Hedge fund alpha and beta corrected for stale pricing

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ABSTRACT

This paper introduces a novel method for estimating the alpha and beta of hedge fund indices that corrects for stale pricing in reported returns. This approach can be further used to estimate volatility and other risk measures. We apply this technique to a composite hedge fund index and six strategy indices provided by HFR. Once corrected for stale pricing, we find these indices exhibit higher betas and volatility with negative or statistically insignificant positive alpha.

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Over the past three decades, alternative investments, such as private equity, venture capital and hedge funds, have become an increasingly large portion of institutional portfolios. Over half of the $647bn of assets managed by United States-based university endowments were invested in alternatives in 2020[1]. As much as 20% was invested in hedge funds alone. Public pension schemes, traditionally more risk-averse, have allocated over 27% of their $4.5trillion of capital to alternatives in 2020[2].

At least as far back as 2001, concerns have been raised that the reported returns of alternatives may understate market beta and volatility. One early study, Asness, Crail, and Liew (2001), found that the market beta of monthly reported hedge fund returns greatly underestimated equity market exposure. They argue that this was due to the stale or managed prices of illiquid holdings.

Getmansky, Lo, and Makarov (2003) further argued that the presence of serial correlation in hedge fund reported returns was evidence of such stale or managed prices. They found that such non-synchronous prices resulted in smoothed returns that artificially reduced estimates of market beta and volatility.

The understatement of market beta and volatility of alternative asset classes poses a significant challenge to allocators of institutional capital, who must have an accurate assessment of risk in order to make informed investment decisions.

A wide body of research has been devoted to the calculation of market beta in the presence of stale (non-synchronous) pricing for a diverse range of investments. In particular early work by Scholes and Williams (1977) and Dimson (1979) developed econometric

[1] 2020 NACUBO-TIAA Study of Endowments
[2] Public Fund Survey, FY 2020, National Association of State Retirement Administrators

models of stale pricing for infrequently traded securities from which estimates of market beta could be derived.

Dimson (1979) demonstrated that the true economic beta of a security was equivalent to the sum of all beta coefficients in a multiple regression of the securities returns against contemporaneous and lagged market returns. Asness, Crail, and Liew (2001) applied this approach to hedge fund indices.

The drawback of this approach is that the residuals of this regression will be serially correlated. While this should not effect the accuracy of the beta or alpha estimates in the regression, it does render the standard errors invalid and therefore does not allow significance testing.

Getmansky, Lo, and Makarov (2003) use the same econometric model but apply a preestablished parameterised relationship between reported and true economic returns. Numerical optimization is then employed to estimate these parameters that can be used to then estimate a market beta.

In this paper, we propose a novel method to calculating the true economic beta and alpha of hedge fund indices that avoids residual serial correlation and does not require numerical optimisation. This approach can be easily implemented by practitioners without complex calculations and applied to other asset classes and securities.

Furthermore, this method allows the approximation of volatility and correlation with equity markets. We can further establish a Stale Pricing Indicator for measuring the degree of stale pricing in reported returns.

We apply this methodology to a composite hedge fund index and six strategy indices provided by Hedge Fund Research (HFR). These return indices aggregate the monthly reported returns from a large number of hedge funds that provide their returns to the HFR database.

Once corrected for stale pricing, we find the composite hedge fund index exhibited a beta of 0.46 and volatility of 0.083 since 2010. This compares to a beta of 0.39 and volatility of 0.062 for un-adjusted reported returns over the same period. We find an alpha of -0.0018 that is significant at the 0.05 level.

All six strategy indices exhibit higher beta and volatility once corrected for stale pricing. No index exhibited significantly positive alpha.

The remainder of this paper is organised as follows. Section I discusses related literature. Section II describes the econometric model and derives the estimators for beta and volatility. Section III describes the hedge fund return data used for the empirical analysis. Section 5 describes the empirical results. The paper concludes with Section 6.

I. Related Literature

This work is related specifically to literature seeking to measure the risk of alternative investment strategies, and hedge funds in particular, but more generally to a larger body of research focused on estimating market beta of assets with stale or non-synchronous pricing.

Scholes and Williams (1977) and Dimson (1979) were among the first to identify that stale or non-synchronous pricing would cause an understatement of market beta. Dimson (1979), similarly to Cohen et al (1986), proposed simple econometric models to relate the reported (observable) prices and returns of an asset to their true economic (but unobservable) prices and returns.

Using these types of econometric models, various methods have been derived to estimate the market beta of the true economic returns. Dimson (1979) proposed using a regression of the observed reported returns to contemporaneous and lagged market returns. He demonstrated that the summation of the beta coefficients of the regression would provide an accurate estimate for the market beta of the true economic returns.

This intuitive approach has the strength of being easy to implement. However, the error terms of the regression coefficient will be serially correlated (in the case that there is stale pricing) which causes the standard errors to become invalid.

The literature related to hedge fund risk builds on this earlier work. Asness, Crail, and Liew (2001) was one of the earliest studies to argue that the stale non-synchronous pricing of illiquid portfolio holdings caused significant understatement of the market beta of hedge funds.

Asness, Crail, and Liew (2001) applied the Dimson (1979) methodology to a family of hedge fund indices that were published by CSFB/Tremont. The results revealed that reported returns did indeed understate market beta and obtained estimates that were substantially higher.

Later work also used the same basic econometric model proposed by Dimson (1979) but with differing approaches to estimating beta. Getmansky, Lo, and Makarov (2003) examined specific smoothing processes of the true economic returns. Using numerical optimization, they sought to estimate the parameters of these smoothing processes and use this to estimate market beta.

This methodology imposes constraints on the relationship between reported returns and true economic returns that may not be applicable in reality. Numerical optimization approaches have the potential, as Getmansky, Lo, and Makarov (2003) discuss, to not perform well in all market environments.

Getmansky, Lo, and Makarov (2003) also examine possible causes for serial correlation and stale pricing in Hedge Fund data, including whether pricing is deliberately managed in order to understate risk and accentuate risk-adjusted return ratios (such as the Sharpe Ratio). Spurgin (2001) gives examples of how hedge fund could structure investments to deliberately raise such ratios, while Bollen and Pool (2009) examine whether hedge funds go as far as deliberately misreporting returns.

Cassar and Gerakos (2011) investigate the mechanisms used to price hedge fund investment holdings. They find that funds where the manager has more pricing discretion and uses less verifiable pricing sources are more likely to have reported returns consistent with managed pricing that would understate risk and correlations. This confirms earlier results from Chandar and Bricker (2002) that (more regulated) mutual funds also apply discretion to the pricing of illiquid holdings to smooth returns.

II. Data

We utilise a family of hedge fund indices provided by specialist data provider Hedge Fund Research (HFR). HFR maintains a database of over 5,900 hedge funds, collating both qualitative and performance data. HFR calculates both a Composite index that aggregates the returns of all funds in their database and indices for certain sub-strategies.

<TABLE I HERE>

We will examine the broad HFRI Composite Index and six representative strategy indices. Table I provides descriptive information on the Composite Index, while Table II supplements this with descriptive information on the six strategy indices. Definitions of each strategy can be found in the appendix.

<TABLE II HERE>

III. Methodology

A. An econometric model of stale pricing

Dimson (1979) proposed a simple econometric model relating the reported (observable) price of an asset p_t^O to the contemporaneous and lagged true economic (unobservable) price p_t as follows:

$$p_t^O = \sum_{i=1}^{n} \theta_i p_{t-i+1} \tag{1}$$

Where:

$\theta_i \in [0,1], \qquad i = 1, \dots, n$

$\sum_{i=1}^{n} \theta_i = 1$

The true economic price is defined as the price that is informationally-efficient, reflecting all available information. In this model, the reported price is determined by some weighted average of the contemporaneous and lagged true economic prices.

Getmansky et al (2003) argue that such a model, weighting current and historic prices, is able to describe situations where prices are a consequence of simple linear extrapolations of acquisition price or 'marking to model' when no market price is available. They further argue that this model can equally describe intentional smoothing of prices and returns over time.

In this specification, when $\theta_1 = 1$, the reported price is equal to the contemporaneous true economic price and there is no stale pricing. Otherwise, when $\theta_1 < 1$, some portion of the reported price is determined by lagged (or stale) true economic prices.

Following Dimson (1979), equation (1) can be reformulated in terms of r_t^O and r_t, the reported (observable) return of the asset and the true economic (unobservable) return of the asset respectively:

$$r_t^O = \sum_{i=1}^{n} \theta_i r_{t-i+1} \tag{2}$$

As per Samuelson (1965) and Fama (1970), the true economic prices and thus returns are informationally efficient. Making a similar assumption for global equity markets, it follows that neither the true economic returns nor market returns should exhibit serial correlation or lagged correlation with each other. This can be formalized as follows for all $i > 0$:

$$Cov(R^M, R^M_{-i}) = Cov(R, R_{-i}) = Cov(R^M, R_{-i}) = Cov(R, R^M_{-i}) = 0 \tag{3}$$

Where:

$R = \{r_t\}$ is the series of true economic returns
$R^O = \{r_t^O\}$ is the series of reported returns
$R^M = \{r_t^M\}$ is the set of market returns
$R_{-i}, R^O_{-i}, R^M_{-i}$ are the respective series lagged by i periods.

B. Risk characteristics of reported (observable) returns

Using the model specified in equation (2), the risk characteristics obtained by using the reported (observable) returns can be formulated in terms of the risk characteristics of the true economic returns:

$$\beta^O = \theta_1 \beta \quad (4)$$

$$\sigma^O = \left(\sqrt{\sum_{i=1}^{n} {\theta_i}^2} \right) \sigma \quad (5)$$

$$\rho^O = \frac{\theta_1}{\sqrt{\sum_{i=1}^{n} {\theta_i}^2}} \rho \quad (6)$$

Where:

$\beta^O, \sigma^O, \rho^O$ is the market beta, volatility and market correlation of the reported (observable) returns respectively

β, σ, ρ the market beta, volatility and market correlation of the true economic returns respectively

When the reported returns are a function not just of contemporaneous true economic returns but also historic lagged returns (that is, when $\theta_1 < 1$), equations (4), (5) and (6) validate the arguments of Asness, Crail, and Liew (2001) that risk characteristics will be understated:

$$|\beta^O| < |\beta| \quad (7)$$

$$\sigma^O < \sigma \quad (8)$$

$$\rho^O < \rho \quad (9)$$

Furthermore, these equations demonstrate that the understatement of risk increases as the degree of stale pricing increases:

$$\theta_1{}' < \theta_1 \Rightarrow \left|\beta^{O'}\right| < \left|\beta^{O}\right| \tag{10}$$

$$\theta_1{}' < \theta_1 \Rightarrow \sigma^{O'} < \sigma^{O} \tag{11}$$

$$\theta_1{}' < \theta_1 \Rightarrow \rho^{O'} < \rho^{O} \tag{12}$$

C. Estimating the market beta of true economic (unobservable) returns

Equation (7) confirms that, when stale pricing is present, the beta obtained using reported returns will underestimate the true economic beta of the index. We wish therefore to derive an estimate of the true economic beta that is more accurate than this reported beta.

In order to proceed, we first define consecutive m-period trailing averages of reported returns and market returns as:

$$MA_m^O = \left\{ ma_{m,mt}^O = \frac{1}{m}\sum_{i=1}^{m} r_{mt-i+1}^O \right\} \tag{13}$$

$$MA_m^M = \left\{ ma_{m,mt}^M = \frac{1}{m}\sum_{i=1}^{m} r_{mt-i+1}^M \right\} \tag{14}$$

Using the relationship between reported and true economic returns defined in equation (2), the beta of the trailing average of reported returns against the trailing average of market returns can be formulated as:

$$\beta(MA_m^O, MA_m^M) = \frac{\sum_{i=1}^{m}\sum_{j=1}^{m}\sum_{k=1}^{n}\frac{1}{m^2}\theta_k Cov\left(R_{-i-k+2}, R_{-j+1}^M\right)}{\left[\sum_{i=1}^{m}\frac{1}{m^2}\right]Var(R^M)} \tag{15}$$

From equation (3) we note that lagged correlations between true economic returns and market returns are zero:

$$Cov\left(R_{-i-k+2}, R_{-j+1}^M\right) = \begin{cases} Cov(R, R^M) & k = j - i + 1 \\ 0 & k \neq j - i + 1 \end{cases} \tag{16}$$

With some rearrangement, equation (15) can therefore be simplified as:

$$\begin{aligned} \beta(MA_m^O, MA_m^M) &= \frac{\sum_{i=1}^{Min(m,n)}\theta_i\left(\sum_{j=1}^{m-i+1}\frac{1}{m^2}\right)}{\sum_{i=1}^{m}\frac{1}{m^2}}\beta \\ &= \left[\theta_1 + \frac{\sum_{i=2}^{Min(m,n)}\theta_i(m-i+1)}{m}\right]\beta \end{aligned} \tag{17}$$

We can now proceed to define an estimator of the true economic beta, $\hat{\beta}_m = \beta(MA_m^O, MA_m^M)$, and prove it is a better estimator than the reported beta, β^O.

PROPOSITION 1: The beta estimator, $\hat{\beta}_m$, has the following properties:

(a) When the true economic beta, β, is greater than zero, $\hat{\beta}_m$ is lower bounded by the reported beta and upped bounded by the true economic beta

$$\beta \geq 0 \Rightarrow 0 \leq \beta^O \leq \hat{\beta}_m \leq \beta \tag{18}$$

(b) When the true economic beta, β, is less than zero, $\hat{\beta}_m$ is upper bounded by the reported beta and lower bounded by the true economic beta

$$\beta \leq 0 \Rightarrow 0 \geq \beta^O \geq \hat{\beta}_m \geq \beta \tag{19}$$

(c) When $\hat{\beta}_m$ is equal to the reported beta, then there is no stale pricing and it is also equal to the true economic beta

$$\beta^O = \hat{\beta}_m \Rightarrow \theta_1 = 1, \hat{\beta}_m = \beta \tag{20}$$

(d) When $\hat{\beta}_m$ is not equal to the reported beta, it is a closer estimate of the true economic beta

$$\beta^O \neq \hat{\beta}_m \Rightarrow \theta_1 < 1, \left|\hat{\beta}_m - \beta\right| < |\beta^O - \beta| \tag{21}$$

Proof: Since all $\theta_i \geq 0$ and $\sum_{i=1}^{n} \theta_i = 1$, from equations (4) and (17) we have:

$$\theta_1 \leq \theta_1 + \frac{\sum_{i=2}^{Min(m,n)} \theta_i (m - i + 1)}{m} \leq 1 \tag{22}$$

which can be seen to directly prove (a) and (b).

The proof of (c) also immediately follows from equation (17), since $\beta^O = \hat{\beta}_m$ only when $\theta_i = 0$ for all $i > 1$, that is to say when $\theta_1 = 1$. Likewise (d) also follows, since $\beta^O \neq \hat{\beta}_m$ can happen only when there exists $\theta_i > 0$ for some $i > 1$.

PROPOSITION 2: The magnitude of the beta estimator increases with m, and converges to the true economic beta

$$\left|\hat{\beta}_{m+1}\right| \geq \left|\hat{\beta}_m\right| \tag{23}$$

$$\lim_{m \to \infty} \hat{\beta}_m = \beta \tag{24}$$

Proof: Since, for $m > 2$, $2 \leq i \leq m$,

$$\frac{m-i+2}{m+1} > \frac{m-i+1}{m} \tag{25}$$

$$\lim_{m \to \infty} \frac{m-i+1}{m} = 1 \tag{26}$$

it follows immediately from equation (17) that the magnitude of the beta estimator is increasing and will converge to the true economic beta.

D. The Stale Pricing Indicator

Using the estimator of the true economic beta, $\hat{\beta}_m$, we can define an estimator to measure the degree of stale pricing present in a series of reported returns. we proceed by first defining an estimator for θ_1 as:

$$\hat{\theta}_{1_m} = \frac{\beta^O}{\hat{\beta}_m} \tag{27}$$

From the proof of Proposition 1, it follows that $\hat{\theta}_{1_m} \in [0,1]$. Equations (4) and (17) give us

$$\lim_{m\to\infty} \hat{\theta}_{1_m} = \theta_1 \tag{28}$$

since the proof of Proposition 2 demonstrates that $\hat{\beta}_m$ converges to β.

As θ_1 measures the proportion of the reported returns that is determined by contemporaneous true economic returns, it serves to indicate the presence of stale pricing in reported returns.

We can therefore define an indicator of stale pricing, the Stale Pricing Indicator, as follows:

$$SPI_m = 1 - \hat{\theta}_{1_m} = 1 - \frac{\beta^O}{\hat{\beta}_m} \tag{29}$$

This indicator provides an estimate for the degree of stale pricing in a series of reported returns. A value of 0 indicates that reported returns are precisely equal to true economic returns and that there is no stale pricing. A value of 1 indicates that reported returns is entirely determined by lagged (stale) true economic returns.

E. Estimating true economic volatility

The convergence of $\hat{\theta}_{1_m}$ to θ_1 expressed in equation (28) can be further exploited to derive an estimator for the volatility of the true economic returns, σ.

Noting that $0 \leq {\theta_1}^2 + (1-\theta_1)^2 \leq \sum_{i=1}^{n} \theta_i \leq 1$, equation (5) can be used to derive the following relationship:

$$\sigma \geq \frac{1}{\sqrt{{\theta_1}^2 + (1-\theta_1)^2}}\, \sigma^O \geq \sigma^O \tag{30}$$

We can then use $\hat{\theta}_{1_m}$ to define an estimator of σ as follows:

$$\hat{\sigma}_m = \frac{1}{\sqrt{{\hat{\theta}_{1_m}}^2 + \left(1-\hat{\theta}_{1_m}\right)^2}}\, \sigma^O \tag{31}$$

From equation (28) it can be immediately be seen that:

$$\sigma^O \leq \lim_{m\to\infty} \hat{\sigma}_m = \frac{1}{\sqrt{{\theta_1}^2 + (1-\theta_1)^2}} \sigma^O \leq \sigma \tag{32}$$

Therefore $\hat{\sigma}_m$ will converge to an estimator of the volatility of the true economic returns that is superior to that obtained using reported (observable) returns.

F. Estimating alpha

Since it is evident that the mean of the *m*-period moving average reported returns is equivalent to the mean of the true economic returns, the alpha resulting from a univariate regression of *m*-period moving average of reported returns against the *m*-period average of market returns will yield an alpha estimate for the true economic returns.

IV. Results

Considering first the Hedge Fund Composite index, a summary of results is given in Table III. As the hedge fund industry has grown and matured over time, we examine three time periods to see if the results for the most recent period (2010 to 2020) produce similar results to the past.

<TABLE III HERE>

We find that, when corrected for stale pricing, the Composite index exhibits a beta of 0.46 from 2010 to 2020. These values are higher than those obtained from un-adjusted reported returns of 0.39.

A similar pattern emerges for previous periods, where adjusting for stale pricing yields betas of 0.45 and 0.40 for 1990 to 1999 and 2000 to 2009 respectively. These values are higher than the betas of 0.36 and 0.35 obtained from reported returns over those periods respectively.

We find negative alpha, significant at the 0.05 threshold, during bother 2000 to 2009 and 2010 to 2020. In contrast, the earliest period (1990 to 1999) exhibited significant positive alpha at the 0.01 threshold.

<TABLE IV HERE>

Estimates of volatility and other risk measures for the Composite Index can be found in Table IV. From 2010 to 2020, we estimate a volatility for the Composite index of 0.083 significantly higher than the 0.062 obtained from reported returns.

Results for the six strategy indices over the period 2010 to 2020 can be found in Table V and Table VI. Similarly to the Composite index, we find higher betas and volatility across all strategies.

<TABLE V HERE>

Four strategy indices (Equity Hedge, Global Macro, Event Driven, and Activist) exhibited negative alphas over the period, while two (Relative Value and Credit) were positive but insignificant.

<TABLE VI HERE>

V. Conclusions

With a substantial portion of institutional portfolios allocated to alternative investments in general and hedge funds in particular, it is critical that allocators assessment of alpha, beta and volatility reflect true economic reality in order to make informed decisions.

Reported hedge fund returns rely on estimated valuations of illiquid portfolio holdings that are at risk of having stale (or managed) pricing. The serial correlation exhibited by reported returns is a sign that such stale pricing is evident. We have demonstrated that this causes estimates of beta and volatility obtained from reported returns to be understated.

In this paper, we present a novel method to estimate the true economic alpha, beta and volatility of hedge funds. This method allows for valid standard errors and significance testing. It does not require either numerical optimisation or assumptions on the relationship of reported returns and true economic returns.

Applying this approach to a Composite Hedge Fund index, we estimate values for market beta and volatility higher than those obtained from un-adjusted reported returns. We find alpha is negative.

When further applying this approach to six hedge fund strategy indices we obtain similar results, with higher betas and volatility. While not all indices exhibit negative alpha, the two (Relative Value and Credit) that have positive values are insignificant at all levels.

Overall, we confirm that it is important to correct hedge fund risk estimates for the effect of stale pricing. Once corrected, risk estimates are substantially higher and alphas are negative or negligibly positive.

Appendix: Hedge Fund Research (HFR) Index Descriptions

Definitions of the eight HFR indices used in this analysis taken directly from HFR documentation.

1. HFRI Fund Weighted Composite Index

   The HFRI Fund Weighted Composite Index is a global, equal-weighted index of single-manager funds that report to HFR Database. Constituent funds report monthly net of all fees performance in US Dollar and have a minimum of $50 Million under management or $10 Million under management and a twelve (12) month track record of active performance. The HFRI Fund Weighted Composite Index does not include Funds of Hedge Funds.

2. HFRI Equity Hedge Index

   Investment Managers who maintain positions both long and short in primarily equity and equity derivative securities. A wide variety of investment processes can be employed to arrive at an investment decision, including both quantitative and fundamental techniques; strategies can be broadly diversified or narrowly focused on specific sectors and can range broadly in terms of levels of net exposure, leverage employed, holding period, concentrations of market capitalizations and valuation ranges of typical portfolios. EH managers would typically maintain at least 50% exposure to, and may in some cases be entirely invested in, equities, both long and short.

3. HFRI Macro Index

   Investment Managers which trade a broad range of strategies in which the investment process is predicated on movements in underlying economic variables and the impact these have on equity, fixed income, hard currency and commodity markets. Managers employ a variety of techniques, both discretionary and systematic analysis, combinations of top down and bottom up theses, quantitative and fundamental approaches and long and short term holding periods. Although some strategies employ RV techniques, Macro strategies are distinct from RV strategies in that the primary investment thesis is predicated on predicted or future movements in the underlying instruments, rather than realization of a valuation discrepancy between securities. In a similar way, while both Macro and equity hedge managers may hold equity securities, the overriding investment thesis is predicated on the impact movements in underlying macroeconomic variables may have on security prices, as opposes to EH, in which the fundamental characteristics on the company are the most significant are integral to investment thesis.

4. HFRI Event-Driven Index

   Investment Managers who maintain positions in companies currently or prospectively involved in corporate transactions of a wide variety including but not limited to mergers, restructurings, financial distress, tender offers, shareholder buybacks, debt exchanges, security issuance or other capital structure adjustments. Security types can range from most senior in the capital structure to most junior or subordinated, and frequently involve additional derivative securities. Event Driven exposure includes a combination of sensitivities to equity markets, credit markets and idiosyncratic, company specific developments. Investment theses are typically predicated on fundamental characteristics (as opposed to quantitative), with the realization of the thesis predicated on a specific development exogenous to the existing capital structure.

5. HFRI Relative Value Index

Investment Managers who maintain positions in which the investment thesis is predicated on realization of a valuation discrepancy in the relationship between multiple securities. Managers employ a variety of fundamental and quantitative techniques to establish investment theses, and security types range broadly across equity, fixed income, derivative or other security types. Fixed income strategies are typically quantitatively driven to measure the existing relationship between instruments and, in some cases, identify attractive positions in which the risk adjusted spread between these instruments represents an attractive opportunity for the investment manager. RV position may be involved in corporate transactions also, but as opposed to ED exposures, the investment thesis is predicated on realization of a pricing discrepancy between related securities, as opposed to the outcome of the corporate transaction.

6. HFRI Credit Index

HFRI Credit Index is a composite index of strategies trading primarily in credit markets. It is an aggregation of following 7 HFRI sub-strategy indices. HFRI ED: Credit Arbitrage Index, HFRI ED: Distressed/Restructuring Index, HFRI ED: Multi-Strategy Index, HFRI RV: Fixed Income-Asset Backed Index, HFRI RV: Fixed Income-Convertible Arbitrage Index, HFRI RV: Fixed Income-Corporate Index, and HFRI RV: Multi-Strategy Index.

7. HFRI Activist Index

Activist strategies may obtain or attempt to obtain representation of the company's board of directors in an effort to impact the firm's policies or strategic direction and in some cases may advocate activities such as division or asset sales, partial or complete corporate divestiture, dividend or share buybacks, and changes in management. Strategies employ an investment process primarily focused on opportunities in equity and equity related instruments of companies which are currently or prospectively engaged in a corporate transaction, security issuance/repurchase, asset sales, division spin-off or other catalyst oriented situation. These involve both announced transactions as well as situations which pre-, post-date or situations in which no formal announcement is expected to occur. Activist strategies are distinguished from other Event Driven strategies in that, over a given market cycle, Activist strategies would expect to have greater than 50% of the portfolio in activist positions, as described.

Table I: Hedge Fund Indices. Descriptive information on the hedge fund composite index provided by Hedge Fund Research (HFR) used in this paper. HFR maintains a database of performance on over 5,900 hedge funds. This database is used to calculate monthly composite returns across all funds in the database. Market beta is calculated on excess returns over USD 3mth LIBOR against the S&P 500 Total Return Index.

	HFRI Composite Index		
	Period 1	Period 2	Period 3
Start Date	January 1990	January 2000	January 2010
End Date	December 1999	December 2009	December 2020
Frequency	Monthly	Monthly	Monthly
No. Observations	120	120	132
Mean	0.0143	0.0054	0.0040
Min	-0.0870	-0.0684	-0.0908
Max	0.0765	0.0616	0.0586
St. Deviation	0.0200	0.0200	0.0177
Correlation to Market	0.6998	0.7422	0.8893
Beta to Market	0.3650	0.3202	0.3895

Table II: Hedge Fund Strategy Indices. Descriptive information on the hedge fund strategy indices provided by Hedge Fund Research (HFR) used in this paper. HFR maintains a database of performance on over 5,900 hedge funds. HFR categorises each fund according to its strategy, and aggregate each funds monthly returns in to strategy indices. Market beta is calculated on excess returns over USD 3mth LIBOR against the S&P 500 Total Return Index.

January 2010 to December 2020; Monthly Frequency; 132 observations			
	Equity Hedge	Global Macro	Event Driven
Mean	0.0050	0.0016	0.0045
Min	-0.1089	-0.0331	-0.1240
Max	0.0828	0.0482	0.0704
St. Deviation	0.0247	0.0120	0.0195
Correlation to Market	0.9137	0.6555	0.8119
Beta to Market	0.5578	0.1948	0.3908
	Relative Value	Credit	Activist
Mean	0.0042	0.0045	0.0060
Min	-0.0977	-0.1043	-0.2033
Max	0.0274	0.0349	0.1151
St. Deviation	0.0128	0.0137	0.0379
Correlation to Market	0.7260	0.6987	0.8170
Beta to Market	0.2300	0.2368	0.7646

Table III: Alpha and beta of composite hedge fund returns. Table III shows the results of linear univariate regressions of consecutive *m*-period averages of reported hedge fund returns against consecutive *m*-period averages of market returns. As *m* increases, it can be seen that beta coefficient converges to the true economic hedge fund beta. Standard errors of beta and alpha estimates are given in brackets, however these are only valid when there is insignificant serial correlation of the residuals. The t-stat of the serial correlation is given in brackets. ***, **, * indicate the value is significant at 0.01, 0.05 and 0.10 threshold respectively (for alpha and beta estimates only valid when standard errors are valid). Excess returns over USD 3mth LIBOR. S&P 500 Total Return used of market returns.

	HFRI Composite Index			
	m=1	*m=2*	*m=3*	*m=4*
PANEL A: January 1990 to December 1999				
Beta	0.3650***	0.4144***	0.4478***	0.4485***
	(0.0343)	(0.062)	(0.0757)	(0.0969)
Alpha	0.0060***	0.0055***	0.0051***	0.0051***
	(0.0014)	(0.0017)	(0.0018)	(0.002)
Serial correlation of residuals	0.3811***	0.3275**	0.3732**	0.3528*
	(4.459)	(2.617)	(2.447)	(1.959)
R2	0.49	0.43	0.48	0.43
No. Obs.	120	60	40	30
PANEL B: January 2000 to December 2009				
Beta	0.3459***	0.4021***	0.3854***	0.4030***
	(0.016)	(0.0273)	(0.0302)	(0.038)
Alpha	-0.0010*	-0.0016**	-0.0014**	-0.0016**
	(0.0006)	(0.0007)	(0.0007)	(0.0008)
Serial correlation of residuals	0.2097**	0.2182*	0.1500	-0.0386
	(2.320)	(1.688)	(0.923)	(-0.201)
R2	0.80	0.79	0.81	0.80
No. Obs.	120	60	40	30
PANEL C: January 2010 to December 2020				
Beta	0.3895***	0.4346***	0.4557***	0.4578***
	(0.0176)	(0.0307)	(0.0305)	(0.0449)
Alpha	-0.001*	-0.0015**	-0.0017**	-0.0018**
	(0.0007)	(0.0009)	(0.0008)	(0.001)
Serial correlation of residuals	0.2157**	0.1352	0.1562	0.0655
	(2.509)	(1.083)	(1.013)	(0.359)
R2	0.79	0.76	0.84	0.77
No. Obs.	132	66	44	33

Table IV: Risk estimates of composite hedge fund returns. Table V shows risk estimates for the HFRI Composite index derived from the relationship between *m*-period average hedge fund returns with *m*-period average market returns. Risk estimates are presented in annualised form where applicable. *SPI* is the Stale Pricing Indicator, a measure of the degree of stale pricing in reported return varying between 0 (no stale pricing) and 1 (completely stale pricing). Returns are monthly excess of USD 3mth LIBOR. Market is S&P 500 Total Return index.

	HFRI Composite Index			
	m=1	*m=2*	*m=3*	*m=4*
PANEL A: January 1990 to December 1999				
Beta	0.3650	0.4144	0.4478	0.4485
Volatility	0.0701	0.0887	0.1003	0.1006
Variance	0.0049	0.0079	0.0101	0.0101
Covariance to market	0.0066	0.0075	0.0081	0.0081
Correlation to market	0.6998	0.6277	0.5998	0.5993
SPI	0.0000	0.1192	0.1849	0.1862
No. Obs.	120	60	40	30
PANEL B: January 2000 to December 2009				
Beta	0.3459	0.4021	0.3854	0.4030
Volatility	0.0699	0.0920	0.0856	0.0923
Variance	0.0049	0.0085	0.0073	0.0085
Covariance to market	0.0091	0.0105	0.0101	0.0106
Correlation to market	0.8020	0.7082	0.7293	0.7072
SPI	0.0000	0.1396	0.1023	0.1416
No. Obs.	120	60	40	30
PANEL C: January 2010 to December 2020				
Beta	0.3895	0.4346	0.4557	0.4578
Volatility	0.0617	0.0758	0.0821	0.0827
Variance	0.0038	0.0057	0.0067	0.0068
Covariance to market	0.0077	0.0086	0.0090	0.0091
Correlation to market	0.8893	0.8076	0.7820	0.7798
SPI	0.0000	0.1040	0.1453	0.1493
No. Obs.	132	66	44	33

Table V: Alpha and beta of hedge fund strategy returns since 2010. Table IV shows the results of linear univariate regressions of consecutive *m*-period averages of six reported hedge fund strategy returns against consecutive *m*-period averages of market returns. Strategy definitions are presented in the Appendix. As *m* increases, the beta coefficient converges to the true economic hedge fund strategy beta. Standard errors of beta and alpha estimates are given in brackets, however these are only valid when there is insignificant serial correlation of the residuals. The t-stat of the serial correlation given in brackets. ***, **, * indicate the value is significant at 0.01, 0.05 and 0.10 threshold respectively (for alpha and beta estimates only valid when standard errors are valid). Excess monthly returns over USD 3mth LIBOR. S&P 500 Total Return used of market returns. Returns from January 2010 to December 2020.

	Equity Hedge		Macro		Event Driven	
	m = 1	m = 4	m = 1	m = 4	m = 1	m = 4
Beta	0.5578*** (0.0218)	0.6327*** (0.0575)	0.1948*** (0.0197)	0.2347*** (0.0417)	0.3908*** (0.0246)	0.4554*** (0.0651)
Alpha	-0.0019** (0.0009)	-0.0027** (0.0013)	-0.0013* (0.0008)	-0.0017** (0.0009)	-0.0005 (0.001)	-0.0012 (0.0015)
Serial correlation of residuals	0.3070*** (3.663)	0.0001 (0.001)	-0.0025 (-0.029)	0.1694 (0.941)	0.2295*** (2.678)	0.0375 (0.205)
R2	0.83	0.80	0.43	0.51	0.66	0.61
No. Observations	132	33	132	33	132	33

	Rel. Value		Credit		Activist	
	m = 1	m = 4	m = 1	m = 4	m = 1	m = 4
Beta	0.2300*** (0.0191)	0.2860*** (0.0456)	0.2368*** (0.0213)	0.3020*** (0.0509)	0.7646*** (0.0473)	0.8471*** (0.1064)
Alpha	0.0009 (0.0008)	0.0003 (0.001)	0.0012* (0.0009)	0.0005 (0.0011)	-0.0031* (0.002)	-0.0040** (0.0024)
Serial correlation of residuals	0.1718** (1.981)	0.0944 (0.519)	0.0339 (0.385)	-0.1271 (-0.702)	0.0516 (0.587)	-0.1966 (-1.098)
R2	0.53	0.56	0.49	0.53	0.67	0.67
No. Observations	132	33	132	33	132	33

Table VI: Risk estimates of hedge fund strategy returns. Table VI shows risk estimates for six hedge fund strategy indices derived from the relationship between their *m*-period average reported returns with *m*-period average market returns. Strategy definitions given in the Appendix. Risk estimates are presented in annualised form where applicable. *SPI* is the Stale Pricing Indicator, a measure of the degree of stale pricing in reported return varying between 0 (no stale pricing) and 1 (completely stale pricing). Returns are monthly excess of USD 3mth LIBOR. Market is S&P 500 Total Return index.

	Equity Hedge		Macro		Event Driven	
	$m = 1$	$m = 4$	$m = 1$	$m = 4$	$m = 1$	$m = 4$
Beta	0.5578	0.6327	0.1948	0.2347	0.3908	0.4554
Volatility	0.0860	0.1087	0.0419	0.0583	0.0678	0.0896
Variance	0.0074	0.0118	0.0018	0.0034	0.0046	0.0080
Covariance w/mkt	0.0111	0.0126	0.0039	0.0047	0.0078	0.0090
Correlation w/mkt	0.9137	0.8201	0.6555	0.5669	0.8119	0.7158
SPI	0.0000	0.1183	0.0000	0.1700	0.0000	0.1418
No. Observations	132	33	132	33	132	33

	Rel. Value		Credit		Activist	
	$m = 1$	$m = 4$	$m = 1$	$m = 4$	$m = 1$	$m = 4$
Beta	0.2300	0.2860	0.2368	0.3020	0.7646	0.8471
Volatility	0.0446	0.0651	0.0477	0.0722	0.1318	0.1599
Variance	0.0020	0.0042	0.0023	0.0052	0.0174	0.0256
Covariance w/mkt	0.0046	0.0057	0.0047	0.0060	0.0152	0.0168
Correlation w/mkt	0.7260	0.6185	0.6987	0.5894	0.8170	0.7460
SPI	0.0000	0.1956	0.0000	0.2158	0.0000	0.0974
No. Observations	132	33	132	33	132	33

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