2003	19.681	1.902
2004	19.592	2.881
2005	21.482	2.736
2006	29.328	3.345
2007	22.368	3.322
2008	29.909	2.143
2009	30.959	3.369
2010	21.918	1.489
2011	21.172	1.654
1990-2000	25.353	4.163
2001-2011	25.390	2.540
All Years	25.371	3.352

Table 4: Portfolio Attributes under Alternative Rebalance Frequency

This table reports performance, tracking errors, and portfolio turnover rates of FIX under different full rebalance schedules: 1 month, 3 month, 6 months, and 12 months. Alternative portfolio attributes include raw return (Raw), Carhart alpha (alpha), volatility (Vol), Sharpe ratio (SR), excess return of FIX relative to Russell 1000 (EX), tracking error (TR), information ratio (IR), and turnover rate (TURN). Panel A is for the result over the full sample period (1990-2011). Panels B and C report the results of sub-sample periods, 1990-2000 and 2001-2011, respectively.

Panel A: Full Sample

Port	Rebalance	Raw	Alpha	Vol	SR	EX	TR	IR	TURN
R1000	1m	9.72	0.28	15.35	0.39	0.00	0.00	N/A	3.39
FIX	1m	11.30	1.70	15.05	0.50	1.58	1.56	1.01	25.70
FIX	3m	11.23	1.64	15.01	0.50	1.51	1.55	0.98	20.18
FIX	6m	11.19	1.55	14.96	0.50	1.47	1.52	0.97	17.11
FIX	12m	11.02	1.38	14.95	0.48	1.30	1.44	0.91	13.83

Panel B: 1990-2000

Port	Rebalance	Raw	Alpha	Vol	SR	EX	TR	IR	TURN
R1000	1m	15.41	0.24	14.25	0.71	0.00	0.00	N/A	4.16
FIX	1m	16.07	1.39	13.86	0.78	0.66	1.58	0.42	26.06
FIX	3m	15.97	1.33	13.80	0.78	0.57	1.58	0.36	19.76
FIX	6m	15.97	1.18	13.84	0.78	0.57	1.53	0.37	16.48
FIX	12m	15.74	0.95	13.90	0.76	0.33	1.36	0.25	12.71

Panel C: 2001-2011

Port	Rebalance	Raw	Alpha	Vol	SR	EX	TR	IR	TURN
R1000	1m	3.76	0.19	16.29	0.09	0.00	0.00	N/A	2.58
FIX	1m	6.30	1.76	16.13	0.25	2.54	1.48	1.71	24.60
FIX	3m	6.26	1.74	16.12	0.25	2.50	1.47	1.71	19.91
FIX	6m	6.19	1.68	15.98	0.25	2.43	1.47	1.66	16.77
FIX	12m	6.08	1.58	15.92	0.24	2.32	1.47	1.58	13.36

Table 5: Performance and Portfolio Turnover of Fundamental factor Tilt Index (FIX) and the Russell 1000 (R1000): Varying Sensitivities to Fundamental Factors and Residuals

This table reports performance attributes, tracking errors, and portfolio turnovers of FIX and R1000 under alternative tilts of portfolio sensitivities to fundamental factors and the residuals. The following variables are included: the name of the portfolio (Port), raw return (RAW, in percent), Carhart alpha (alpha, in percent), standard deviation of portfolio returns (Vol, in percent), Sharpe ratio (SR), excess return of FIX relative to R1000 (Ex Ret, in percent), tracking error (TR, in percent), information ratio (IR), and annual turnover rate (TURN, in percent). While FIX is rebalanced monthly, all the numbers are based on annual portfolio performance. The selected adjustment parameter $\boldsymbol{\delta^*}$ are reported in the last four columns. Panels A and B respectively present the results when different tilts on portfolio sensitivities to the residuals from the regressions of portfolio weights on the risk-adjusted fundamental factors are applied.

Panel A: $\boldsymbol{\delta^*}$ on Residual Beta = 2/3

Port	Raw	Alpha	Vol	SR	Ex Ret	TR	IR	TURN	$\delta^*(ROA)$	$\delta^*(NS)$	$\delta^*(D)$
R1000	9.72	0.28	15.35	0.39	0.00	0.00	N/A	3.39	1	1	1
X1	10.73	1.21	15.11	0.46	1.01	1.09	0.93	16.71	2	1	1
X2	10.84	1.35	15.08	0.47	1.12	1.15	0.97	19.61	3	1	1
X3	10.95	1.48	15.08	0.48	1.23	1.24	0.99	22.46	4	1	1
X4	11.05	1.47	15.06	0.48	1.33	1.36	0.98	22.10	2	2/3	1
X5	11.14	1.61	15.04	0.49	1.42	1.40	1.01	24.42	3	2/3	1
X6	11.24	1.72	15.04	0.50	1.52	1.47	1.03	26.80	4	2/3	1
X7	11.35	1.71	15.07	0.50	1.63	1.70	0.96	27.75	2	1/3	1
X8	11.43	1.83	15.04	0.51	1.71	1.73	0.99	29.49	3	1/3	1
X9	11.51	1.93	15.04	0.51	1.79	1.78	1.01	31.41	4	1/3	1
X10	11.00	1.46	15.08	0.48	1.28	1.26	1.01	20.12	2	1	2/3
X11	11.09	1.59	15.07	0.49	1.38	1.32	1.04	22.62	3	1	2/3
X12	11.19	1.70	15.07	0.49	1.48	1.40	1.06	25.16	4	1	2/3
X13 (FIX)	11.30	1.70	15.05	0.50	1.58	1.56	1.01	25.69	2	2/3	2/3
X14	11.38	1.83	15.03	0.51	1.67	1.60	1.04	27.62	3	2/3	2/3
X15	11.46	1.93	15.04	0.51	1.75	1.66	1.05	29.71	4	2/3	2/3
X16	11.57	1.91	15.08	0.52	1.85	1.89	0.98	31.04	2	1/3	2/3
X17	11.64	2.02	15.05	0.52	1.93	1.92	1.00	32.52	3	1/3	2/3
X18	11.71	2.11	15.05	0.53	1.99	1.96	1.02	34.17	4	1/3	2/3
X19	11.26	1.70	15.09	0.50	1.55	1.48	1.05	23.94	2	1	1/3
X20	11.35	1.81	15.08	0.50	1.63	1.52	1.07	25.98	3	1	1/3
X21	11.44	1.92	15.08	0.51	1.72	1.59	1.08	28.17	4	1	1/3
X22	11.53	1.90	15.08	0.51	1.81	1.77	1.02	29.25	2	2/3	1/3
X23	11.61	2.02	15.06	0.52	1.89	1.80	1.05	30.83	3	2/3	1/3
X24	11.67	2.10	15.07	0.52	1.96	1.86	1.05	32.61	4	2/3	1/3
X25	11.76	2.06	15.12	0.53	2.05	2.09	0.98	34.13	2	1/3	1/3
X26	11.84	2.17	15.09	0.53	2.12	2.11	1.00	35.33	3	1/3	1/3
X27	11.89	2.24	15.09	0.54	2.17	2.15	1.01	36.74	4	1/3	1/3

Panel B: $\boldsymbol{\delta^*}$ on Residual Beta = 1/3

Port	Raw	Alpha	Vol	SR	Ex Ret	TR	IR	TURN	$\delta^*(ROA)$	$\delta^*(NS)$	$\delta^*(D)$
X1	11.44	1.73	15.20	0.50	1.72	1.94	0.88	29.97	2	1	1
X2	11.51	1.84	15.17	0.51	1.79	1.96	0.91	31.83	3	1	1
X3	11.59	1.94	15.16	0.52	1.87	2.00	0.93	33.85	4	1	1
X4	11.73	1.97	15.18	0.52	2.01	2.21	0.91	34.58	2	2/3	1
X5	11.79	2.07	15.15	0.53	2.08	2.22	0.94	36.11	3	2/3	1
X6	11.86	2.16	15.14	0.53	2.14	2.25	0.95	37.79	4	2/3	1
X7	12.01	2.19	15.21	0.54	2.29	2.51	0.91	38.98	2	1/3	1
X8	12.06	2.28	15.17	0.55	2.34	2.51	0.93	40.23	3	1/3	1
X9	12.12	2.36	15.16	0.55	2.40	2.53	0.95	41.63	4	1/3	1
X10	11.69	1.96	15.18	0.52	1.97	2.10	0.94	32.74	2	1	2/3
X11	11.75	2.06	15.16	0.53	2.04	2.12	0.96	34.40	3	1	2/3
X12	11.83	2.15	15.15	0.53	2.11	2.16	0.98	36.19	4	1	2/3
X13	11.96	2.18	15.18	0.54	2.24	2.38	0.94	37.31	2	2/3	2/3
X14	12.02	2.28	15.15	0.54	2.30	2.39	0.96	38.68	3	2/3	2/3
X15	12.08	2.36	15.15	0.55	2.36	2.42	0.98	40.18	4	2/3	2/3
X16	12.19	2.34	15.23	0.55	2.48	2.68	0.92	41.46	2	1/3	2/3
X17	12.25	2.43	15.19	0.56	2.53	2.68	0.94	42.51	3	1/3	2/3
X18	12.30	2.51	15.18	0.56	2.58	2.70	0.96	43.72	4	1/3	2/3
X19	11.93	2.17	15.20	0.54	2.21	2.29	0.96	35.58	2	1	1/3
X20	11.99	2.27	15.17	0.54	2.28	2.30	0.99	37.03	3	1	1/3
X21	12.05	2.35	15.17	0.55	2.33	2.33	1.00	38.61	4	1	1/3
X22	12.16	2.34	15.22	0.55	2.44	2.57	0.95	39.94	2	2/3	1/3
X23	12.22	2.44	15.19	0.56	2.50	2.57	0.97	41.08	3	2/3	1/3
X24	12.27	2.51	15.18	0.56	2.55	2.59	0.98	42.37	4	2/3	1/3
X25	12.35	2.46	15.28	0.56	2.64	2.86	0.92	43.79	2	1/3	1/3
X26	12.41	2.55	15.24	0.57	2.69	2.85	0.94	44.65	3	1/3	1/3
X27	12.46	2.63	15.23	0.57	2.74	2.86	0.96	45.67	4	1/3	1/3

Table 6: Portfolio Returns due to Fundamental Factors

This table reports the attribution of FIX to i) R1000, ii) three fundamental factors: ROA, NS and D, iii) the residual in each year. All the reported numbers are in percent. The last column, the sum of returns, is the aggregation of the attributed performance, the return of R1000 together with returns from fundamental beta tilts and the tilt on the residual beta. The last three rows report the averages of sub-sample periods (1990-2000 and 2001-2011) and the entire sample period (1990-2011).

Year	FIX	R1000	ROA	NS	D	Residual	Sum
1990	-2.658	-3.393	0.675	0.420	0.309	-0.343	-2.332
1991	31.287	30.625	0.243	0.019	0.108	0.281	31.277
1992	9.729	9.245	-0.283	-0.020	0.089	0.509	9.540
1993	9.423	9.867	-0.246	-0.112	-0.286	0.423	9.645
1994	1.716	0.881	0.006	0.074	0.104	0.334	1.398
1995	30.847	32.435	-0.113	-0.637	-0.397	-0.641	30.646
1996	20.547	20.810	0.052	-0.086	0.029	-0.781	20.025
1997	29.856	28.847	0.018	0.040	0.156	0.408	29.470
1998	23.772	26.644	-0.010	-0.623	-0.259	-1.476	24.275
1999	21.545	22.561	-0.149	0.442	0.509	-0.681	22.681
2000	0.013	-9.047	0.253	1.142	0.659	4.499	-2.494
2001	-4.625	-11.491	0.201	1.402	0.662	3.179	-6.048
2002	-17.494	-21.775	0.394	1.724	1.026	1.341	-17.289
2003	28.855	26.825	-0.220	-0.039	-0.128	1.044	27.482
2004	12.708	11.179	-0.021	0.284	0.176	1.132	12.751
2005	7.456	6.515	0.155	0.241	0.252	0.729	7.893
2006	14.227	14.649	-0.056	-0.241	-0.102	0.103	14.352
2007	5.831	6.246	0.221	-0.234	0.203	-0.537	5.900
2008	-38.980	-43.739	1.321	2.117	1.793	1.246	-37.261
2009	31.488	28.250	-0.502	0.447	-0.086	1.246	29.354
2010	20.867	16.985	0.017	1.024	0.779	1.686	20.491
2011	14.356	11.646	0.309	0.419	0.378	1.298	14.050
1990-2000	16.007	15.407	0.041	0.060	0.093	0.230	15.830
2001-2011	6.790	4.117	0.165	0.650	0.450	1.133	6.516
All Years	11.398	9.762	0.103	0.355	0.271	0.682	11.173

Figure 1: Three-year Rolling Volatilities of FIX and Russell 1000

This figure depicts the rolling volatilities of FIX and Russell 1000. The volatilities are annualized and calculated based on monthly returns in a 36-month rolling window. For example, the volatility of July, 2010 is calculated using returns from August 2007 to July 2010.

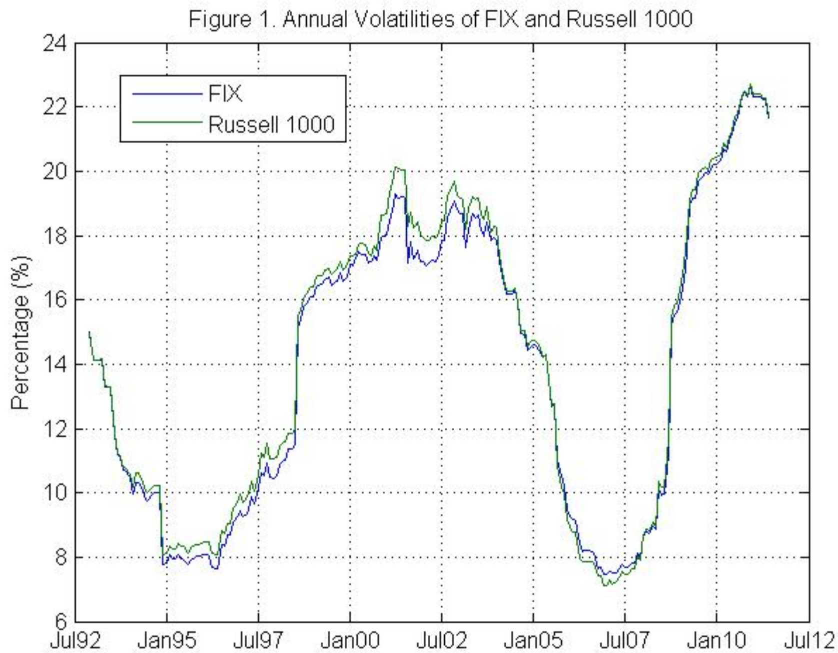

Figure 2: Stock Performance Attributed to ROA, Net Sales, and Long-term Debt

This figure plots the performance of FIX attributed to three fundamental factors: ROA, net sales, and long term debt.

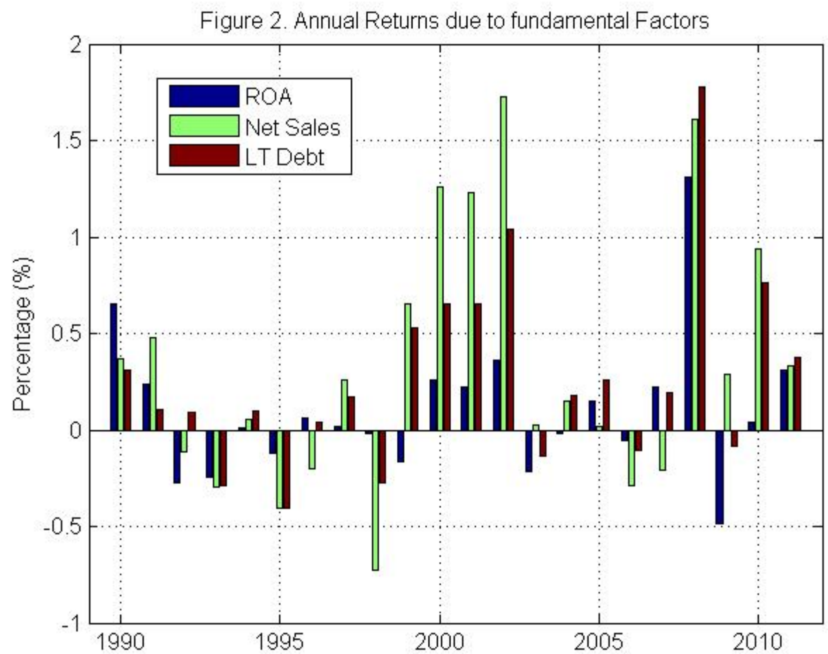

Figure 3: Sector Performance of FIX and Russell 1000

This figure plots the performance of FIX and Russell 1000 attributed to 10 industrial sectors, including i) energy, ii) materials, iii) industrials, iv) consumer discretionary goods, v) consumer stable goods, vi) health care, vii) financial sector, viii) information technology, ix) telecom service, and x) utilities.