

**REPLICATING HEDGE FUND RETURNS:
A FACTOR MODEL APPROACH**

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Abstract

Growth in the Hedge Fund industry mirrors the growth in the Mutual Fund industry. This raises the possibility of creating a passive strategy that replicates Hedge Fund returns at lower cost using liquid, exchange-traded instruments. Using monthly returns for the period 1991-2005 on thirteen Hedge Fund strategies, I build a linear factor models (“clones”) that replicate Hedge Fund returns. I use six common factors to determine the amount of expected return and variation in returns that can be explained by these factors alone. I find that for certain strategies “clones” outperform their Hedge Fund counterparts on an absolute basis, and clones outperform on a risk adjusted basis for all strategies. This finding merits serious consideration by institutional investors whose goals of transparency, liquidity, and lower fees conflict with those of Hedge Funds.

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1. Introduction

As institutional investors recognize the potential merits of alternative investments, the recent exponential growth in the hedge fund industry will continue. The draw of the hedge funds is twofold, historically attractive risk-adjusted returns and diversification resulting from low correlation with traditional asset classes. According to Hedge Fund Research (HFR) the first half of 2006 has seen inflows of \$66 billion, the highest growth on record if the pace continues. As Table I demonstrates, the returns obtained by investing in hedge funds are indeed attractive on a risk adjusted basis when compared to those of the broader stock market (S&P 500 index).

Institutional investors have investment goals that can conflict with those of the hedge fund manager. Pension plan sponsors require transparency from managers; hedge fund managers have proprietary trading strategies and do not allow position level transparency. Pension plans require a degree of liquidity in order to meet benefit obligations; hedge fund managers typically impose lockup periods. As fiduciaries, plan sponsors are concerned about the significant fees and incentive structures of hedge funds; managers of hedge funds argue that their unique trading talents justify those fees.

The goals of transparency and liquidity can be resolved if it is possible to replicate hedge fund returns using commonly traded, liquid instruments. The concern over hedge fund fees can be dealt with if replication can be achieved using a passive investment strategy. Passive replication of hedge fund index returns using liquid financial instruments is the

goal of this paper. The idea of passive investment is a very popular method for investing in traditional asset classes. As the hedge fund industry matures, this idea will become increasingly attractive in that industry as well.

Table 1 Comparison of Hedge Funds and S&P index - Return and Risk

Fund Strategy	Mean	Standard Deviation	Sharpe Ratio
Convertible Arbitrage	10.09	3.45	2.92
Distressed	14.86	5.84	2.55
Emerging Markets	16.91	14.30	1.18
Equity Hedge	16.48	8.72	1.88
Market Neutral	8.46	3.16	2.67
Equity Non Hedge	17.37	13.70	1.27
Event Driven	14.76	6.12	2.41
Fixed Income	7.92	4.28	1.85
Fund of Funds	9.18	5.63	1.63
Macro	15.16	8.27	1.83
Merger Arbitrage	10.38	3.59	2.89
Sector	17.37	13.50	1.29
Short Selling	1.83	20.83	0.09
S&P	8.87	14.04	0.63

Notes: A comparison of risk and return of Hedge Fund strategies with the S&P 500 for the period 1991-2005. All returns are annualized.

Two methods for achieving the above goals have been attempted in the literature:

- creating long/short portfolios of liquid assets such as stocks, bonds, currencies and commodities,
- mechanically investing in strategies similar to those employed by hedge funds, for example, merger arbitrage.

In this paper, I attempt to employ the first of these strategies in replicating or “cloning” the returns of several indexes of common hedge fund strategies. Specifically, I attempt to replicate thirteen of the strategies reported on by HFR database. The cloned portfolios

consist of common risk factors, as identified by several authors, consisting of the equity market index, currencies, commodities and bonds. The portfolio weights are determined by regressing the various HFR index returns on the risk factors identified. The idea is to generate those returns of hedge funds that are due to common risk exposures. I use five factors identified in the study by Hasanhodzic and Lo (2006b), equity market index, bond market index, credit spreads, commodities index, and currency index. These factors have the advantage of being traded through liquid securities such as futures and forwards.

I use linear regression to decompose hedge fund index returns into manager specific alpha and return due to the risk factors identified. I find that for hedge funds a significant fraction of funds expected returns are due to risk premia. Although alpha for these funds is also significant, it has two components, manager skill, and variables omitted from the model. These components are difficult to separate and, therefore, it is hard to draw conclusions regarding alpha.

I then compute the historical performance of the linear clones and compare it with those of hedge funds from the HFR database. I find that the clones exhibit performance that is similar to the original fund indexes. Hasanhodzic and Lo (2006b) also show that the correlations of the clones to the market indices are also similar to those of the hedge funds, thus facilitating diversification. The clones have the added advantage of being extremely liquid and transparent. Based on these results, I conclude that passive hedge fund investing in the case of the funds from the HFR database is worthy of consideration by institutional investors that have the goals stated earlier, specifically, liquidity, transparency and low cost.

2. Motivation

With exponential growth in assets under management, the hedge fund industry is maturing. This is increasing competition for returns, manager talent, and top-quality fund of funds that can identify and access the best performing hedge funds. However, it may be increasingly difficult for investors to justify paying lofty hedge fund fees for the performance of the average active manager. Passive alternatives to actively managed hedge funds represent a natural evolution in this developing industry. Already very popular as a means of investing in traditional asset classes, passive strategies will gain popularity with hedge fund investors, particularly as the industry reaches its growth potential.

Since 1990 hedge fund assets have grown 31-fold to an estimated \$1.2 trillion, while the number of hedge funds in the market has increased 13-fold to nearly 7,000 according to Hedge Fund Research, Merrill Lynch (2006). In addition to sheer growth and size, distinct changes to the hedge fund industry illustrate its increasing maturity, including, a shift toward institutional investors as the dominant drivers of asset growth; increased pressure to regulate hedge funds due to their broader investor reach; increasing concentration in assets toward the largest hedge funds; rapid growth in the fund of hedge funds industry aimed to help investors identify the best funds out of an increasingly large pool of hedge funds consolidating within larger financial institutions and asset managers.

These were all signs of maturation in the mutual fund industry and are paralleled in the hedge fund industry.

Competition for available returns in the market is rising as a greater number of funds employ similar strategies. As with the development of any cottage industry, there is an increasing value to having a certain size, and it is becoming more difficult for the smallest players to remain competitive. According to a recent article by Hasanhodzic and Lo (2006a), the largest 100 hedge funds managed \$720bn or 65% of total single-manager hedge fund assets at the end of 2005, leaving about 7000 funds managing the remaining 35%. This is an increase in concentration from 2004 when the largest 100 funds managed only 58% of total hedge fund assets.

Perhaps an even more important reason for consolidation as the hedge fund industry matures is the limited supply of manager talent. The best managers are given as much capital as they can handle, while thousands of newcomers with lesser track-records find it more difficult to reach critical mass in an increasingly competitive market. There will always be a group of high-quality fund managers who can consistently outperform their peers; however, as the industry grows there will be an increasing number who can not.

Another negative by-product of increased competition within the hedge fund industry is the tendency for hedge funds to take on either larger risks or unfamiliar risks in order to boost returns and remain competitive. This is expected to have the impact of increasing manager specific-risk (Merrill Lynch, 2006). HFR estimated that in 2005 the attrition rate for hedge fund managers reached 11.4%, the highest level ever recorded and an increase from 4.7% in 2004. As more hedge funds enter the market, skilled fund of funds

managers become even more valuable for their ability to sort through the vast sea of potential investment opportunities and identify those managers and hedge fund styles that have the potential to consistently deliver above-average returns.

The argument for passive management is based on the idea that as the level of competition among active fund managers grows, it becomes more difficult for the average active manager to outperform their benchmark after fees. Hence investors who have little skill in selecting outperforming active managers are better off with a strategy that mechanically replicates the benchmark at a much lower cost. Cost savings come from avoiding the need to continually decide which assets are most likely to outperform the benchmark, and instead using a rules-based mechanical strategy which emulates an index. As the mainstream asset management industry has matured, passive investing has become an increasingly important and accepted alternative to active management.

It is interesting to compare the rapid growth in the hedge fund industry to the mutual fund industry, which in the US really started to expand about 10 years before hedge funds. In 1980 approximately 550 mutual funds operated in the US, which is the same as the number of hedge funds in existence in 1990. From 1980-1995, the number of US mutual funds grew tenfold to nearly 6,000 (Merrill Lynch, 2006). This is similar to the growth witnessed by hedge funds between 1990 and 2005, which expanded from approximately 500 to 6,500. The total number of mutual funds peaked after about 20 years of solid growth and eventually started to decline in 2002 (corresponding to 2012). While the concept of passive management and the active/passive debate dates back further, it was not until the 1990's that passive funds started to represent a meaningful proportion of US

mutual fund assets. Between 1990 and 2004, passively managed funds grew from 2% of equity mutual fund assets to 17% (Merrill Lynch, 2006). Passive investment strategies could gain similar importance in the hedge fund industry.

3. Passive Strategies – An Introduction

Passive strategies take varying forms and offer several benefits. As the hedge fund industry matures and it becomes increasingly difficult for many investors to identify and invest in the top-performing hedge funds, passive management should gain wider appeal with hedge fund investors. The same forces in the mutual fund industry that drove the growth in low-cost, mechanically driven portfolio management strategies should also help to shape the hedge fund industry. It has been slower to take hold compared with passive management in the mutual fund space, which started to gain meaningful traction 10 years into the growth of mutual funds. This is perhaps understandable given that hedge funds are often equated with the purest form of active management.

Actively managed hedge funds typically charge much higher fees than mutual funds (when they are performing well). If strategies can be developed that provide returns similar to those of hedge funds without the need for active management, and provided that lower management costs are reflected in the structures, these passive vehicles have the potential to significantly outperform actively managed hedge funds on an after-fee basis. Depending on the investment style, passive hedge fund management also has the ability to add value in terms of increased transparency and liquidity, as well as reduced single-manager risk – features that become even more important to investors as the market matures and the risks of selecting a poor manager increase.

One of the complexities of passive hedge fund investing is that there are several possible approaches. Among these are strategies that track hedge fund benchmarks by mechanically investing in all hedge funds in an investable benchmark; replicate hedge fund, or hedge fund benchmark performance by investing in a portfolio of liquid assets that statistically track hedge fund returns; and mechanically investing in strategies similar to those hedge funds execute, but at lower cost by removing the element of active management. If passive strategies can provide similar returns to hedge funds, they have potential to outperform actively managed hedge funds whose returns are reduced by higher hedge fund fees. Passive strategies also offer greater liquidity and transparency.

Now I will look at the two most popular ways of passively investing in the hedge fund industry.

Passive fund of hedge funds

So far the most common way to employ passive hedge fund management is for fund of hedge funds to systematically track benchmarks either by aiming to purchase all funds in an investable benchmark or through representative sampling – picking a mix of funds that best mimic the benchmark without investing in every fund. By using mechanical methods to select the hedge funds (versus actively selecting them), the fund of funds fees can be reduced and the cost benefits of passive management are passed on to the investor.

This method still has several drawbacks; liquidity and transparency are not significantly improved over traditional hedge fund investing; Fund of Funds charge another layer of

fees above those of the underlying hedge funds; performance of investable hedge fund benchmarks have notably trailed broader hedge fund benchmarks.

While passive fund of funds is perhaps the most straightforward method of employing passive techniques to hedge fund investing (and the closest parallel to traditional passive management), there are other methods that are expected to reach the market as it develops.

An alternative method for using passive management to access hedge fund returns, which has been the subject of academic research, is to replicate hedge fund or hedge fund index returns using liquid investments such as equities, bonds, currencies and commodities.

Extensive academic research has shown that many hedge fund investment styles can be replicated by creating long/short portfolios of liquid assets optimized to track hedge funds or hedge fund benchmarks. This is possible given that many hedge fund investments are made up of long and short positions of various liquid instruments, or assets that correlate well with liquid instruments. This style of hedge fund index replication is not designed to capture the star-performing hedge fund, but rather to replicate the return of the average hedge fund without paying the high hedge fund fees. If the strategy is able to sufficiently track a hedge fund benchmark, the reduced costs of mechanically generating the returns will provide the out-performance over investable hedge fund indices.

There are other material benefits to this style of passive hedge fund investing: enhanced liquidity and transparency compared with the average hedge fund; elimination of single-manager risk; ability to invest in smaller sizes, potentially opening up hedge fund-style

investments to a larger number of investors; ability to scale investments to a larger size due to the liquidity of the tracking assets, potentially increasing the capacity of certain hedge fund styles; ability to create derivatives on these indices.

There is also another benefit to this style of hedge fund replication, which is the potential to create truly liquid and tradable hedge fund benchmark products, allowing investors not only to go long a hedge fund-like investment, but expanding the investment universe by allowing short selling. For example, a star hedge fund manager or an investor that owned a star hedge fund may want to short an underlying hedge fund benchmark instrument to obtain the pure out-performance versus the benchmark and reduce the risk that a particular hedge fund style may not do well as a whole. Hedge funds themselves could also potentially use these products for short-term investment vehicles to allocate assets while they scale into their specific investment strategy – analogous to the way traditional asset managers use liquid benchmark tracking instruments today.

Academic research over the last ten years has demonstrated that a significant portion of many hedge fund returns can be replicated using liquid assets. The underlying instruments (sometimes referred to as risk factors) include: Small and large-cap US equity and Non US equity, including emerging market equity, US government and corporate bonds, Short-term interest rates, Commodities, Currencies, Options on these underlying assets, Liquid and tradable hedge fund benchmark products potentially offer hedge fund investors a set of hedging tools analogous to those employed by traditional asset managers.

When hedge fund returns are averaged together (for example, in the form of an index) common risk exposures can be identified – particularly for funds within in a specific investment style such as long/short or global macro, for example. Using a regression model, these common risks can be identified and linked to specific liquid assets. The outcome is a portfolio of liquid assets (stocks, bonds, currencies, etc ...) that aims to replicate average hedge fund returns. However, this portfolio is considerably more transparent and liquid compared with a direct investment in the underlying hedge funds.

4. Literature Review

Jaeger (2005), Jaeger and Wagner (2005), Jensen and Rotenberg (2005), Kat and Palaro (2006) show that hedge fund returns are derived from common risk factors, that is, Beta, rather than exploitation of inefficiencies or manager skill, better known as alpha. Given this conclusion there have been several attempts in the literature to replicate hedge fund returns.

Following an approach similar to Sharpe (1992) where he shows that the returns of a large number of mutual funds can be replicated using only a few major asset classes, there have been several attempts to apply this method to replicating hedge fund returns. Both linear and non linear approaches to replication have been attempted.

Fung and Hsieh (1997), Capocci and Hubner (2004), Hasanhodzic and Lo (2006b), successfully use a linear model that modifies Sharpe's stylistic approach to fit the alternative investment world that employs dynamic trading strategies that frequently involve short sales, leverage and derivatives. The risk factors are US and non US equities, US and non US bonds, US dollar, Gold, Emerging markets and high yield corporate bonds.

Several authors have used non-linear, option writing approaches to successfully replicate hedge fund returns. These strategies yield a better fit, but at the cost of adding increased complexity. I now review some of the literature on these replication attempts.

Fung and Hsieh (1997), Agarwal and Naik (2004) determine the risk exposures of hedge funds using buy-and-hold options based strategies. They show that a large number of hedge funds have returns that can be modeled using a short position in a put option. The authors go on to model hedge fund returns using option based strategies, which, of course, are non linear. Jaeger and Wagner (2005) show that returns on hedge fund indices can be replicated by using equally weighted combination of three simple strategies, each targeting a particular risk premia. The portfolio consists of three risk factors: a trend following model on 25 liquid futures markets summarized in what is known as the SGFI index, the BMX index which represents a 'buy write' strategy on the S&P 500; and the CSFB high yield bond index. The authors demonstrate that following the above strategy yields a risk adjusted return that outperforms both the HFR composite index and the HFR Fund of Funds index. The authors conclude that hedge funds generate returns primarily through risk premia and only secondarily through the exploitation of market inefficiencies, that is, through manager skill. They go on to state that based on their results hedge fund fees are not justified. The authors state that investable benchmarks based on risk factor analysis have the potential to offer a valid, theoretically sound, and cheaper alternative to the currently offered hedge fund index products available today.

Ennis and Sebastian (2003) provide evidence against the diversification benefits cited by hedge funds. In this paper, they conclude that the performance of hedge funds over the period of 1994-2002 does not justify their inclusion in diversified portfolios. They claim that this is particularly true in the case of hedge fund of funds. The authors use large cap S&P, small cap (Willshire 4500), non US equities, emerging market, duration and credit

spreads in their analysis. They find that hedge funds produced bond like returns with greater volatility than bonds, but lower than equities. The fees for hedge funds are 5% per year.

The above literature demonstrates that a significant portion of hedge fund returns are due to risk premia and not alpha, and that Hedge Fund returns can be replicated using linear and non linear models. Finally, the literature casts doubt on the diversification benefits of some hedge fund strategies. Taken together, this makes a strong argument for further studying replication approaches. In the current study, I follow the linear approach used by Hasanhodzic and Lo (2006b) because of the ease with which it can be implemented.

5. Strategy Definitions

In this section, I provide brief definitions of the hedge fund strategies discussed in this paper. For more detail on the strategy definitions please see the web site www.hfr.com.

Convertible Arbitrage: involves the purchase of a convertible security, usually convertible bonds, and simultaneously selling short the underlying common stock.

Distressed Securities: seeks to invest in companies that face distress situations, such as bankruptcies, distressed sales and corporate restructurings. Investment is usually in bank debt, corporate debt or warrants.

Emerging Markets: these funds invest in securities of developing countries in Latin America, Africa, Asia, and Eastern Europe.

Equity Hedge: these funds have a core holding of long equities which are hedged with short sales of stock or index options. There are conservative and aggressive funds, so determined by the percentage of their hedged positions.

Equity Market Neutral: managers of these funds attempt to neutralize market risk by combining long and short positions in related securities. For example, a manager may be long stocks he considers strong within a sector and short stocks he considers weak in the same sector.

Equity Non-Hedge: similar to Equity Hedge, but these funds do not always have a hedged positions against their core holdings. Funds can and do hold short positions as opportunities arise.

Event-Driven: funds invest in companies that are going through major events, such as spin offs, merger and acquisitions, bankruptcies and share buybacks. Instruments used are long/short common stock, debt securities, and options.

Fixed Income: or Fixed Income Arbitrage is a market neutral hedging strategy that seeks to profit by exploiting pricing inefficiencies between related fixed income securities while neutralizing exposure to interest rate risk. Fixed Income Arbitrage is a generic description of a variety of strategies involving investment in fixed income instruments, and weighted in an attempt to eliminate or reduce exposure to changes in the yield curve.

Macro: managers of these funds make leveraged bets based on Macro events such as political situations, global demand for resources, currencies et cetera. Instruments include stocks, interest rates, foreign exchange and commodities.

Merger or Risk Arbitrage: these funds seek to invest in event driven situations such as buyouts, mergers, and takeovers. Return is generated, for example, by purchasing the stock of an acquired company and selling short the acquirer.

Sector: managers of these funds specialize in specific sectors. For example, commodities, precious metals, retail, entertainment et cetera.

Short Selling: these funds sell securities they deem over valued. Managers do not own the security they sell, the security is borrowed with the hope that it will decline, at which point the manager purchases the security and returns it to the lender.

Fund of Funds: these funds seek to invest in a variety of hedge funds using different strategies. This is similar to an index approach. There are two layers of fees, one for the hedge fund in which the manager invests, a second fee is charged by the Fund of Funds.

6. Data and Methodology

I use monthly returns on 13 of the 21 indexes of hedge fund strategies reported on by Hedge Fund Research (HFR). These strategies are chosen because they most closely match those used by Hasanhodzic and Lo (2006b). The HFR monthly indexes (HFRI) are equal weighted performance indexes. These indexes are used by hedge fund managers to benchmark their funds. There are 1800 hedge funds that comprise the various indexes. HFR does not reveal names of the funds included in their indexes. The indexes included are those that meet the following criteria.

- Report monthly returns
- Report returns net of all fees
- Report assets in US dollars
- No required minimum asset size
- No minimum time a fund must be actively traded
- Updated three times a month
- Funds remain in the index after closure/liquidation up to the month they last report
- Offshore and domestic funds are included

The sample period is from 1991 – 2005 as data on all variables is available over this sample period. These factors were selected because they represent the risk factors for many of the hedge fund strategies as has been documented in the literature discussed previously. The factors have the added advantage of being traded through liquid,

investable instruments: forward contracts in the case of the US Dollar, futures contracts for the remaining risk factor.

I use a linear combination of the following risk factors in an attempt to replicate hedge fund index returns.

1. S&P 500 total return (SP)
2. Bond: AAA corporate bond total return (B)
3. Credit Spread: BAA – T-Bill (CS)
4. Dow Jones Commodity Index: composed of futures contracts on 9 physical commodities. Weighting is based on liquidity and production. The total return index is used in this paper (CI)
5. US Dollar Index: return on the US Dollar Index provides a general indication of the international value of the US Dollar, similar to the Federal reserve Board's trade weighted index. The weights are Euro .576, Yen .136, Pound .119, CDN\$.091, Swedish Krona .042, Swiss Franc .036 (USDIX)

I first attempt to determine the variation in hedge fund index returns, for the chosen strategies, that can be explained by the risk premia discussed in detail above. This is carried out using an Ordinary Least Squares (OLS) linear regression approach. The regression is carried out using MATLAB software, with the dependent variable being hedge fund index returns, and the independent or explanatory variables being the five risk factors outlined above.

The model is

$$R_{it} = \alpha_i + \beta_{i1} SP_{1t} + \beta_{i2} B_{2t} + \beta_{i3} CS_{3t} + \beta_{i4} CI_{4t} + \beta_{i5} USDX_{5t} + e_{it} \quad (1)$$

From this model we can obtain the expected return and variance:

$$E(R_{it}) = \alpha_i + \beta_{i1} E(SP_{1t}) + \beta_{i2} E(B_{2t}) + \beta_{i3} E(CS_{3t}) + \beta_{i4} E(CI_{4t}) + \beta_{i5} E(USDX_{5t}) \quad (2)$$

From equation (2) it is apparent that there are two sources of expected return: risk premia and alpha, often referred to as excess return or manager alpha. Alpha is commonly used to benchmark manager skill, however, it is more of a catch all term that includes variables (risk factors) missing from the model. In this simple model there are likely some omitted risk factors.

7. Potential Data Issues

There are several major issues with the data used in this study: data aggregation, look-ahead bias, survivorship bias, selection bias and backfilling. The first of these exaggerates the clone returns and is a problem in that the fit seems sufficient over historical data, but when we attempt to apply the model in practice the results may not be as good. The latter three issues tend to exaggerate the returns reported by hedge funds. This makes comparison of hedge fund and clones somewhat unfair and makes alpha seem more prominent than it actually is. I will discuss each of these issues briefly.

Data Aggregation: in the current study, I have used data on returns of hedge fund indexes, which are by definition aggregated. This is in contrast to the Hasanhodzic and Lo (2006b) study where they start with disaggregated data on individual hedge fund returns, and aggregate only as a final step. Data aggregation has the effect of smoothing data and can yield results that appear superior to those obtained using disaggregated data. However, the results obtained in this study are similar to those of Hasanhodzic and Lo (2006b). I conclude that data aggregation is not a significant issue.

Look Ahead Bias: this bias is created because I have used data that would not have been available to investors when they would make their investment decision in practice. This is a major problem in implementing the model discussed in this paper. However, the aim of this paper is to show that hedge fund index returns can be decomposed into the risk factors stated in this paper, among other possibilities. The goal is to demonstrate that a

passive strategy similar to that in the mutual fund world is possible and will likely be implemented in the future. Another fact that tempers this issue is that Hasanhodzic and Lo (2006b) show that the replication strategy works even better when using a rolling window approach. This approach corrects for look ahead bias.

Survivorship bias: The lack of transparency and uniform reporting standards in the hedge fund industry are sources of measurement errors that plague hedge fund performance analysis. The most important of these are the survivorship and the backfilling bias. It has been demonstrated that these effects account for at least 3-4% of the reported hedge fund out-performance (Malkiel and Saha, 2005).

The survivorship bias occurs when unsuccessful managers leave the industry, thus removing unsuccessful funds ex post from the representative index. Only their successful counterparts remain; creating a positive bias. Many hedge fund databases only provide information on currently operating funds, this is the case with Hedge Fund Research whose data is used in this paper, that is funds that have ceased operation are considered irrelevant for the investor and are purged from the database. This leads to an upwards bias in the index performance, since the performance of the disappearing funds is most likely worse than the performance of the surviving funds.

However, the importance of such a bias for our application is reduced by two considerations. First, many successful funds leave the sample as well as the poor performers, reducing the upward bias in expected returns. In fact, Fung and Hsieh (2000) estimate the magnitude of survivorship bias to be 3.00% per year. Second, the focus of my study is on the relative performance of hedge funds versus relatively passive

portfolios of liquid securities, and as long as the cloning process is not selectively applied to a peculiar subset of funds in the HFR database, any survivorship bias should impact both funds and clones identically, leaving their relative performance unaffected.

Backfilling: this is a variation of the survivorship bias and can occur when a new fund is included into the index and his past performance is added or “backfilled” into the database. This creates an upward bias, that is, new managers enter the database only after a period of good performance, when entry seems most attractive. Since fewer managers enter during periods of bad performance, bad performance is rarely backfilled into the averages.

Selection bias: Unlike equity and bond indices, hedge fund index providers rely on hedge fund managers to voluntarily and correctly submit return data on their funds. Hedge fund managers are private investment vehicles and are thus not required to make public disclosure of their activities. Some managers refuse to submit data to any index providers. This “self-selection bias” causes significant distortions in the construction of the index and often skews the index towards a certain set of managers and strategies on a going forward basis. Again, managers that are performing well are more likely to report, creating an upward bias.

8. Results

As can be seen from the R-square values in Table II, a significant amount of variation in hedge fund index returns is explained using the five risk factors (S&P, Bond, Credit Spread, Commodities, and USDX) as evidence by the high R-square values. The R-square values range from a low of 12 percent for fixed income funds to a high of 63 percent for Equity Non Hedge funds. Most other fund clones are in the range of forty to fifty percent. The R-square for the clones is 37 percent, this compares to 18.9 obtained by Hasanhodzic and Lo (2006b). The reason for this discrepancy is likely data aggregation. In the current paper, I have used data on hedge fund indexes, whereas Hasanhodzic and Lo use data on individual funds and aggregate as a final step. That said, the high R-square values suggest that the relationship between the various hedge fund strategies and the five risk factors is linear.

I now investigate the error terms to determine if there is significant autocorrelation before proceeding with the model. The Durbin-Watson statistics shown in Table II are all close to two, with the majority being between 1.7 and 2.0. We can conclude that there is no significant autocorrelation.

As a final check on the model, I examine the p-values for the risk factor coefficients (Betas) for significance at the 95 percent level. As Table II shows most of the p-values are significant at this level. There are two interesting observations. First, I note that there is only one significant p-value for alpha – manager skill. This implies that hedge

fund index returns are likely due to factors other than alpha. Second, I have obtained far more significant p-values at the 95 percent level in this paper than those obtained by Hasanhodzic and Lo (2006b).

Given the fact we have high R-square, no significant autocorrelation, and significant p-values, it is possible to continue to next step in my analysis. I will now use equation (2) to decompose the hedge fund index returns by the five risk factors. The results are shown in Table III. As this table demonstrates the percentage return attributed to alpha is significant for all hedge fund strategies, they range from 56 to 112. Although alpha is sometimes used as a proxy for managerial skill, this is not necessarily the case. In fact, alpha is really a catch all term that stands not only for the managerial skill but for all variables missing from the model. The model is very simple and it is likely that there are some omitted risk factors given that I am attempting to replicate hedge fund strategies that are complex and dynamic. Keeping this in mind, the expected return due to the risk factors is on average 25 percent which is close to the 30 percent found by Hasanhodzic and Lo (2006b). The expected return from the risk factors ranges from zero for Short Selling funds to 52 percent for Emerging Market Funds. I conclude that the current risk factors are sufficient and account for ample expected return of hedge funds to be used as a proxy, that is, as clones for hedge fund strategies.

Table 2. Results of Multivariate Linear Regression

Fund Strategy	Intercept	S&P	Bonds	Credit Spread	Commodities	USDX	R-square	Durbin Watson
Convertible Arbitrage	1.15 (0.12)	-1.03 (0.0)	2.48 (0.0)	-0.41 (0.56)	-0.08 (0.26)	0.0 (0.54)	0.48	1.86
Distressed	-1.46 (0.10)	0.17 (0.0)	2.33 (0.08)	3.54 (0.0)	0.06 (0.09)	0.12 (0.01)	0.25	1.79
Emerging Markets	-2.89 (0.12)	0.58 (0.0)	0.91 (0.75)	9.70 (0.0)	0.18 (0.01)	0.29 (0.01)	0.42	1.30
Equity Hedge	-0.45 (0.67)	0.41 (0.0)	3.10 (0.06)	-0.99 (0.43)	0.11 (0.0)	0.07 (0.24)	0.49	1.77
Market Neutral	-0.16 (0.74)	0.03 (0.05)	2.53 (0.0)	-1.91 (0.0)	0.02 (0.39)	-0.03 (.34)	0.14	2.09
Equity Non Hedge	-1.85 (0.20)	0.75 (0.0)	2.72 (0.22)	3.27 (0.06)	0.13 (0.02)	0.11 (0.17)	0.63	1.77
Event Driven	-0.20 (0.80)	0.27 (0.0)	1.65 (0.18)	0.71 (0.44)	0.07 (0.01)	0.08 (0.06)	0.44	1.69
Fixed Income	-1.89 (0.0)	-0.01 (0.67)	2.89 (0.0)	2.51 (0.0)	0.04 (0.1)	0.10 (0.0)	0.12	1.40
Fund of Funds	-0.19 (0.81)	0.19 (0.0)	0.89 (0.47)	0.78 (0.41)	0.09 (0.0)	0.12 (0.0)	0.31	1.40
Macro	-2.34 (0.07)	0.20 (0.0)	4.27 (0.03)	2.67 (0.07)	0.14 (0.0)	0.16 (0.02)	0.21	1.58
Merger Arbitrage	-0.02 (0.97)	0.10 (0.0)	2.49 (0.0)	-1.99 (0.0)	0.05 (0.0)	0.02 (0.53)	0.31	1.97
Sector	-1.84 (0.30)	0.60 (0.0)	3.77 (0.16)	1.72 (0.40)	0.19 (0.0)	0.03 (0.78)	0.43	1.73
Short Selling	1.16 (0.65)	-1.03 (0.0)	2.60 (0.51)	-5.18 (0.09)	-0.09 (0.35)	-0.08 (0.56)	0.49	1.89

Notes: The table shows regression coefficients and their p-values in brackets. It also shows R-square values and the Durbin-Watson statistic for each hedge fund strategy being replicated.

Table 3. Expected Returns of Risk Factors

Fund	Intercept	S&P	Bonds	Credit	Commodities	USDX
Convertible	93.64	-9.15	17.47	1.66	-0.29	0.0
Distressed	67.58	1.48	16.39	14.28	0.20	0.07
Emerging	48.44	5.18	6.43	39.12	0.64	0.17
Equity Hedge	78.13	3.60	21.82	3.99	0.40	0.04
Market	89.59	0.28	17.80	7.71	0.06	-0.02
Equity Non	60.46	6.69	19.14	13.18	0.46	0.06
Event Driven	82.78	2.42	11.62	2.86	0.26	0.05
Fixed Income	69.35	0.08	20.37	10.14	0.15	0.06
Fund of	88.50	1.72	6.24	3.13	0.33	0.07
Macro	56.76	1.78	30.06	10.79	0.52	0.10
Merger	89.39	0.90	17.53	-8.03	0.19	0.01
Sector	60.55	5.28	26.52	6.94	0.69	0.02
Short Selling	112.11	-9.15	18.32	-20.91	-0.32	-0.05

Notes: The table shows expected returns for each strategy being replicated. The calculations are carried out as follows. First, the beta value from Table II for each risk factor is multiplied by the expected (average) return for that risk factor; this gives the expected annualized return for that risk factor. Second, I sum the expected returns from each of the five risk factors, obtaining the total expected return from all risk factors. Finally, the expected return from alpha is calculated by subtracting the total expected return from all risk factors from one hundred. All returns are annualized.

Rolling Window Approach

Following the rolling window approach in Berkowitz and O'Brien (2007), I investigate the possibility of improving clone returns by varying risk factor coefficients (Betas) over time. That is, are the betas constant or do they vary over time?

First, using MATLAB I regress hedge fund index returns on the five risk factors as before, but this time using data for the first five years only (1991-1995). The rolling window, therefore, is five years. The regression equation is re-estimated every six months, dropping the last six months and adding data six months forward. The results

are shown in Table IV and graphically in Figure 1. The figure displays the results for one of the clones (Convertible Arbitrage) which represents the typical case. All other clones had similar results. This figure clearly demonstrates that the betas for Bonds and Credit Spreads are not constant over time. Betas for the remaining risk factors also display some variability, but it is not as pronounced. The results suggest that it will be of some benefit, that is, the returns of clones, can be improved by varying betas, especially of Bonds and Credit Spreads over time. This re-balancing aspect should be considered in future attempts to replicate hedge fund index returns. However, we should be mindful that the idea is to passively manage portfolios and, thereby, offer cloned products at a reduced cost.

9. Building Clones

The results of the previous section suggest that hedge fund index returns can be replicated. That is the R-square values are high and the expected return from the five risk factors is sufficient for me to continue to the next step. I now build a fixed weight portfolio consisting of the five risk factors. I will use the dataset as before to obtain the weights. The model will be modified from (1) and is as follows.

$$R_{it} = \beta_{i1} SP_t + \beta_{i2} B_t + \beta_{i3} CS_t + \beta_{i4} CI_t + \beta_{i5} USDX_t + e_{it} \quad (3)$$

$$t = 1 \dots T$$

Subject to:

$$1 = \beta_{i1} + \beta_{i2} + \beta_{i3} + \beta_{i4} + \beta_{i5} \quad (4)$$

The next step is to run an Ordinary Least Squares regression on the models outlined in equations 2 and 3, again using the MATLAB software. This is the same model as in the previous section with two exceptions. First, we add the constraint that the sum of the regression coefficients (that is, coefficients of the risk factors) be restricted to one. This will allow me to interpret the resulting coefficients as portfolio weights. I implement this constraint in MATLAB using the function `fmincon`. This function allows me to input the above constraint and carry out the linear regression as previously. Note that I do not restrict the weights to be positive as short sales are possible in my model; they are, in fact, necessary for fund strategies such as Short Selling.

Table 4. Summary Statistics for Rolling Window Regression

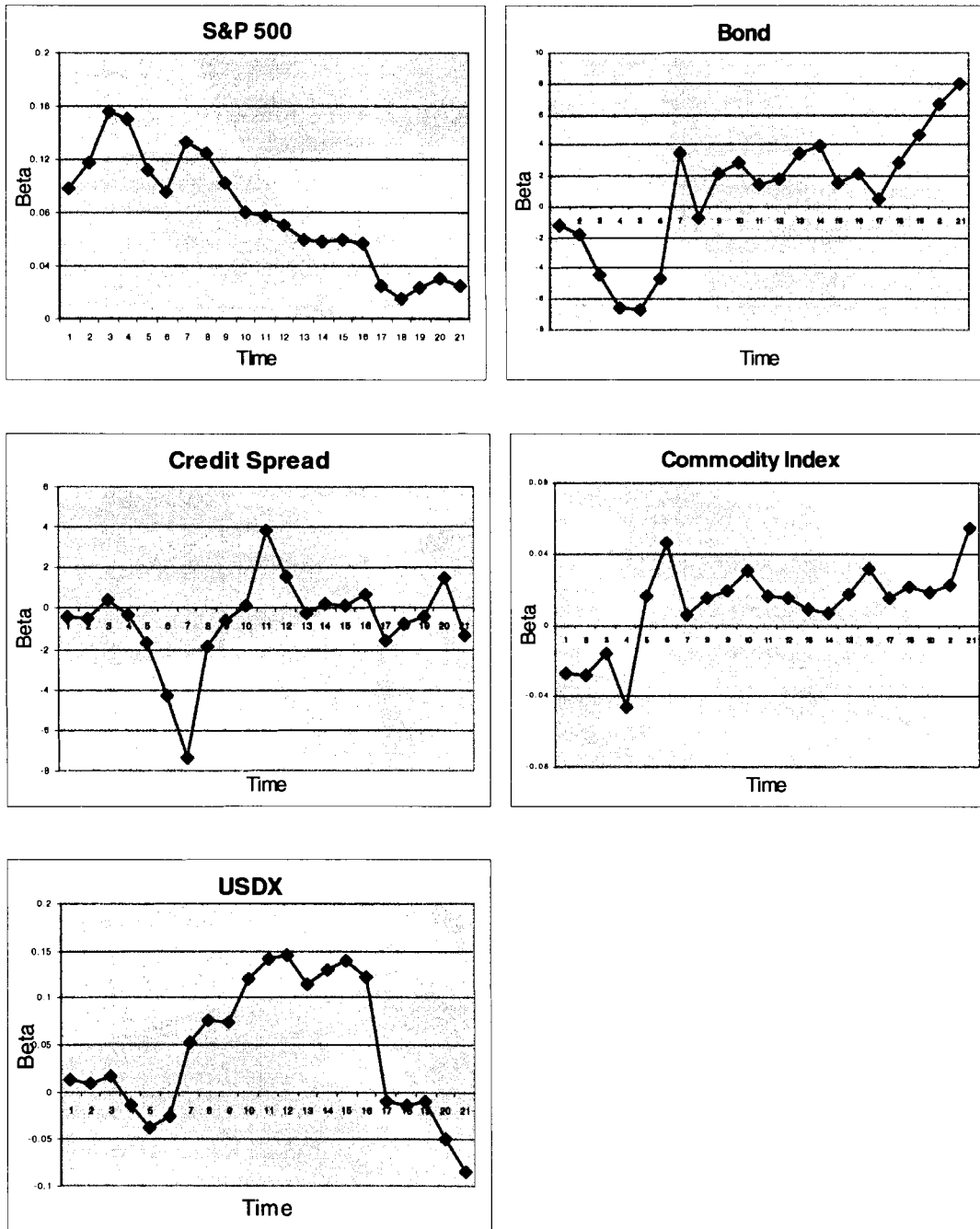
Fund Strategy	Betas: Mean/Standard Deviation				
	S&P	Bond	Credit	Commodities	USDX
Convertible Arbitrage	0.058 / 2.52	0.08 / 0.04	0.91 / 4	-0.62 / 2.2	0.04 / 0.07
Distressed	0.017 / 0.04	-0.36 / 6.99	2.61 / 3.30	0.04 / 0.06	0.07 / 0.12
Emerging Markets	0.58 / 0.1	-1.82 / 19.03	19.39 / 15.48	0.09 / 0.10	0.33 / 0.24
Equity Hedge	0.4 / 0.03	-3.67 / 4.36	0.43 / 3.87	0.11 / 0.06	-0.02 / 0.09
Market Neutral	0.04 / 0.05	3.0 / 4.56	-3.14 / 2.20	0.0 / 0.03	-0.06 / 0.03
Equity Non Hedge	0.74 / 0.03	-1.50 / 4.47	5.36 / 5.70	0.11 / 0.06	-0.03 / 0.14
Event Driven	0.27 / 0.03	-2.32 / 5.81	1.08 / 3.75	0.06 / 0.04	0.05 / 0.08
Fixed Income	-0.03 / 0.04	3.41 / 6.50	1 / 2.81	0.04 / 0.03	0.10 / 0.11
Fund of Funds	0.21 / 0.06	0.17 / 7.33	1.72 / 2.89	0.09 / 0.04	0.14 / 0.14
Macro	0.24 / 0.17	-2.91 / 6.14	-1.45 / 8.05	0.15 / 0.05	0.17 / 0.27
Merger Arbitrage	0.10 / 0.05	-0.12 / 4.14	-1.27 / 1.97	0.03 / 0.03	-0.01 / 0.04
Sector	0.58 / 0.07	-2.12 / 7.38	6.39 / 8.60	0.20 / 0.10	-0.03 / 0.12
Short Selling	-1.05 / 0.11	2.96 / 6.78	-9.33 / 8.70	-0.04 / 0.18	0.11 / 0.27

Notes: Table shows the mean value for each beta and its standard deviation.

The second difference in this model is that I drop the intercept (alpha) term from the model. This forces the regression to fit the data using only the five risk factors leaving out “managerial” skill since we are pursuing a passive strategy.

The results of the new model are displayed in Table V. I make the following observations from the table. The largest weights on average are placed on the S&P, Bond and Credit Spread risk factors. The weights are as expected, for example, the largest weight on the S&P risk factor are placed in the Equity Non Hedge funds with a weight of 0.74 and Short Selling with a weight of -1.0.

Figure 1. Rolling Window Regression – Time Variation in Betas of Risk Factors



Notes: graphs show the variation over time of the Betas, from the Rolling Window regression, of each risk factor. The range is widest for the Bond and Credit Spread Betas, suggesting rebalancing is a possibility.

Table 5. Results of Multivariate Linear Regression – Cloned Funds

Fund Strategy	S&P	Bonds	Credit Spread	Commodities	USDX	Tracking Error Mean	Tracking Error SD
Convertible Arbitrage	0.06	1.94	-1.03	0.02	0.01	0.00	3.22
Distressed	0.16	2.44	-1.71	0.05	0.06	3.00	5.44
Emerging Markets	0.56	1.47	-1.36	0.18	0.16	6.36	11.71
Equity Hedge	0.40	3.22	-2.78	0.11	0.05	1.08	6.27
Market Neutral	0.03	1.72	-0.75	0.02	-0.01	-0.96	2.98
Equity Non Hedge	0.74	2.32	-2.24	0.13	0.05	3.00	8.63
Event Driven	0.27	2.59	-1.98	0.07	0.05	1.80	4.71
Fixed Income	-0.02	1.11	-0.21	0.04	0.08	0.96	4.16
Fund of Funds	0.19	1.23	-0.62	0.09	0.10	0.96	4.71
Macro	0.19	2.80	-2.23	0.14	0.11	2.28	7.59
Merger Arbitrage	0.05	2.14	-1.32	0.05	0.03	-0.48	3.01
Sector	0.59	2.81	-2.57	0.19	-0.02	2.04	10.29
Short Selling	-1.02	1.95	0.18	-0.09	-0.02	-3.24	15.00

Notes: Table shows the coefficient values for the cloned funds from equations 3 and 4 - model with no intercept. The table also shows the annualized Mean and Standard Deviation of the Tracking Error for the period 1991-2005.

Table V also shows the Tracking Error for each fund strategy. These errors are small, on average approximately 1.3%, annualized. As expected, the Tracking errors are highest for the fund strategies that are most volatile, specifically, Emerging Markets and Short Selling.

Table VI shows the annualized mean returns and standard deviations for each cloned fund in my study. The replication strategy has produced some very interesting results. In general, we see that the returns produced by investing in the risk factors are very close to the actual hedge fund strategy I attempt to replicate, with standard deviation generally lower for the cloned funds.

Table 6. Performance Statistics of Cloned Funds

Fund Strategy	Mean	Standard Deviation	Sharpe Ratio
Convertible Arbitrage	10.09	1.18	8.57
Distressed	11.87	2.64	4.50
Emerging Markets	10.52	8.47	1.24
Equity Hedge	15.43	6.19	2.49
Market Neutral	9.38	0.79	11.83
Equity Non Hedge	14.41	10.81	1.33
Event Driven	12.93	4.16	3.10
Fixed Income	7.00	0.84	8.34
Fund of Funds	8.28	3.13	2.65
Macro	12.92	3.60	3.58
Merger Arbitrage	10.87	1.87	5.81
Sector	15.28	8.89	1.72
Short Selling	5.06	14.47	0.35

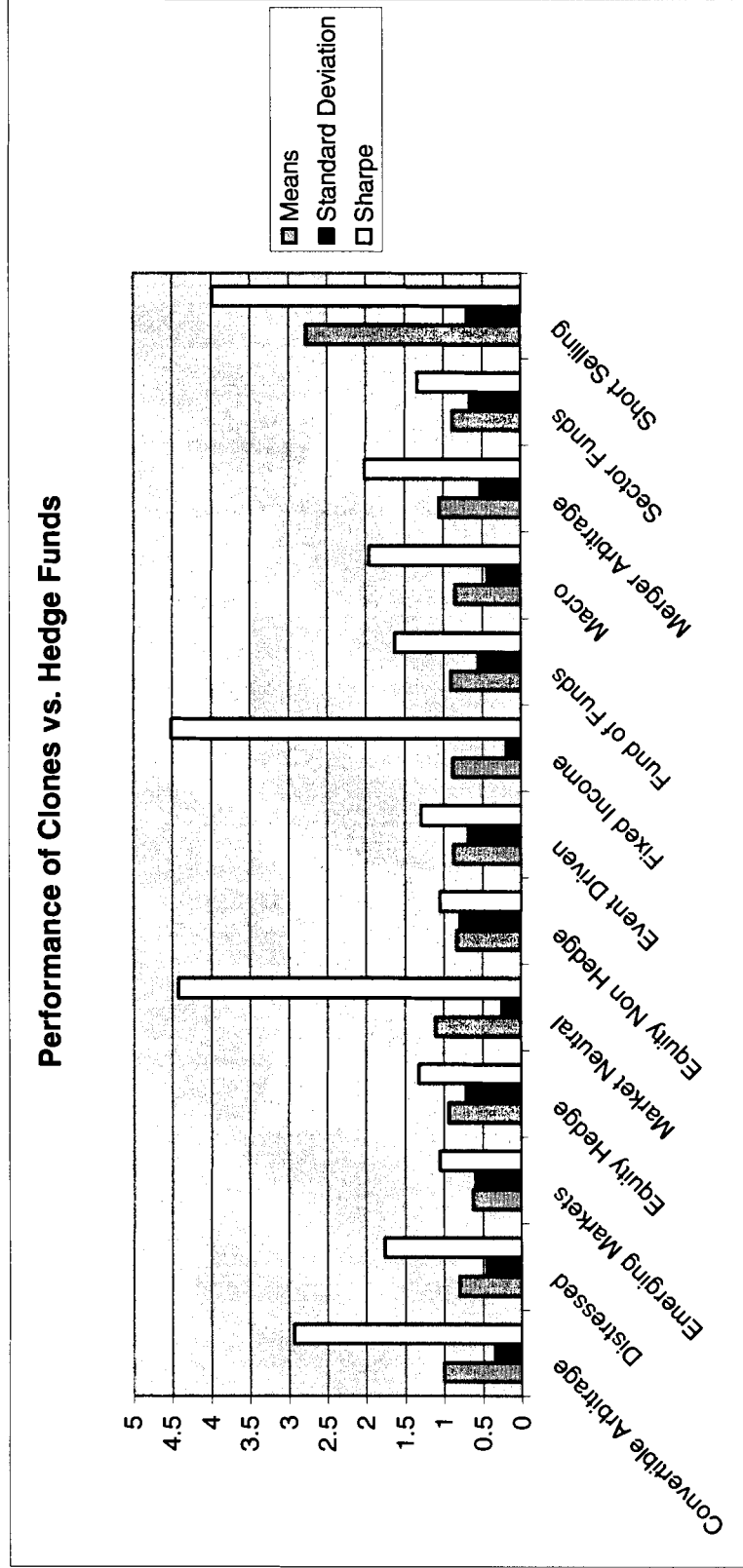
Notes: All values are annualized. Data is for the period 1991-2005.

Despite the above qualification which must be kept in mind, the results in Table VI demonstrate that the chosen risk factors are very successful in replicating the various

hedge fund strategies. In three cases the cloned funds actually outperformed (annualized returns) hedge fund strategies on both a risk adjusted and raw basis. The three strategies were Market Neutral, Merger Arbitrage, and Short Selling hedge funds. Clones outperformed Market Neutral funds by nearly one percent annualized; Merger Arbitrage by .48 percent; and Short Selling funds by over three percent. In each of the above cases the standard deviation of the cloned funds is also significantly lower relative to the actual hedge fund.

For the remaining ten fund strategies, hedge funds outperformed their clones. Hedge fund out performance ranged from less than one percent for Convertible Arbitrage funds to over six percent for Emerging Market funds. However, on a risk adjusted basis, using the Sharpe ratio, none of the hedge funds outperformed their clones. This is demonstrated in Figure 2 which shows the ratios of mean, standard deviation, and Sharpe ratio of clones versus hedge funds. This figure makes clear the out-performance of clones. However, some care must be exercised in interpreting these results, especially the data issues already discussed, in particular look-ahead bias.

Figure 2. Ratio of Clones to Hedge Funds



Notes: Figure demonstrates the out-performance achieved by the clones. Sharpe ratios of clones are far superior.

10. Conclusion

As institutions, such as pension funds, search for ways to boost their portfolio returns they have become increasingly interested in alternative investment vehicles such as hedge funds. This trend is likely to continue. Large institutions have discovered that they need to expose themselves to risk factors offered by hedge funds: liquidity, tail, and credit risks. These risks are not always accessible in the wider equity markets. The growth rates experienced by hedge funds due to the institutional investing have increased competition among fund managers, and it has become increasingly difficult for the average fund manager to outperform their benchmark after fees. For this reason, and others already discussed such as high fee structures already discussed, many investors will be better off investing in a passive investment strategy that attempts to replicate hedge fund index returns but with lower fees.

This study has shown that replication of hedge fund strategies is a real possibility. The cloning or re-engineering approach followed in this paper is similar to Sharpe's (1992) stylistic approach. The rationale for following this approach is that the growth in the hedge fund industry parallels that of the growth in the mutual fund industry. Since the passive investment approach has been successful in the mutual fund industry it is worth investigating for the hedge fund industry.

I have shown that clone portfolios produce returns that are comparable on a raw basis and very attractive on a risk adjusted basis, in fact superior to those of hedge funds. Although, the results of the paper are impressive there are several qualifications that must be considered before drawing any conclusions. First, the fixed weight clones suffer from look ahead bias and the cloning approach, although impressive over historical data, may not achieve similar results in practice. Second, several authors including Agarwal and Naik (2004) have shown that hedge fund returns exhibit non linear properties similar to options. This suggests that a linear approach such as the one followed here may not be appropriate going forward. The current approach was chosen as a compromise between simplicity of application and best fit. Finally, transaction costs were not incorporated into the reported returns for the clone portfolios, while hedge fund returns are reported net of fees. The idea here is that fees for passive funds would be low and can be neglected.

The model can be improved in several ways. First, I have used only a subset of the myriad liquid instruments available to investors. The model can surely be improved by adding derivative instruments such as options, which have non-linear returns, as demonstrated in the literature, for example, by Agarwal and Naik (2004). Second, many hedge funds now invest in Emerging Markets, therefore it would be interesting to add such an index or indexes to the model. Third, a time varying or rebalancing aspect can be added to this model. As we have seen the Betas for Bonds and Credit Spreads vary significantly over time. Taking advantage of this variation can help improve fit and clone returns. Finally, a volatility component such as the VIX can be added to the model in order to capture the volatility premium.

Despite the above qualifications, this paper has demonstrated that we can identify common risk factors from which hedge funds derive some (not all) of their expected return. By investing in these risk factors investors can earn risk premia similar to that of hedge funds, and they can do so at a lower cost and added liquidity

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