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Convertible Arbitrage: Risk and Return

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Abstract

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Abstract: This paper specifies a simulated convertible arbitrage portfolio to characterise the risks in convertible arbitrage. For out-of-sample comparison the risk profile of convertible arbitrage hedge fund indices is also examined. Results indicate that convertible arbitrage is positively related to default and term structure risk factors. These risk factors are augmented with the simulated convertible arbitrage portfolio, mimicking a passive investment in convertible arbitrage, to assess the risk and return of individual hedge funds. As the simulated portfolio's excess return exhibits negative skew and excess kurtosis it helps account for the non-normality in individual fund returns. Two factor models of convertible arbitrage fund performance are estimated. The first model specifies lagged and contemporaneous observations of the risk factors, controlling for illiquidity in the securities held by funds. In the second model a factor mimicking illiquidity risk is also specified. We find weak evidence of abnormal risk adjusted returns in the individual fund data and no evidence of out-performance in the hedge fund indices.

1. Introduction

Convertible arbitrageurs attempt to capture profit by combining long positions in convertible bonds with short positions in the issuer's equity. The positions are designed to generate returns from two sources: (i) income from the convertible bond coupon and short interest, and (ii) long volatility exposure from the option component of the convertible bond. In this paper, we provide estimates of the abnormal returns to convertible arbitrage hedge fund investments, and also describe the risks associated with these returns.

Income from the convertible bond comes from the coupon paid periodically by the issuer to the holder of the bond and interest on the proceeds of the short stock sale. As the coupon is generally fixed it leaves the holder of the convertible bond exposed to term structure risk. As the convertible bond remains a debt instrument until converted, the holder of the convertible bond is also exposed to the risk of default by the issuer. The return from the long volatility exposure comes from the equity option component of the convertible bond. To capture the long volatility exposure, the arbitrageur initiates a dynamic hedging strategy. The hedge is rebalanced as the stock price and/or convertible price move.

Previous research has highlighted that hedge fund returns contain statistical features unusual in financial time series.[1] Hedge fund returns are generally non-normally distributed exhibiting negative skewness and excess kurtosis. Linear analysis of non-normal returns using standard normally distributed asset benchmarks yields inefficient results, leading to erroneous conclusions about hedge fund performance. To address this issue previous research has specified

[1] Kat and Lu (2001) and Brooks and Kat (2001) amongst others document these characteristics in hedge fund returns.

risk factors that have non-normal characteristics correcting for much of the non-normality in the return distribution of the funds. Fung and Hsieh (2001) focus on the trend following strategy specifying lookback straddles as risk factors and Mitchell and Pulvino (2001) focus on the risk arbitrage strategy constructing a risk arbitrage portfolio which serves as a benchmark of risk arbitrage performance.

The task of performance evaluation is further complicated when looking at convertible arbitrage as funds typically follow quite different strategies[2] and the returns of convertible arbitrage hedge funds exhibit serial correlation. Kat and Lu (2001) and Getmansky et al. (2004) hypothesise that the observed autocorrelation in hedge fund returns is due to illiquidity in the securities held by these funds. In the case where the securities held by a fund are not actively traded, the returns of the fund will appear smoother than true returns, be serially correlated, resulting in a downward bias in estimated return variance and a consequent upward bias in performance when the fund is evaluated using mean-variance analysis.

Overall, existing academic studies find that convertible arbitrage hedge funds generate significant abnormal returns. Capocci and Hübner (2004) specify a linear factor model to model the returns of several hedge fund strategies and estimate that convertible arbitrage hedge funds earn an abnormal return of 0.42% per month. Fung and Hsieh (2002) estimate the convertible arbitrage hedge fund index generates alpha of 0.74% per month.

These findings suggest that financial markets exhibit significant inefficiency in the pricing of convertible bonds.[3] However, there are two alternative non-competing explanations for the large abnormal returns documented in previous studies. The first explanation is that convertible arbitrage funds are receiving a risk premium for bearing risks, which are unique to the strategy and have not been fully adjusted for in previous studies. The second explanation is that the illiquidity in the securities held by individual hedge funds leads to underestimation of risk factor coefficients and upward biased estimates of performance. In this paper we attempt to address these issues.

To assess convertible arbitrage hedge fund performance we specify a simulated convertible arbitrage portfolio augmented with default and term structure risk factors to capture the return generating process common to convertible arbitrage hedge funds. By defining a set of risk factors that match an investment strategy's aims and returns, individual fund's exposures to

[2] Kat and Lu (2001) provide evidence that the cross correlations between hedge fund returns within strategies are low.

[3] Ammann et al. (2004) and King (1986) document evidence of convertible bond under pricing on the French and US convertible bond markets. Kang and Lee (1996) also find evidence of convertible bond under pricing at issue.

variations in the returns of the risk factors can be identified. Following the identification of exposures, the effectiveness of the manager's activities can be compared with that of a passive investment in the risk factors. For out-of-sample comparison we demonstrate empirically that the simulated convertible arbitrage portfolio returns strongly resemble the returns of convertible arbitrage hedge fund indices.

As the simulated portfolio is constructed as a passive[4] convertible arbitrage investment and also shares the characteristics of the hedge fund indices, but contains none of the biases, it serves as a useful benchmark risk factor of individual fund performance.[5] Furthermore, as the simulated portfolio exhibits negative skewness and positive excess kurtosis its specification as a risk factor also helps account for the non-normality in the returns of individual convertible arbitrage hedge funds.

The second explanation for the high abnormal returns to convertible arbitrage reported in previous studies is that the illiquidity in the securities held by the funds leads to underestimation of risk factor coefficients and a corresponding overestimation of performance. Although previous studies have identified the serial correlation in hedge fund returns and attributed this to illiquidity, studies of convertible arbitrage performance have made the implicit assumption that contemporaneous risk factors fully capture the risk in convertible arbitrage investments despite the presence of autocorrelation. Drawing on the non-synchronous trading literature on beta estimation in the presence of thin trading we specify contemporaneous and lagged observations of the risk factors in a convertible arbitrage performance evaluation model.[6, 7] Furthermore, to correct for the serial correlation in hedge fund returns we specify a lag of the individual hedge fund return as an explanatory variable. This variable can be interpreted as a factor mimicking illiquidity risk. Estimates of abnormal return to convertible arbitrage from this model are not significantly different from zero for the hedge fund indices, and are 1.8% per annum, on average, for the individual hedge funds.

The remainder of the paper is organised as follows. In the next section we describe the construction of the simulated portfolio. Section 3 provides a definition of the risk factor models specified to test the out of sample properties of the simulated portfolio, and Section 4 presents

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[4] No analysis is undertaken on the relative valuations of the convertible bonds.

[5] The difficulty with the use of hedge fund benchmark returns to define the characteristics of a strategy and measure the performance of individual funds is hedge fund data contains three main biases, instant history bias, selection bias and survivorship bias as discussed in detail by Fung and Hsieh (2000).

[6] Asness et al. (2001) demonstrate that lagged S&P500 returns are significant explanatory variables for several hedge fund indices.

[7] Techniques for estimating betas so as to control for thin trading bias have been proposed by Scholes and Williams (1977) and Dimson (1979) amongst others.

results from estimation of risk factors on the simulated convertible arbitrage portfolio and the convertible arbitrage hedge fund indices. Section 5 describes the convertible arbitrage performance measurement models and Section 6 presents results from the estimation of convertible arbitrage risk and performance. Section 7 concludes the paper.

2. Constructing the Convertible Arbitrage Benchmark Portfolio

To provide a benchmark for the convertible arbitrage strategy we construct a simple convertible arbitrage portfolio, designed to capture income and volatility. The portfolio combines long positions in convertible bonds with delta neutral hedged short positions in the issuer's equity. These hedges are then rebalanced daily, maintaining the delta neutral hedge.

The simulated portfolio focuses exclusively on the traditional convertible bond as this allows us to use a universal hedging strategy across all instruments in the portfolio. Due to data constraints, we focus exclusively on convertible bonds listed in the United States between 1990 and 2002. To enable the forecasting of volatility, issuers with equity listed for less than one year were excluded from the sample.[8] Any non-standard convertible bonds and convertible bonds with missing or unreliable data were removed from the sample. The final sample consists of 503 convertible bonds, 380 of which were live at the end of 2002, with 123 dead. The terms of each convertible bond, daily closing prices and the closing prices and dividends of their underlying stocks were included. Convertible bond terms and conditions data were provided by Monis. Closing prices and dividend information came from DataStream and interest rate information came from the United States Federal Reserve Statistical Releases.

The convertible bond portfolio is an equally weighted portfolio of delta neutral hedged long convertible bonds and short stock positions. In order to initiate a delta neutral hedge for each convertible bond the delta for each convertible bond is estimated on the trading day it enters the portfolio.[9] The delta estimate is then multiplied by the convertible bond's conversion ratio to calculate Δ_{it} the number of shares to be sold short in the underlying stock (the hedge ratio) to initiate the delta neutral hedge. On the following day the new hedge ratio, Δ_{it+1}, is calculated, and if $\Delta_{it+1} > \Delta_{it}$ then $\Delta_{it+1} - \Delta_{it}$ shares are sold, or if $\Delta_{it+1} < \Delta_{it}$, then $\Delta_{it} - \Delta_{it+1}$ shares are

[8] GARCH(1,1) is specified to estimate volatility. There is a variety of volatility forecasting models such as GARCH, EGARCH, IGARCH, A-GARCH, NA-GARCH, V-GARCH in the literature. Poon and Granger (2003) provide a comprehensive review of volatility forecasting. None of the variants consistently outperforms the GARCH model of Bollerslev (1986).

[9] Delta estimates are generated using Monis ConvertiblesXL convertible bond pricing software.

purchased maintaining the delta neutral hedge. The delta of each convertible bond is then recalculated daily and the hedge is readjusted maintaining the delta neutral hedge.

Daily returns were calculated for each position on each trading day up to and including the day the position is closed out. A position is closed out on the day the convertible bond is delisted from the exchange. Convertible bonds may be delisted for several reasons: the company may be bankrupt, the convertible may have expired or the convertible may have been fully called by the issuer.

The daily returns for a position *i* on day *t* are calculated as follows.

$$R_{it} = \frac{P_{it}^{CB} - P_{it-1}^{CB} + C_{it} - \Delta_{it-1}(P_{it}^{U} - P_{it-1}^{U} + D_{it}) + r_{t-1}S_{i,t-1}}{P_{it-1}^{CB} + \Delta_{it-1}P_{it-1}^{U}} \tag{1}$$

where R_{it} is the return on position *i* at time *t*, P_{it}^{CB} is the convertible bond closing price at time *t*, P_{it}^{U} is the underlying equity closing price at time *t*, C_{it} is the coupon payable at time *t*, D_{it} is the dividend payable at time *t*, Δ_{it-1} is the delta neutral hedge ratio for position *i* at time *t – 1* and $r_{t-1}S_{i,t-1}$ is the interest on the short proceeds from the sale of the shares. Daily returns are then compounded to produce a position value index for each hedged convertible bond over the entire sample period.

The value of the convertible bond arbitrage portfolio on a particular date is given by the formula.

$$V_t = \frac{\sum_{i=1}^{i=N_t} W_{it} PV_{it}}{F_t} \tag{2}$$

where V_t is the portfolio value on day *t*, W_{it} is the weighting of position *i* on day *t*, PV_{it} is the value of position *i* on day *t*, F_t is the divisor on day *t* and N_t is the total number of position on day *t*. W_{it} is set equal to one for each live hedged position.

On the inception date of the portfolio, the value of the divisor is set so that the portfolio value is equal to 100. Subsequently the portfolio divisor is adjusted to account for changes in the constituents in the portfolio. Following a portfolio change the divisor is adjusted such that equation (3) is satisfied.

$$\frac{\sum_{i=1}^{i=N_t} W_{ib} PV_i}{F_b} = \frac{\sum_{i=1}^{i=N_t} W_{ia} PV_i}{F_a} \quad (3)$$

where PV_i is the value of position *i* on the day of the adjustment, W_{ib} is the weighting of position *i* before the adjustment, W_{ib} is the weighting of position *i* after the adjustment, F_b is the divisor before the adjustment and F_a is the divisor after the adjustment.

Thus the post adjustment index factor F_a is then calculated as follows:

$$F_a = \frac{F_b x \sum_{i=1}^{i=N_t} W_{ib} PV_i}{\sum_{i=1}^{i=N_t} W_{ia} PV_i} \quad (4)$$

As the margins on the strategy are small relative to the nominal value of the positions convertible bond arbitrageurs usually employ leverage. Calamos (2003) and Ineichen (2000) estimate that for an individual convertible arbitrage hedge fund this leverage may vary from two to ten times equity. However, the level of leverage in an efficiently run portfolio is not static and varies depending on the opportunity set and risk climate. Khan (2002) estimates that in mid 2002 convertible arbitrage hedge funds were at an average leverage level of 2.5 to 3.5 times, whereas Khan (2002) estimates that in late 2001 average leverage levels were approximately 5 to 7 times.

From a strategy analysis perspective it is therefore difficult to ascribe a set level of leverage to the portfolio. Changing the leverage applied to the portfolio has obvious effects on returns and risk as measured by standard deviation. We apply leverage of two times to the portfolio as this produces a portfolio with a similar average return to indices of convertible arbitrage hedge fund returns. Finally monthly returns[10] were calculated from the index of convertible bond portfolio values.

Insert Table 1 about here

Summary statistics for the monthly returns on the simulated convertible arbitrage portfolio in excess of the risk free rate of interest, *CBRF*, are presented in Panel A of Table 1 with

[10] All monthly return calculations are logarithmic.

summary statistics for the excess return on two hedge fund indices; the HFRI Convertible Arbitrage Index, *HFRIRF*; and, the CSFB Tremont Convertible Arbitrage Index, *CSFBRF*. The CSFB Tremont Convertible Arbitrage Index is an asset-weighted index (rebalanced quarterly) of convertible arbitrage hedge funds beginning in 1994 whereas the HFRI Convertible Arbitrage Index is equally weighted with a start date of January 1990.[11] Although the CSFB Tremont indices controls for survivor bias, according to Ackermann et al. (1999), HFR did not keep data on dead funds before January 1993. This will bias upwards the performance of the HFRI index pre 1993. The average return on *CBRF* is 0.33% per month with a variance of 3.104. The average return is lower and the variance higher than the two convertible arbitrage hedge fund indices, *CSFBRF* and *HFRIRF*. *CBRF* is negatively skewed and has positive kurtosis as do the two hedge fund indices.

3. Testing the Robustness of the Convertible Arbitrage Benchmark Portfolio

In this section six asset pricing models are employed to test the out of sample properties of the simulated portfolio: the market model derived from the Capital Asset Pricing Model (CAPM) described in Sharpe (1964) and Lintner (1965), the Fama and French (1993) three factor stock model, the Fama and French (1993) three factor bond model, the Fama and French (1993) combined stock and bond model, the Carhart (1997) four factor model and Eckbo and Norli's (2005) liquidity factor model. This section briefly describes these models, providing an explanation of the expected relationship between convertible arbitrage excess returns and the individual factors.

The market model is a single index model, which assumes that all of a stock's systematic risk can be captured by one market factor. The intercept of the equation, α, is commonly called Jensen's (1968) alpha and is usually interpreted as a measure of out- or under-performance. The equation to estimate is the following:

$$y_t = \alpha + \beta_{RMRF} RMRF_t + \varepsilon_t \qquad (5)$$

where $y_t = R_t - R_{ft}$, R_t is the return on the hedge fund index at time *t*, R_{ft} is the risk free rate at month *t*, $RMRF_t$ is the excess return on the market portfolio on month *t*, is the error term α and

[11] For details on the construction of the CSFB Tremont Convertible Arbitrage Index see www.hedgeindex.com. For details on the construction of the HFRI Convertible Arbitrage Index see www.hfr.com.

β_{RMRF} are the intercept and the slope of the regression, respectively. As convertible arbitrageurs are exposed to credit risk, which is typically strongly related to equity market returns, there should be a significantly positive β_{MKT} coefficient.

The Fama and French (1993) three factor stock model is estimated from an expected form of the CAPM model. This model extends the CAPM with the inclusion of two factors to account for size and market to book ratio of firms. It is estimated from the following equation:

$$y_t = \alpha + \beta_{RMRF} RMRF_t + \beta_{SMB} SMB_t + \beta_{HML} HML_t + \varepsilon_t \tag{6}$$

where SMB_t is the factor mimicking portfolio for size (small minus big) at time t and HML_t is the factor mimicking portfolio for book to market ratio (high minus low) at time t.[12] Capocci and Hübner (2004) specify the *HML* and *SMB* factors in their models of hedge fund performance. Moreover, Agarwal and Naik (2004) specify the *SMB* factor in a model of convertible arbitrage performance and find it has a positive relation with convertible arbitrage returns. As the opportunities for arbitrage are greater in the smaller less liquid issues e*x ante* it would be expected that a positive relationship between convertible arbitrage returns and the size factor. There is no *ex ante* expectation of the relationship between the factor mimicking for book to market equity and convertible arbitrage returns though Capocci and Hübner (2004) report a positive *HML* coefficient for convertible arbitrage.

Fama and French (1993) also propose a three factor model for the evaluation of bond returns. They draw on the seminal work of Chen et al. (1986) to extend the CAPM incorporating two additional factors taking the shifts in economic conditions that change the likelihood of default and unexpected changes in interest rates into account. This model is estimated from the following equation

$$y_t = \alpha + \beta_{RMRF} RMRF_t + \beta_{DEF} DEF_t + \beta_{TERM} TERM_t + \varepsilon_t \tag{7}$$

where DEF_t is the difference between the overall return on a market portfolio of long-term corporate bonds[13] minus the long term government bond return[14] at month t. $TERM_t$ is the factor

[12] For details on the construction of SMB and HML see Fama and French (1992, 1993).

[13] The return on the CGBI Index of high yield corporate bonds is used rather than the return on the composite portfolio from Ibbotson and Associates used by Fama and French (1993) due to its unavailability.

proxy for unexpected changes in interest rates. It is constructed as the difference between monthly long term government bond return and the short term government bond return.[15]

It is expected that convertible arbitrage returns will be positively related to both of these factors as the strategy generally has term structure and credit risk exposure. The growth of the credit derivative market has provided the facility for arbitrageur's to hedge credit risk. The magnitude and significance of the DEF_t coefficient, (β_{DEF}) should indicate to what degree hedge funds have availed of this facility.

Fama and French (1993) also estimate a combined model when looking at the risk factors affecting stock and bond returns. As a convertible bond is a hybrid bond and equity instrument we also estimate this model using the following equation:

$$y_t = \alpha + \beta_{RMRF} RMRF_t + \beta_{SMB} SMB_t + \beta_{HML} HML_t + \beta_{DEF} DEF_t + \beta_{TERM} TERM_t + \varepsilon_t \quad (8)$$

As arbitrageurs attempt to hedge equity market risk, it is expected that the bond market factors will be the most significant in explaining convertible arbitrage excess returns in this model.

Carhart's (1997) four factor model is an extension of Fama and French's (1993) stock model. It takes into account size, book to market and an additional factor for the momentum effect. This momentum effect can be described as the buying of assets that were past winners and the selling of assets that were past losers. This model is estimates using the following equation:

$$y_t = \alpha + \beta_{RMRF} RMRF_t + \beta_{SMB} SMB_t + \beta_{HML} HML_t + \beta_{UMD} UMD_t + \varepsilon_t \quad (9)$$

where UMD_t is the factor mimicking portfolio for the momentum effect. *UMD* is constructed in a slightly different manner to Carhart's (1997) momentum factor[16]. Six portfolios are constructed by the intersection of two portfolios formed on market value of equity and three portfolios formed on prior twelve month returns. *UMD* is the average return on the two high prior return portfolios and the two low prior return portfolios. There is no *ex ante* expectation for the relationship

[14] The return on the Lehman Index of long term government bonds is used rather than the return on the monthly long term government bond return from Ibbotson and Associates used by Fama and French (1993) due to its unavailability.
[15] The return on the Lehman Index of short term government bonds is used rather than the one month treasury bill rate from the previous month used by Fama and French (1993).
[16] Carhart (1997) constructs his factor as the equally weighted average of firms with the highest thirty percent eleven-month returns lagged one period minus the equally weighted average of firms with the lowest thirty percent eleven month returns lagged by one period.

between convertible arbitrage returns and the momentum factor. Capocci and Hübner (2004) report a negative coefficient for convertible arbitrage hedge funds.

The final model employed is Eckbo and Norli's (2005) extension of the Carhart model incorporating a liquidity factor. Eckbo and Norli (2005) estimated the following equation:

$$y_t = \alpha + \beta_{RMRF} RMRF_t + \beta_{SMB} SMB_t + \beta_{HML} HML_t + \beta_{UMD} UMD_t + \beta_{TO} TO_t + \varepsilon_t \quad (10)$$

where *TO* is the return on a portfolio of low-liquidity stocks minus the return on a portfolio of high-liquidity stocks.[17] Arbitrageurs generally operate in less liquid issues so a negative relationship between the liquidity factor and convertible arbitrage returns is expected.

Table 1, Panel B presents summary statistics of the explanatory factor returns.[18] The average risk premium for the risk factors is simply the average values of the explanatory variables. *UMD* the momentum factor produces a large 1.14% average return but this factor also has the largest variance and standard error. The two bond market factors *DEF* and *TERM* have low standard errors but of the two only *DEF* exhibits an average return (0.54%) significantly different from zero at standard levels. Other than *SMB* and *TO* all of the explanatory variables returns have significantly negative skew and all have positive kurtosis other than *RMRF*, *TERM* and *TO*.

Insert Table 2 about here

Table 2, Panel A presents a correlation matrix of the explanatory variables. The first thing that should be noted is the potential for multicollinearity. There is a high absolute correlation between *TO* and several factors, *RMRF*, *SMB* and *DEF*. *DEF* is also significantly positively correlated with *RMRF*, *SMB* and *UMD* the momentum factor is negatively correlated with *HML*.

Table 2, Panel B presents the correlations between the three dependent variables, *CBRF*, *CSFBRF* and *HFRIRF* and the explanatory variables. All of the variables are highly correlated as evident by cross correlations ranging from 0.32 to 0.80, all significant at the 1% level. All are positively related to *DEF* the default risk factor and *SMB* the factor proxy for firm size. *CBRF*

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[17] For details on the construction of TO see Eckbo and Norli (2005).
[18] Data on *SMB*, *RMRF*, *HML* and *UMD* was provided by Kenneth French. Liquidity factor data was provided by Øyvind Norli.

and *HFRIRF* are positively correlated with *RMRF* and all are negatively related to *TO* the liquidity factor.

4. Results of Estimating Risk Factor Models

In this section, the results of estimating the risk factor models defined in the previous section on the simulated convertible arbitrage portfolio are presented. Out-of-sample comparison results are also presented from estimating the risk factor models on two indices of convertible arbitrage hedge fund returns.

Insert Table 3 about here

Table 3 presents results of the OLS estimation of the risk factor models discussed above on *CBRF*, the simulated convertible arbitrage portfolio excess returns, from January 1990 to December 2002. The error term of the return regression is potentially heteroskedastic and autocorrelated. Although the conditional heteroskedasticity and autocorrelation are not formally treated in the OLS estimate of the parameter, the t-stats in parenthesis below the parameter estimates are heteroskedasticity and autocorrelation consistent due to Newey and West (1987).[19] Ljung and Box (1978) Q-Statistics, testing the joint hypothesis that the first ten lagged autocorrelations of the residual are all equal to zero, are reported.

The first result is from estimating the market model. The market coefficient value of 0.20 is significantly positive indicating that there is a positive relationship between convertible bond arbitrage returns and the market portfolio. This is a finding consistent with Capocci and Hübner (2004) who estimate a significantly positive market coefficient for convertible arbitrage hedge funds of 0.06. However the low adjusted R^2 indicates that this one factor model may not fully capture the risk in convertible bond arbitrage. The second result is from estimation of the Fama and French (1993) three factor stock model. The factor loadings on all three factors are significantly positive, consistent with Capocci and Hübner's (2004) findings for convertible arbitrage. It should be highlighted that the *SMB* coefficient indicates that convertible arbitrageurs appear to favour issues from smaller companies perhaps due to the greater arbitrage opportunities. The next result is from estimating the Carhart (1997) four factor model. The momentum factor

[19] For all the time-series analysis in this chapter, adjusting the autocorrelation beyond a lag of 3 periods does not yield any material differences. A t-stat based on 3 lags is adopted for regressions.

adds little explanatory value to the regression and the Ecko and Norli (2005) *TO* factor adds no explanatory power to the model.

The penultimate result is from estimation of the Fama and French (1993) bond factor model. The coefficients on both factors, *DEF* and *TERM*, are highly significant, with coefficient weightings greater than 0.20 and the overall explanatory power of the regression improves with an adjusted R^2 of 37.1%. The results indicate that convertible arbitrageurs have significant term structure and credit risk. With the improvement in model fit the estimated alpha coefficient has reduced to 0.07% per month. The final result is an estimation of the combined Fama and French's (1993) bond and stock factor models. The coefficients for *RMRF*, *SMB* and *HML* are all significantly different from zero although the inclusion of these factors adds little to the explanatory power of the model. Consistent with the evidence presented by Brooks and Kat (2001) of serial correlation in convertible arbitrage returns the Q-Stats are significant at the 1% level indicating that the residuals of the estimated regressions presented in Table 3 exhibit serial correlation.

Insert Tables 4 and 5 about here

For out-of-sample comparison, Table 4 and 5 reports results from the same series of regressions, only this time on the HFRI Convertible Arbitrage Index from January 1990 to December 2002 and the CSFB Tremont Convertible Arbitrage Index from January 1994 to December 2002. Results are strikingly similar to the simulated portfolio but the explanatory power of the regressions is lower. Again the major risks faced by the arbitrageur are default risk, term structure risk and the risk from investing in the issues of small companies. The residuals of all estimated regressions exhibit autocorrelation and the Q-Stats are higher than those reported for the simulated portfolio residuals.

The results reveal that of the factors specified, default and term structure risk factors are the most significant risk factors in convertible arbitrage returns. This result is robust for the simulated convertible arbitrage portfolio and two indices of convertible arbitrage hedge fund return, providing evidence to support the simulated convertible arbitrage portfolio capturing the key risk characteristics of the convertible arbitrage strategy.

5. Convertible Arbitrage Performance Measurement Models

By specifying risk factors with returns which capture the data generating process of the convertible arbitrage strategy, we are able to evaluate the performance of the hedge fund indices and individual convertible arbitrage hedge funds relative to this portfolio. In this section the convertible arbitrage performance models, which specify the excess returns of the simulated portfolio (*CBRF*) and default (*DEF*) and term (*TERM*) structure risk factors are defined. As *CBRF* does not include non-traditional convertible bonds, *DEF* and *TERM* are specified to capture the risk from investing in the convertible securities not included in *CBRF*. We consider two risk factor models, a model incorporating lags of the risk factors, and a model incorporating lags of the risk factors augmented with a one period lag of the hedge fund return.

In the initial model convertible arbitrage returns are assumed to be linearly related to the returns on a set of asset class factors described as:

$$y_t = \alpha + \beta_0' \, CBRF + \beta_1' \, DEF + \beta_2' \, TERM + \varepsilon_t \qquad (11)$$

where y_t is the excess return on the hedge fund, $DEF = (DEF_t, DEF_{t-1}, DEF_{t-2})$, $TERM = (TERM_t, TERM_{t-1}, TERM_{t-2})$ and $CBRF = (CBRF_t, CBRF_{t-1}$ and $CBRF_{t-2})$. The β coefficient is the sum of the contemporaneous β and lagged β s.

Lags of the risk factors are specified in (11) to increase efficiency in the estimation of the risk factor coefficients, given illiquidity in the securities held by convertible arbitrage hedge funds. This specification is intended to account for the potential for mis-measurement of market risk when assessing portfolios containing illiquid assets. Asness, et al (2001) and Getmansky et al (2004) show that omitting lagged market observations can lead to downward biased estimates of market risk and upward biased estimates of hedge fund performance.

This model is then augmented in (12) with the one period lag of the hedge fund return to further correct for serial correlation in convertible arbitrage returns.[20] Getmansky et al. (2004) argue that it is illiquidity (and possible return smoothing by hedge fund managers) that causes the perceived serial correlation. In the case where the securities held by a fund are not actively traded, the returns of the fund will appear smoother than true returns and be serially correlated. Assuming serial correlation is caused by illiquidity, if hedge funds hold only liquid securities then the returns at time t should be unrelated to returns at time $t-1$. A positive coefficient on the one period lag of the hedge fund's excess return indicates that the fund is receiving a risk premium for

[20] A similar result would be achieved by estimating the factor model using a statistical autocorrelation correction procedure such as the Corchane-Orcutt (1949) procedure. However, a disadvantage of this statistical procedure is that the results cannot be interpreted easily as functions of risk.

bearing liquidity risk. The coefficient on this term should also capture illiquidity premium received by investors for lockups and other share restrictions imposed on investor redemptions.[21]

The second model we estimate is:

$$y_t = \alpha + \beta_0' \, CBRF + \beta_1' \, DEF + \beta_2' \, TERM + \beta_3 y_{t-1} + \varepsilon_t \tag{12}$$

where y_t is the excess return on the hedge fund, $DEF = (DEF_t, DEF_{t-1}, DEF_{t-2})$, $TERM = (TERM_t, TERM_{t-1}, TERM_{t-2})$, $CBRF = (CBRF_t, CBRF_{t-1}$ and $CBRF_{t-2})$ and y_{t-1} is the one period lag of the hedge fund excess return. The β coefficient is the sum of the contemporaneous β and lagged β s.

Results from estimation of (11) and (12) for the HFRI and CSFB Tremont hedge fund indices and individual convertible arbitrage funds from the HFR database are presented in the following section.

6. Estimation of Convertible Arbitrage Fund Performance

In this section of the paper we present results from estimating the convertible arbitrage performance measurement models (11) and (12). We initially estimate the performance of the two hedge fund indices before examining the performance of the individual funds.

Insert Table 6 about here

Table 6 presents the results from OLS estimation of the two performance measurement models for the HFRI (Panel A) and CSFB Tremont (Panel B) convertible arbitrage hedge fund indices. Panel A, row 1 displays the coefficients from estimating (11) for the HFRI index (with corresponding *P*-Values from the t-tests that $\alpha = 0$ and $\beta_{it} + \beta_{it-1} + \beta_{it-2} = 0$ in row 2).[22] The coefficients on *CBRF*, *DEF* and *TERM* are all significant from zero at, at least, the 5% level. The intercept is significant from zero at the 1% level indicating abnormal performance of 32 basis points per month. Panel A, row 3 contains the coefficients from estimating (12) for the HFRI index (with corresponding *P*-Values from the t-tests that $\alpha = 0$, $\beta_{it} + \beta_{it-1} + \beta_{it-2} = 0$ for I = *CBRF*, *DEF* and *TERM* and $\beta_Y = 0$ in row 2). Again all β coefficients are significant from zero, with the expected sign, but here the measure of abnormal performance, α, is not significantly different from zero.

[21] Aragon (2006) documents a negative relationship between share restrictions and the liquidity of a fund's portfolio.

[22] Test statistics are autocorrelation and heteroskedasticity consistent due to Newey and West (1987).

The results for the CSFB Tremont index are displayed in Panel B. Results from estimating (11) are presented in row 1 (with corresponding P-Values in row 2) and (12) is presented in row 3 (with corresponding P-Values in row 4). Again all β coefficients are significant from zero with the anticipated sign, but for both models the α is not significant different from zero at acceptable statistical levels.

Results from estimating these models, for both the HFRI and CSFB Tremont index, find, at best, weak evidence of abnormal performance by convertible arbitrageurs. The explanatory power of all models is higher than the risk factor specifications estimated in Table 4 and 5, demonstrating the increase in efficiency of these performance models.

Next we estimate the risk and performance of individual convertible arbitrage hedge funds. The individual fund data was sourced from the HFR database. The original database consisted of 105 funds. However, many funds have more than one series in the database. Often this appears to be due to a dual domicile. (E.g. Fund X *Ltd* and Fund X *LLC* with almost identical returns.) To ensure that no fund was included twice, the cross correlations between the individual funds returns were estimated. If two funds had high correlation coefficients then the details of the funds were examined in detail.[23] Finally, in order to have adequate data to run the factor model tests, any fund that does not have 24 consecutive monthly returns between 1990 and 2002 is excluded. The final sample consisted of forty-six hedge funds. Of these forty-six funds, twenty were still alive at the end of December 2002 and twenty-six were dead.

Insert Table 7 about here

Descriptive statistics on each hedge fund are reported in Table 7. The mean number of observations is fifty-eight months up to a maximum of sixty-nine. The mean monthly return is 0.95% and the minimum monthly return by a fund over the sample period was -34%. The maximum monthly return was +23%. The mean skewness is -0.57 and the mean kurtosis is 3.77. The Ljung and Box (1978) Q-Statistic tests the joint hypothesis that the autocorrelations of up to an order of ten are all equal to zero. The results reject this hypothesis for twenty of the hedge funds.

Insert Table 8 about here

[23] These correlations are not reported but are available on request from the authors. In two cases high correlation coefficients were reported due to a fund reporting twice, in USD and in EUR. In this situation the EUR series was deleted.

Table 8 presents results from estimating the risk factor model (11) for individual convertible arbitrage hedge funds.[24] The mean explanatory power of the model is 27% (adjusted R^2).[25] The coefficients on *DEF*, *TERM* and *CBRF* are significantly different from zero for twenty-two, twenty-one and twenty-five hedge funds, respectively. The mean coefficient on *DEF* is 0.21, compared to a range of 0.17 to 0.25 for the convertible arbitrage portfolio and indices. The mean coefficient of *TERM* is 0.16 compared to a range of 0.19 to 0.30 for the convertible arbitrage portfolio and indices and the mean coefficient on *CBRF* is 0.48. The alphas are significantly positive for twenty-four hedge funds and significantly negative for one hedge fund. Furthermore, the mean alpha, for the forty-six hedge funds, is a statistically significant 0.28% per month.[26]

Insert Table 9 about here

Table 9 presents the results of repeating this analysis with the inclusion of the time *t-1* hedge fund excess return as an explanatory variable. The *DEF* coefficients are significant for nineteen hedge funds (mean coefficient of 0.23 compared to 0.17 for the model omitting y_{t-1}), the coefficients on *TERM* (mean coefficient 0.21 compared to 0.14 for the model omitting y_{t-1}), *CBRF* (mean coefficient of 0.43 compared to 0.48 for the model omitting y_{t-1}) and the y_{t-1} coefficients (mean coefficient 0.22) are significant for approximately half of hedge funds. The mean adjusted R^2 of the model is 33%. With the inclusion of the factor mimicking for illiquidity in the securities held by hedge funds the alphas generated by the convertible bond hedge funds are significantly positive for twenty hedge funds and significantly negative for four hedge funds. However, the mean alpha, for the forty-six hedge funds, is 0.15% per month at the 10% statistical significance level, or on an annualised basis of 1.8%, compared to a significantly positive alpha of 0.28% per month for the lagged model omitting the lag of y_t. All other coefficients are significant at the 1% level.

The results reported here for both hedge fund indices and the individual funds are similar demonstrating the robustness of our performance measurement models. The coefficients on *CBRF*, *DEF* and *TERM* are all statistically significant, positive and of similar magnitude. When

[24] As the results are noisy at the individual fund level we concentrate our discussion of Tables 8 and 9 on the mean coefficients reported in row 1 of both tables.
[25] With several lags of the risk factors specified the model is likely to be over-parameterized for some funds leading to lower adjusted R^2s.
[26] All of the coefficients are significant at the 1% level with the exception of β_{TERM} which is significant at the 5% level.

the model (11) is estimated without specifying the lag of the hedge fund return we find some evidence of convertible arbitrage abnormal performance. The HFRI index and the HFR funds exhibit abnormal performance of approximately 30 basis points per month. When this model is specified for the CSFB Tremont index we find no evidence of abnormal risk adjusted performance.

However, when the lag of the hedge fund index is also specified we find no evidence of abnormal performance for either of the hedge fund indices. In the individual fund data we find evidence to suggest weak abnormal performance of 15 basis points per month or approximately 1.8% per annum.

6. Conclusion

In this paper we generated a simple convertible arbitrage portfolio to identify sources of convertible arbitrage risk. This portfolio shares the risk characteristics of convertible arbitrage benchmark indices but contains none of the biases. Evidence from estimating risk factor models on this portfolio and the hedge fund indices finds support for the simulated portfolio capturing the key characteristics in the return generating process of convertible arbitrage. Since the simulated portfolio shares the risk profile of convertible arbitrage, it serves as a useful benchmark of hedge fund performance. The returns on the simulated portfolio also exhibit negative skewness and excess kurtosis, helping to account for the non-normality in convertible arbitrage hedge fund returns.

Evidence from examining the HFRI and CSFB Tremont hedge fund indices and individual hedge funds from the HFR database finds support for the default risk factor, term structure risk factor and the excess return on the simulated portfolio being significant in individual convertible arbitrage hedge fund returns, particularly if both lagged and contemporaneous observations of the risk factors are specified. This is a result which supports Asness et al.'s (2001) findings, that to efficiently estimate the risks faced by hedge funds a model which includes lags of the explanatory variables should be specified. When a non-synchronous model of hedge fund performance is estimated results indicate that convertible arbitrage hedge funds generate a statistically significant alpha of 0.28% per month, or 3.4% per annum. However, residuals from the estimated regressions exhibit autocorrelation. The one period lag of the hedge fund's return is then included, correcting for serial correlation in hedge fund returns. When this model is specified for the hedge fund indices they we find no evidence of abnormal performance. For the individual funds the mean estimate of abnormal performance from this model is lower (1.8% per month) than that reported for the model excluding the serial correlation correction though remains statistically significant from zero at the 10% level. Considering the previously documented survivorship bias in the HFR database[27], this suggests that convertible arbitrage hedge funds generated, at best, only modest abnormal (risk-adjusted) returns over the sample period.

[27] Liang (2000) examines two large databases (HFR and TASS) and finds an upward bias of 2% per annum.

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Table 1: Summary Statistics

RMRF is the excess return on Fama and French's (1993) market proxy, *SMB* and *HML* are Fama and French's factor-mimicking portfolios of size and market to book equity. *UMD* is the Carhart (1997) factor mimicking portfolio for one-year momentum. *TERM* and *DEF* are Fama and French's proxies for the deviation of long-term bond returns from expected returns due to shifts in interest rates and shifts in economic conditions that change the likelihood of default. *TO* is the factor mimicking portfolio for liquidity. *CSFBRF* is the excess return on the CSFB Tremont Convertible Arbitrage index, *HFRIRF* is the excess return on the HFRI Convertible Arbitrage index and *CBRF* is the excess return on the simulated convertible arbitrage portfolio. All of the variables are monthly from January 1990 to December 2002 except the CSFB Tremont Convertible Arbitrage Index which is from January 1994 to December 2002.

	Mean	T-Stat	Variance	Std Error	Skew	Kurtosis	Jarque-Bera
			Panel A: Dependent Variables				
CSFBRF	0.440***	3.291	1.930	1.744	-1.76***	4.61***	151.16***
HFRIRF	0.538***	6.818	0.972	0.986	-1.42***	3.28***	122.46***
CBRF	0.325**	2.307	3.104	1.762	-1.36***	9.00***	573.96***
			Panel B: Explanatory Returns				
RMRF	0.486	1.345	20.391	4.516	-0.61***	0.57	11.66***
SMB	0.152	0.531	12.719	3.566	0.45**	1.72***	24.49***
HML	0.096	0.282	18.032	4.246	-0.64***	5.58***	212.90***
UMD	1.144***	2.805	25.926	5.092	-0.71***	5.46***	207.33***
DEF	0.540***	3.064	9.391	2.455	-0.37*	2.59***	47.2***
TERM	0.112	0.577	5.825	2.413	-0.36*	0.22	3.65
TO	0.089	0.354	9.845	1.118	-0.25	1.62	18.72***

***, ** and * indicate significance at the 1%, 5% and 10% level respectively.
Statistics are generated using RATS 5.0

Table 2: Cross correlations, January 1990 to December 2002

RMRF is the excess return on Fama and French's (1993) market proxy, *SMB* and *HML* are Fama and French's factor-mimicking portfolios of size and market to book equity. *UMD* is the Carhart (1997) factor mimicking portfolio for one-year momentum. *TERM* and *DEF* are Fama and French's proxies for the deviation of long-term bond returns from expected returns due to shifts in interest rates and shifts in economic conditions that change the likelihood of default. *TO* is Eckbo and Norli's (2005) factor mimicking portfolio for liquidity. *CSFBRF* is the excess return on the CSFB Tremont Convertible Arbitrage index, *HFRIRF* is the excess return on the HFRI Convertible Arbitrage index and *CBRF* is the excess return on the simulated convertible arbitrage portfolio. All of the correlations cover the period January 1990 to December 2002 except for correlations with the CSFB Tremont Convertible Arbitrage Index which cover the period January 1994 to December 2002.

Panel A: Explanatory Variables

	RMRF	*SMB*	*HML*	*UMD*	*TERM*	*DEF*	*TO*
RMRF	1.00						
SMB	0.17	1.00					
HML	-0.34	-0.41	1.00				
UMD	-0.20	0.05	-0.62	1.00			
TERM	-0.06	-0.18	-0.03	0.27	1.00		
DEF	0.46	0.33	0.04	-0.39	-0.71	1.00	
TO	-0.68	-0.54	0.34	0.21	0.16	-0.52	1.00

Panel B: Dependent Variables and Explanatory Variables

	RMRF	*SMB*	*HML*	*UMD*	*TERM*	*DEF*	*TO*	*CSFBRF*	*HFRIRF*
CSFBRF	0.15	0.22	0.02	-0.05	0.04	0.23	-0.26	1.00	
HFRIRF	0.35	0.29	-0.10	-0.06	0.09	0.28	-0.42	0.80	1.00
CBRF	0.50	0.30	-0.03	-0.21	0.01	0.39	-0.48	0.32	0.48

With the exception of the *CSFBRF* correlations, coefficients greater than 0.25, 0.19 and 0.17 are significant at the 1%, 5% and 10% levels respectively.

CSFBRF correlation coefficients greater than 0.22, 0.17 and 0.14 are significant at the 1%, 5% and 10% levels respectively.

Table 3: Regressions on the simulated convertible arbitrage portfolio excess returns

This table reports results from regressions on simulated convertible arbitrage portfolio returns in excess of the risk free rate of interest. *RMRF* is the excess return on Fama and French's (1993) market proxy, *SMB* and *HML* are Fama and French's factor-mimicking portfolios of size and market to book equity. *UMD* is the Carhart (1997) factor mimicking portfolio for one-year momentum. *TERM* and *DEF* are Fama and French's proxies for the deviation of long-term bond returns from expected returns due to shifts in interest rates and shifts in economic conditions that change the likelihood of default. *TO* is Eckbo and Norli's (2005) factor mimicking portfolio for liquidity.

α	β_{RMRF}	β_{SMB}	β_{HML}	β_{UMD}	β_{TO}	β_{DEF}	β_{TERM}	Q-Stat	Adj. R^2
0.2268	0.2028							52.06***	26.56%
(1.54)	(5.07)***								
0.1906	0.2186	0.1216	0.105					55.78***	33.46%
(1.40)	(5.21)***	(3.50)***	(4.84)***						
0.0974	0.2464	0.1397	0.1627	0.0624				52.65***	34.69%
(0.57)	(4.86)***	(3.95)***	(3.28)***	(1.48)					
0.0944	0.2522	0.1455	0.1618	0.0607	0.0152			49.13***	34.28%
(0.54)	(4.35)***	(3.44)***	(3.29)***	(1.45)	(0.32)				
0.0738	0.1174					0.2848	0.3656	50.99***	37.11%
(0.52)	(3.64)***					(4.10)***	(3.79)***		
0.0934	0.1528	0.1009	0.0758			0.1868	0.3070	42.46***	39.84%
(0.71)	(4.48)***	(2.92)***	(3.60)***			(3.18)***	(3.59)***		

t-statistics in parenthesis are heteroskedasticity and autocorrelation-consistent, due to Newey and West (1987).
***, ** and * indicate significance at the 1%, 5% and 10% level respectively.

Table 4: Regressions on the HFRI Convertible Arbitrage Index excess returns, January 1990 to December 2002

This table reports results from regressions on HFRI Convertible Arbitrage Index returns in excess of the risk free rate of interest. *RMRF* is the excess return on Fama and French's (1993) market proxy, *SMB* and *HML* are Fama and French's factor-mimicking portfolios of size and market to book equity. *UMD* is the Carhart (1997) factor mimicking portfolio for one-year momentum. *TERM* and *DEF* are Fama and French's proxies for the deviation of long-term bond returns from expected returns due to shifts in interest rates and shifts in economic conditions that change the likelihood of default. *TO* is Eckbo and Norli's (2005) factor mimicking portfolio for liquidity.

α	β_{RMRF}	β_{SMB}	β_{HML}	β_{UMD}	β_{TO}	β_{DEF}	β_{TERM}	Q-Stat	Adj. R^2
0.5010	0.0763							79.76***	11.65%
(4.65)***	(4.00)***								
0.4860	0.0749	0.0820	0.0336					93.07***	18.37%
(4.75)***	(4.11)***	(4.06)***	(2.31)**						
0.4248	0.0932	0.0939	0.0715	0.0410				86.21***	20.13%
(3.73)***	(4.90)***	(4.21)***	(3.12)***	(2.17)**					
0.4326	0.0784	0.0792	0.0737	0.0453	-0.0392			86.0***	20.13%
(3.72)***	(3.02)***	(2.74)***	(3.17)***	(2.49)**	(-1.06)				
0.3958	0.0176					0.2016	0.2230	78.23***	26.41%
(3.56)***	(1.17)					(3.84)***	(4.08)***		
0.4040	0.0177	0.0517	0.0022			0.1738	0.2118	87.79***	28.40%
(3.78)***	(0.96)	(2.66)***	(0.12)			(3.08)***	(3.65)***		

t-statistics in parenthesis are heteroskedasticity and autocorrelation-consistent, due to Newey and West (1987).

***, ** and * indicate significance at the 1%, 5% and 10% level respectively.

Table 5: Regressions on the CSFB Tremont Convertible Arbitrage Index excess returns, January 1994 to December 2002

This table reports results from regressions on the CSFB Tremont Convertible Arbitrage Index returns in excess of the risk free rate of interest. *RMRF* is the excess return on Fama and French's (1993) market proxy, *SMB* and *HML* are Fama and French's factor-mimicking portfolios of size and market to book equity. *UMD* is the Carhart (1997) factor mimicking portfolio for one-year momentum. *TERM* and *DEF* are Fama and French's proxies for the deviation of long-term bond returns from expected returns due to shifts in interest rates and shifts in economic conditions that change the likelihood of default. *TO* is Eckbo and Norli's (2005) factor mimicking portfolio for liquidity.

α	β_{RMRF}	β_{SMB}	β_{HML}	β_{UMD}	β_{TO}	β_{DEF}	β_{TERM}	Q Stat	Adj. R^2
0.4212	0.0425							93.00***	1.23%
(2.08)**	(1.46)								
0.4055	0.0477	0.0927	0.0520					93.63***	5.76%
(2.08)**	(1.66)*	(2.69)***	(2.38)**						
0.3234	0.0783	0.1108	0.1092	0.0550				90.90***	6.86%
(1.44)	(2.21)**	(2.50)**	(2.03)**	(1.31)					
0.3460	0.0405	0.0752	0.1160	0.0656	-0.0984			83.74***	7.95%
(1.52)	(0.91)	(1.39)	(2.16)**	(1.60)	(-1.74)*				
0.3501	-0.0284					0.2587	0.2585	111.1***	11.88%
(1.66)*	(-0.84)					(2.59)***	(3.12)***		
0.3534	-0.0197	0.0564	0.0146			0.2200	0.2410	108.6***	12.03%
(1.72)*	(-0.44)	(2.08)**	(0.45)			(1.97)**	(2.64)***		

t-statistics in parenthesis are heteroskedasticity and autocorrelation-consistent, due to Newey and West (1987).
***, ** and * indicate significance at the 1%, 5% and 10% level respectively.

Table 6: Result of regressions on the HFRI and CSFB Tremont Convertible Arbitrage Index excess returns

This table presents the results of estimating the following models of hedge fund index returns.

$$y_t = \alpha + \beta_0' \, CBRF + \beta_1' \, DEF + \beta_2' \, TERM + \varepsilon_t$$

$$y_t = \alpha + \beta_0' \, CBRF + \beta_1' \, DEF + \beta_2' \, TERM + \beta_3 y_{t-1} + \varepsilon_t$$

Where $DEF = (DEF_t, DEF_{t-1}, DEF_{t-2})$, $TERM = (TERM_t, TERM_{t-1}, TERM_{t-2})$, $CBRF = (CBRF_t, CBRF_{t-1}$ and $CBRF_{t-2})$ and y_t is the excess return on the index at time *t-1*. The β coefficient is the sum of the contemporaneous β and lagged β s. *P*-values from testing $\alpha = 0$ and $(\beta_{it} + \beta_{it-1} + \beta_{it-2}) = 0$, for $i = DEF$, *TERM* and *CBRF* are in parenthesis. T–test statistics are heteroskedasticity and autocorrelation-consistent, due to Newey and West (1987). Panel A presents results for the HFRI hedge fund index and Panel B Presents results for the CSFB Tremont index.

Panel A: HFRI Model 1990 – 2002

α	$\beta_{CBRF(t\ to\ t-2)}$	$\beta_{DEF(t\ to\ t-2)}$	$\beta_{TERM(t\ to\ t-2)}$	β_Y	Q Stat	Adj. R^2
0.0032	0.22	0.23	0.18		72.85	37%
(0.00)	(0.02)	(0.00)	(0.01)		(0.00)	
0.0014	0.08	0.18	0.13	0.49	32.29	52%
(0.11)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	

Panel B: CSFB Tremont Model 1994 – 2002

α	$\beta_{CBRF(t\ to\ t-2)}$	$\beta_{DEF(t\ to\ t-2)}$	$\beta_{TERM(t\ to\ t-2)}$	β_Y	Q Stat	Adj. R^2
0.0019	0.22	0.41	0.29		95.12	20%
(0.41)	(0.02)	(0.07)	(0.02)		(0.00)	
0.0006	0.07	0.34	0.22	0.58	88.99	47%
(0.67)	(0.08)	(0.03)	(0.00)	(0.00)	(0.00)	

Table 7: Statistics on individual hedge fund returns

This table presents descriptive statistics on the fifty five hedge funds included in the sample. For each fund *N* is the number of monthly return observations, *Min* and *Max* are the minimum and maximum monthly return, *Skew* and *Kurt* are the skewness and kurtosis of the hedge funds return distribution and *Q-Stat* is the Ljung and Box (1978) Q-Statistic jointly testing the series' ten lags of autocorrelation are significantly different from zero.

Fund	*N*	*Mean*	*Min*	*Max*	*Skew*	*Kurt*	*Q-Stat*
1	69	1.01	-4.41	4.95	-0.65	3.05	6.94
2	69	1.04	-8.07	9.77	0.32	2.80	13.11
3	38	1.74	-1.57	11.21	1.92	6.66	7.68
4	60	1.55	-1.62	11.74	2.08	8.85	9.46
5	69	1.31	-10.27	12.08	-0.64	4.44	12.36
6	69	1.33	-8.99	9.31	-1.19	4.37	16.39*
7	58	0.98	-2.49	3.43	-0.61	1.78	8.82
8	57	0.80	-5.70	9.03	0.01	0.02	6.66
9	27	1.23	-1.69	5.48	0.25	-0.02	14.13
10	30	0.33	-0.77	0.95	-1.11	3.49	4.24
11	55	1.02	-0.81	2.88	0.27	0.13	26.07***
12	38	1.18	0.00	2.87	0.46	-0.55	16.40*
13	25	0.45	-0.59	1.65	0.20	-0.49	9.33
14	36	1.27	-2.51	7.08	0.90	2.65	11.88
15	69	0.92	-5.20	3.17	-2.34	5.87	37.27***
16	69	1.02	-4.31	3.64	-1.71	3.99	10.88
17	37	0.24	-34.16	3.84	-5.72	34.05	0.76
18	69	1.37	-2.77	5.08	0.32	0.18	21.23**
19	69	0.68	-1.88	2.75	-0.58	1.09	18.23*
20	69	0.85	-2.17	6.53	1.27	6.12	7.50
21	69	1.02	-4.31	3.64	-1.71	3.99	10.88
22	69	0.96	-4.41	4.95	-0.53	2.56	7.94
23	69	1.05	-2.13	3.11	-0.55	1.20	18.14*
24	25	0.92	-0.88	2.60	-0.10	-0.73	14.13
25	24	-0.40	-5.52	4.00	-0.21	-0.66	18.33**
26	38	1.21	-2.68	6.88	0.56	1.14	9.43
27	69	1.06	-8.96	5.54	-2.04	6.49	23.27***
28	69	0.82	-1.70	3.86	0.36	-0.07	12.58
29	69	0.41	-24.68	23.25	-0.17	2.22	6.66
30	69	1.24	-3.98	6.77	-0.14	0.50	23.27***
31	69	1.00	-11.88	7.14	-1.29	4.62	17.20*
32	69	0.69	-1.61	1.78	-1.21	3.22	57.12***
33	36	0.83	-1.78	2.92	-0.19	1.49	13.55
34	69	0.87	-4.82	4.07	-1.22	5.80	11.67
35	51	0.94	-2.30	3.95	0.03	1.07	14.97
36	51	0.92	-1.60	2.41	-0.85	1.78	17.50*
37	69	1.25	-9.19	4.10	-3.01	12.59	24.62***
38	69	1.66	-9.56	5.20	-2.86	11.47	30.42***
39	69	0.95	-2.30	4.16	0.43	3.25	24.78***

Fund	*N*	*Mean*	*Min*	*Max*	*Skew*	*Kurt*	*Q-Stat*
40	69	0.98	-1.32	4.83	0.45	1.73	10.20
41	69	0.82	-1.08	2.22	-0.49	0.97	13.15
42	67	0.80	-3.29	3.37	-0.77	1.51	17.65*
43	57	0.93	-8.34	4.21	-2.34	10.54	14.35
44	69	1.02	-3.70	6.05	-0.51	4.32	23.33***
45	57	0.72	-2.00	2.28	-0.84	2.89	19.30**
46	69	0.82	-0.98	2.01	-0.53	1.09	18.54**
Mean	58	0.95	-4.89	5.28	-0.57	3.77	
Min	24	-0.40	-34.16	0.95	-5.72	-0.73	
Max	69	1.74	0.00	23.25	2.08	34.05	

***, ** and * indicate significance at the 1%, 5% and 10% level respectively.
Statistics are generated using RATS 5.0

Table 8: Estimating non-synchronous regressions of individual fund risk factors

This table presents the results of estimating the following model of hedge fund returns.

$$y_t = \alpha + \beta_0' \, CBRF + \beta_1' \, DEF + \beta_2' \, TERM + \varepsilon_t$$

Where y_t is the excess return on the portfolio at time *t-1*, $DEF = (DEF_t, DEF_{t-1}, DEF_{t-2})$, $TERM = (TERM_t, TERM_{t-1}, TERM_{t-2})$ and $CBRF = (CBRF_t, CBRF_{t-1}$ and $CBRF_{t-2})$. The β coefficient is the sum of the contemporaneous β and lagged βs. ***, ** and * indicate significance, at the 1%, 5% and 10% level respectively, for α and βs for *DEF*, *TERM* and *CBRF*. T-test statistics are heteroskedasticity and autocorrelation-consistent, due to Newey and West (1987).

	$r_i - r_f$	α	$\beta_{CBRF(t\ to\ t-2)}$	$\beta_{DEF(t\ to\ t-2)}$	$\beta_{TERM(t\ to\ t-2)}$	Adj R^2	Q stat	N
Mean		0.28***	0.48***	0.21***	0.16**	27%		

Fund	$r_i - r_f$	α	$\beta_{CBRF(t\ to\ t-2)}$	$\beta_{DEF(t\ to\ t-2)}$	$\beta_{TERM(t\ to\ t-2)}$	Adj R^2	Q stat	N
1	0.65	0.51***	0.42	0.08	0.00	10.3%	7.90	69
2	0.69	-0.01	1.18*	0.04	-0.41	17.0%	21.01***	69
3	1.38	1.28***	1.34**	-0.47*	-0.70	21.8%	24.80***	38
4	1.19	1.09***	1.40***	-0.46**	-0.73***	30.0%	24.20***	60
5	0.95	0.15	0.97	1.01**	0.76***	52.4%	33.92***	69
6	0.97	0.43	1.13	0.56	0.38	30.2%	18.00**	69
7	0.62	0.58***	0.50**	0.18**	0.25***	32.0%	23.47***	58
8	0.44	-0.01	0.54*	0.28	0.62	46.7%	21.71***	57
9	0.87	1.04***	0.05	0.40**	0.43	17.6%	15.84**	27
10	-0.03	-0.10**	0.46***	-0.09***	0.01	48.6%	21.00***	30
11	0.66	0.63***	0.44***	-0.01	0.07	2.9%	19.87***	55
12	0.82	0.66***	0.76***	-0.10	0.12	12.5%	18.54**	38
13	0.09	0.08	0.33*	-0.20***	-0.20***	4.6%	19.95***	25
14	0.91	1.10***	-0.21	0.28	0.20	25.0%	14.42**	36
15	0.56	-0.22	0.13	0.89***	0.88***	42.6%	7.61	69
16	0.66	0.33	0.12	0.31	0.27	7.4%	7.76	69
17	-0.12	-0.47	0.25	0.61	1.91**	29.4%	17.67***	37
18	1.11	0.86**	-0.12	0.21	0.49*	7.5%	20.69***	69
19	0.38	-0.20	0.03	0.51***	0.53***	25.7%	22.65***	69
20	0.38	-0.05	-0.20	0.60***	0.71***	26.3%	22.83***	69
21	0.66	0.33	0.12	0.31	0.27	7.4%	23.10***	69
22	0.60	0.47**	0.36	0.08	0.06	7.5%	7.05	69
23	0.69	0.20*	0.02	0.66***	0.51***	40.3%	12.81**	69
24	0.56	0.47***	0.50**	0.09	0.23*	39.5%	17.22**	25
25	-0.76	0.09	-1.69***	0.49***	-0.98***	73.9%	18.18***	24
26	0.85	0.70**	0.97**	0.09	0.08	47.4%	18.85***	38
27	0.70	0.45	1.02**	-0.31	-0.80*	11.6%	24.15***	69

Fund	r_i - r_f	α	$\beta_{CBRF(t\ to\ t-2)}$	$\beta_{DEF(t\ to\ t-2)}$	$\beta_{TERM(t\ to\ t-2)}$	Adj R^2	Q stat	N
28	0.33	-0.05	0.37*	0.26	0.19	5.0%	28.35***	69
29	0.05	-1.58	4.52***	-0.96	-1.12	10.1%	17.50**	69
30	0.67	-0.37	0.78**	0.51**	0.33	29.0%	38.28***	69
31	0.64	-0.61	1.03**	1.03*	0.51	41.1%	7.22	69
32	0.13	0.18*	-0.14*	0.13**	0.32***	21.0%	12.74**	69
33	0.47	0.40**	0.09	-0.16	0.05	16.2%	34.31***	36
34	0.52	0.10	0.52**	0.38**	0.26*	38.3%	23.62***	69
35	0.58	0.43**	0.82***	0.05	0.08	49.9%	6.73	51
36	0.52	0.25***	0.14	0.19**	0.16**	53.4%	5.24	51
37	0.89	0.55	0.77*	-0.01	-0.22	17.0%	47.83***	69
38	1.30	0.67	0.89***	0.22	0.03	22.0%	26.23***	69
39	0.36	0.44**	-0.09	0.14	0.39**	19.3%	29.79***	69
40	0.62	0.29***	0.59***	0.21*	0.21	30.4%	37.23***	69
41	0.46	0.19**	0.16*	0.18**	0.14**	43.3%	53.46***	69
42	0.44	0.33**	0.61***	0.00	-0.07	35.8%	18.30***	67
43	0.58	0.64***	0.11	0.15	0.13	7.1%	20.65***	52
44	0.66	0.22	-0.25	0.72***	0.66***	13.4%	26.31***	69
45	0.36	0.32***	0.46***	0.01	0.12	16.2%	40.07***	57
46	0.46	0.17**	0.01	0.38***	0.29***	38.0%	22.84***	69

Table 9
Results of estimating non-synchronous regressions of individual fund risk factors augmented with a liquidity risk factor proxy

This table presents the results of estimating the excess returns of individual hedge funds on the following model of hedge fund returns.

$$y_t = \alpha + \beta_0' \, CBRF + \beta_1' \, DEF + \beta_2' \, TERM + \beta_3 y_{t-1} + \varepsilon_t$$

Where y_t is the excess return on the portfolio at time t-1, $DEF = (DEF_t, DEF_{t-1}, DEF_{t-2})$, $TERM = (TERM_t, TERM_{t-1}, TERM_{t-2})$, $CBRF = (CBRF_t, CBRF_{t-1}$ and $CBRF_{t-2})$ and y_{t-1} is the one period lag of the excess return on the portfolio. The β coefficient is the sum of the contemporaneous β and lagged β s. ***, ** and * indicate significance, at the 1%, 5% and 10% level respectively, for α and β s. T-test statistics are heteroskedasticity and autocorrelation-consistent, due to Newey and West (1987).

	α	$\beta_{CBRF(t\ to\ t-2)}$	$\beta_{DEF(t\ to\ t-2)}$	$\beta_{TERM(t\ to\ t-2)}$	β_Y	Adj R^2
Mean	0.15*	0.43***	0.23***	0.21***	0.22***	33%

Fund	$r_i - r_f$	α	$\beta_{CBRF(t\ to\ t-2)}$	$\beta_{DEF(t\ to\ t-2)}$	$\beta_{TERM(t\ to\ t-2)}$	β_Y	Adj R^2	Q Stat	N
1	0.65	0.49***	0.39	0.08	0.03	0.08	9.3%	9.49	69
2	0.69	-0.10	1.00*	0.07	-0.25	0.26***	20.8%	6.40	69
3	1.38	1.08**	1.33**	-0.46	-0.70	0.16	19.1%	12.07*	38
4	1.19	0.87***	1.36***	-0.43**	-0.66*	0.20	31.2%	11.63*	60
5	0.95	0.07	0.78	0.99***	0.82***	0.18	53.3%	9.91	69
6	0.97	0.26	0.91	0.64	0.60**	0.25**	35.7%	4.83	69
7	0.62	0.45***	0.41***	0.22**	0.31***	0.29**	40.8%	9.77	58
8	0.44	1.55***	0.68	-1.12	0.21	0.24	21.9%	31.14***	57
9	0.87	0.83***	-0.24	0.42**	0.51**	0.26	11.5%	23.43***	27
10	-0.03	-0.07	0.40***	-0.07	0.02	0.03	51.3%	25.39***	30
11	0.66	0.34***	0.33***	-0.03	0.07	0.44***	17.5%	32.71***	55
12	0.82	0.23*	0.38***	0.02	0.27**	0.60***	38.5%	27.13***	38
13	0.09	0.04	0.40***	-0.24***	-0.20***	0.21*	10.0%	29.01***	25
14	0.91	1.12***	-0.21	0.28	0.17	0.02	21.6%	22.07***	36
15	0.56	-0.35***	0.19	0.67***	0.66***	0.47***	60.3%	10.09	69
16	0.66	0.21	0.11	0.28	0.24	0.28*	13.6%	11.52*	69
17	-0.12	-0.49	0.17	0.70	1.97**	0.17**	29.4%	19.56***	37
18	1.11	0.30	-0.16	0.60	0.69**	0.35***	20.0%	19.09***	69
19	0.38	-0.11	0.07	0.41***	0.43***	0.11	24.6%	21.34***	69
20	0.38	-0.09	-0.05	0.48**	0.55***	0.17	30.5%	21.41***	69
21	0.66	0.21	0.11	0.28	0.24	0.28*	13.6%	20.75***	69
22	0.60	0.42***	0.31	0.08	0.07	0.12	7.3%	8.36	69
23	0.69	0.20	0.00	0.61***	0.46***	0.09	42.9%	15.18**	69
24	0.56	0.31***	0.51***	0.01	0.24***	0.29**	47.5%	11.54*	25

Fund	r_i -r_f	α	$\beta_{CBRF(t\ to\ t-2)}$	$\beta_{DEF(t\ to\ t-2)}$	$\beta_{TERM(t\ to\ t-2)}$	β_Y	Adj R^2	Q Stat	N
25	-0.76	0.07	-1.27***	0.19	-0.97***	0.35***	77.4%	12.60**	24
26	0.85	0.39*	0.83**	0.03	0.12	0.36**	50.5%	9.92	38
27	0.70	0.30	0.91**	-0.29	-0.71*	0.28**	17.2%	13.79**	69
28	0.33	-0.47**	0.14	0.79***	0.58***	-0.34***	15.7%	18.43***	69
29	0.05	-1.51	4.33***	-0.96	-1.14	0.16	10.7%	10.19	69
30	0.67	-1.46***	0.62*	1.75***	1.04***	0.28**	41.0%	19.22***	69
31	0.64	-0.57	1.04**	0.97	0.47	0.04	40.2%	8.54	69
32	0.13	-0.30***	-0.04	0.50***	0.57***	-0.23	47.0%	11.03*	69
33	0.47	0.27***	-0.19	-0.03	0.13	0.44***	30.8%	34.03***	36
34	0.52	0.06	0.53**	0.33*	0.22	0.22***	44.3%	16.09***	69
35	0.58	0.39***	0.66*	0.06	0.10	0.15	49.4%	4.65	51
36	0.52	0.10*	0.45***	0.40***	0.36***	0.00	62.2%	5.46	51
37	0.89	0.16	0.59***	0.06	-0.05	0.53***	41.4%	5.04	69
38	1.30	0.25	0.49***	0.31	0.14	0.47***	40.2%	6.33	69
39	0.36	-0.06	0.08	0.30*	0.38**	0.30**	58.0%	22.80***	69
40	0.62	0.28***	0.54***	0.22**	0.24*	0.08	30.9%	36.59***	69
41	0.46	0.09	0.16**	0.14**	0.11*	0.32***	48.9%	45.23***	69
42	0.44	0.29**	0.55***	0.03	0.01	0.14	37.1%	16.64***	67
43	0.58	0.50***	0.14	0.13	0.15	0.17	7.2%	17.23***	52
44	0.66	0.14	-0.27	0.65***	0.63***	0.24**	17.4%	25.69***	69
45	0.36	0.24***	0.32**	0.04	0.14	0.32***	21.7%	43.27***	57
46	0.46	0.17**	0.00	0.35***	0.26***	0.09	41.6%	11.14**	69