Survival, Look-Ahead Bias and the Persistence in Hedge Fund Performance*

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Abstract

In this paper we analyze the persistence in the performance of hedge funds taking into account look-ahead bias (multi-period sampling bias). To do so, we model liquidation of hedge funds and analyze how it depends upon historical performance. Next, we use a weighting procedure that eliminates look-ahead bias in measures for performance persistence. In contrast to earlier results for mutual funds, the impact of look-ahead bias is exacerbated for hedge funds due to their greater level of total risk. At the four quarter horizon, look-ahead bias can be as large as 3.8%, depending upon the decile of the distribution. At the quarterly level, we find positive persistence in hedge fund returns, also after correcting for investment style. The empirical pattern at the annual level is also consistent with positive persistence, but its statistical significance is weak.

Jel-codes: G11, G12, G23

1 Introduction

During the last decade, hedge funds have gained tremendous popularity, particularly in the USA. Hedge funds are similar to mutual funds in that they provide actively managed portfolios in publicly traded assets. Unlike mutual funds however, they have a broad flexibility in the type of securities they hold and the type of positions they take. They can invest in international and domestic equities and debt, and the entire array of derivative securities. They may take undiversified positions, sell short and lever up the portfolio (see, e.g., Fung and Hsieh, 1997, Liang, 2000). According to Brown and Goetzmann (2001), hedge funds are best defined by their freedom from regulatory controls stipulated by the Investment Company Act of 1940. Especially these non-standard features make hedge funds an interesting investment alternative with potential diversification benefits for the existing portfolio.

The question whether mutual funds and hedge funds show persistence in their performance receives much attention in the literature (see, e.g. Gruber, 1996, Carhart, 1997, Agarwal and Naik, 2000, Boyson, 2003, Bollen and Busse, 2004). The underlying idea behind these studies is that investors usually invest more in funds that recently performed well in the expectation that these funds will continue to do so in the future. In the mutual fund literature it is commonly found that the well performing funds attract much larger money-flows than badly performing funds (see, e.g. Sirri and Tufano,

1998). A recent paper of Agarwal, Daniel and Naik (2003) reports similar findings for the hedge fund industry. Apparently, it is also the case in the hedge fund industry that money-flows chase recent performance. Although the evidence is somewhat ambiguous, the majority of empirical studies concerning mutual funds show that active selection, on average, underperforms passive investment strategies. As argued by Berk and Green (2004), the absence of persistence in mutual fund returns might be due to the fact that persistence in returns is competed away by mutual fund investors rationally shifting their capital in search of superior investments. For hedge funds, however, there are substantial hurdles to the quick and cheap movements of capital. Hedge fund investors are often confronted with lockup periods, that may be as long as one year, during which the invested money cannot be withdrawn. Moreover, many funds apply a redemption notice period of up to 90 days. Therefore, one might expect to see more persistence for hedge funds than for mutual funds.

A major problem in evaluating hedge fund performance and its persistence is the relatively high attrition rate. For example, Brown, Goetzmann and Ibbotson (1999) report an attrition rate of about 14% per year over 1987-1996. If fund survival (directly or indirectly) depends upon historical performance, it is well known that standard methods of analysis may lead to biased results (see, e.g. Brown et al., 1992, Carpenter and Lynch, 1999, or ter Horst, Nijman and Verbeek, 2001). Spurious persistence patterns may arise, the form of which depends upon the survival process and the underlying het-

erogeneity in fund characteristics. While most studies attempt to eliminate survivorship bias by taking fund returns into account until the moment of disappearance, a second ex-post conditioning bias, the so-called look-ahead bias, is usually not accounted for. This bias arises because the employed methodology implicitly or explicitly conditions upon survival over a number of consecutive periods. When analyzing performance persistence, for example, the fact that funds dissolve in a nonrandom way during the ranking or evaluation period may cause a bias (see e.g. Brown et al., 1992, or Carhart, 1997). As stressed by ter Horst, Nijman and Verbeek (2001), the elimination of look-ahead bias requires that the methodology be adjusted. An essential step in the correction procedure (see Brown, Goetzmann and Ross, 1995) is to model the survival process of hedge funds and how it relates to their (historical) performance.

As noted by Fung and Hsieh (1997, 2000) and Liang (2000), practical problems may complicate this issue. Because the hedge fund industry is highly unregulated, and data sets may be subject to backfilling biases, a careful analysis is required. A wide range of empirical problems need to be taken into account in order to prevent biased results (see, e.g. Fung and Hsieh, 1997, Ackermann, McEnally and Ravenscraft, 1999, Agarwal and Naik 2000). One of these potential biases is a self-selection bias that arises due to the fact that hedge funds voluntarily report to a data vendor. Since hedge funds are not allowed to advertise publicly, these data vendors serve as an important distribution channel. Thus, self-selection bias exists either because

underperfomers do not wish to make their performance known, because funds that performed well have less incentive to report to data vendors to attract potential investors, or because funds do not wish intervention in case SEC interprets reporting as illegal advertising. Therefore, in contrast to mutual funds, where fund attrition is usually related to bad performance, hedge funds disappear from a database because of various reasons. Examples are that the fund is liquidated, that it is closed to new investments, or that the manager voluntarily decides to stop reporting. Out of these reasons, liquidation is the relevant event related to the issue of survival. In our analysis, we focus on the case where death is due to liquidation, as opposed to the case where the fund continues to exist but stops reporting to the database vendor. Empirically, about two thirds of hedge fund attrition can be attributed to liquidation.

In this paper we study liquidation, look-ahead bias and the persistence in the performance of hedge funds that report returns in US$ over the period 1994-2000. The contributions of this paper are threefold. First and most importantly, we find that, compared to the mutual fund literature, look-ahead bias for hedge funds is quite severe, especially at one-year horizons and for funds with high attrition rates. Ignoring look-ahead bias, average returns may be overestimated by as much as 3.8% per year. In contrast, ter Horst, Nijman and Verbeek (2001), studying persistence in performance of 'growth' and 'income' mutual funds, report only slightly different estimates after correcting for look-ahead bias. These findings show that the impact of look-ahead bias in persistence estimates is much larger for hedge funds than

it is for mutual funds. Apparently, it is the case that due to the greater total risk of hedge funds over their mutual fund counterparts, look-ahead bias is exacerbated. This is consistent with Brown, Goetzmann and Ross (1995) who document the precise relationship between total volatility and return in a survival conditioned sample. Second, we extend the previous literature on hedge fund attrition, by modelling the liquidation process allowing for a flexible impact of historical returns, by incorporating fund size as well as aggregate time effects to capture economy-wide shocks that affect liquidation rates of all hedge funds, and by testing for potential sources of misspecification. Our model for hedge fund liquidation provides an alternative for the model of Brown, Goetzmann, and Park (2001), who explain survival from style-adjusted returns, the age of the fund, a measure for relative performance (i.e. the alpha), absolute performance, style adjusted return risk and a time trend. Finally, we investigate persistence in hedge fund performance with and without correcting for look-ahead bias using the methodology of ter Horst, Nijman and Verbeek (2001). We conclude that correcting for look-ahead bias increases the difference in average returns of the top and bottom deciles at the annual horizon. Nevertheless, we only find a statistically significant positive persistence pattern at the one-quarter horizon, no matter whether the corrected or uncorrected method is used. This corresponds to the findings of Agarwal and Naik (2000).

The remainder of this paper is organized as follows. In Section 2 we describe the sample of hedge funds that we employ and describe the potential

biases that could arise. In Section 3 we model the liquidation process of hedge funds. Section 4 examines persistence in performance for a sample of hedge funds over the period 1994 - 2000, taking into account the potential biases that might be present, and we briefly discuss the robustness of our results. Finally, Section 5 concludes.

2 Hedge funds data

Hedge funds seek to deliver high absolute returns and typically have features such as hurdle rates and incentive fees with high watermark provision. Investors in hedge funds are often confronted with lockup periods and redemption notice periods. Such restrictions on withdrawals imply smaller cash fluctuations, and give fund managers more freedom in setting up long-term or illiquid positions. However, investors that follow an active selection strategy of investing in funds that recently performed well might be negatively affected by this lockup period.

As mentioned above, U.S. based (onshore) hedge funds are free from regulatory controls stipulated by the Investment Company Act of 1940. Since 1996 the number of U.S. investors allowed in unregulated funds is 500. Moreover, domestic hedge funds can accept money from "qualified investors", who have at least $5 million to invest and have "sophisticated understanding" of financial markets. In addition they can accept money from pension funds that have at least $25 million in capital. A distinction is made between on-

shore and offshore funds, where the latter type of funds is typically developed to raise capital from non-US investors. Offshore hedge funds are non-U.S. corporations, typically registered in a tax-haven and as such they are not regulated by the SEC. While the number of net worth investors is unlimited, participation from U.S. investors is still restricted.

These distinctive features, particularly the low level of regulation and the long lockup periods, give hedge funds large flexibility in the types of positions they can take, by using short selling, leverage and derivatives. It allows them to have a dynamic position by holding diverse asset categories and moving quickly across them. Besides lack of regulation, strong managerial incentives constitute a second important feature characterizing this industry. Such incentives are largely based on performance. On average, fund managers receive around 20% of annual profits, as well as an annual management fee of about 1%. There is no incentive fee until the fund has recovered past losses (i.e. returns have to surpass a threshold or "high water-mark"). This incentive structure could lead to excessive risk taking, although this is often dampened by a substantial managerial investment in the fund and the fact that managers may incur in liabilities as general partners.

In this paper we use hedge fund data from TASS Management Limited. In principle, the TASS database goes back to 1979, although the initial years typically contain very few funds. By the beginning of the 1990s, about 200 funds were in the database. The fact that by 1998 more than 1400 active funds are available illustrates the increased importance of the hedge fund in-

dustry. Information on defunct funds is available only for funds that attrited in 1994 or later. For the empirical results we shall therefore concentrate on the period 1994-2000. Because our interest lies in persistence at horizons of at least one quarter, we aggregate all information to quarterly levels. This has the advantage of reducing the impact of return smoothing due to the possibility that a hedge fund invests in securities that are not actively traded (see Getmansky, Lo and Makarov, 2004).

During the sample period 612 hedge funds disappear from the sample. Using additional information provided in the TASS database, we classify these cases into 'liquidation' and 'self-selection'. This latter category refers to cases where the fund continues to exist but stops reporting to TASS. When it is mentioned that the fund stopped reporting because of one of the following reasons 'closed to new investors', 'at fund manager request', or 'fund matured', we consider it as self-selection. This is the case for 219 hedge funds. For 316 funds TASS reports that the fund is liquidated. However, for 77 hedge funds the reason is unknown. In order to make an assessment of the death reason for the funds where the disappearance reason is unknown, we estimate quarterly money flows according to the procedure mentioned in Agarwal, Daniel and Naik (2003). We aggregate these money flows over the four quarters preceding the disappearance. If this final year money flow is negative, we classify the fund as liquidated, while otherwise it is considered as self-selected. In this way, 49 of the remaining cases were classified as being liquidated, while 28 funds were considered as self-selected.

Below we shall focus on hedge funds reporting returns in US$. This results in a total of 1797 funds, of which 1185 are active in the first quarter of 2000. This corresponds with an average annual attrition rate of 8.6% from 1994 to 2000[1], very close to the rate of 8.3% that was reported for 1994-1998 by Liang (2000) (using a similar data set). However, recall that attrition is caused by both self-selection and fund liquidation, while liquidation is the relevant event related to the issue of survival. Table 1 provides detailed information on the numbers of funds that enter, are liquidated or are self-selected in our data set in each quarter. For example, in the first quarter of 1997, 69 funds enter the sample, while 20 funds are liquidated and 10 funds are self-selected. Given that 1069 funds were present at the beginning of the quarter, this corresponds to an attrition rate of 2.81% and a liquidation rate of 1.87%.

In Table 2 we provide average quarterly returns for different subsets of funds, as well as the returns on the S&P 500 index. The column labelled 'all funds' refers to all funds that were present in a given quarter, the column labelled 'active' refers to funds that are still active in the first quarter of 2000, and the column labelled 'non-liquidated' refers to all funds that were present in a certain quarter and have not been liquidated (but may have stopped reporting) during the sample period. Finally, the column labelled 'liquidated' refers to funds that had left the database by the end of the

[1]The average annual attrition rate is computed as four times the (unweighted) average quarterly attrition rate.

Quarter	Funds entering	existing	liquidated	self-selected	attrition rate	liquidation rate
1994-I	50	577	0	0	0.00	0.00
1994-II	38	627	0	0	0.00	0.00
1994-III	60	665	0	2	0.30	0.00
1994-IV	55	723	4	1	0.69	0.55
1995-I	64	773	3	0	0.39	0.39
1995-II	47	834	3	11	1.68	0.36
1995-III	52	867	10	4	1.61	1.15
1995-IV	53	905	9	1	1.10	0.99
1996-I	67	948	15	3	1.90	1.58
1996-II	51	997	17	6	2.31	1.71
1996-III	63	1025	17	17	3.32	1.66
1996-IV	44	1054	21	8	2.75	1.99
1997-I	69	1069	20	10	2.81	1.87
1997-II	56	1108	16	10	2.35	1.44
1997-III	65	1138	15	13	2.46	1.32
1997-IV	46	1175	11	6	1.45	0.94
1998-I	68	1204	12	15	2.24	1.00
1998-II	41	1245	20	11	2.49	1.61
1998-III	57	1255	24	34	4.62	1.91
1998-IV	32	1254	19	19	3.03	1.52
1999-I	49	1248	15	12	2.16	1.20
1999-II	26	1270	17	23	3.15	1.34
1999-III	34	1256	25	20	3.58	1.99
1999-IV	13	1245	39	13	4.18	3.13
2000-I	20	1206	33	8	3.40	2.74
overall			365	247	2.16	1.30

Table 1: Quarterly numbers of US hedge funds in the TASS database that enter, liquidate or self-select (stop reporting) during the sample period 1994-2000

Quarter	**all funds**	**active funds**	**non-liquidated**	**liquidated**	**S&P 500**
1994-I	-0.018	-0.015	-0.016	-0.024	-0.035
1994-II	0.011	0.009	0.009	0.018	0.008
1994-III	0.017	0.026	0.024	-0.004	0.042
1994-IV	-0.011	-0.010	-0.011	-0.013	0.002
1995-I	0.034	0.040	0.038	0.020	0.100
1995-II	0.041	0.054	0.050	0.010	0.097
1995-III	0.039	0.049	0.047	0.014	0.069
1995-IV	0.041	0.042	0.039	0.050	0.065
1996-I	0.031	0.036	0.036	0.014	0.067
1996-II	0.060	0.063	0.067	0.033	0.040
1996-III	0.019	0.024	0.022	0.007	0.025
1996-IV	0.057	0.066	0.063	0.032	0.081
1997-I	0.045	0.046	0.046	0.042	0.030
1997-II	0.051	0.054	0.055	0.033	0.178
1997-III	0.075	0.080	0.077	0.065	0.077
1997-IV	-0.010	-0.004	-0.007	-0.024	0.020
1998-I	0.048	0.058	0.055	0.010	0.146
1998-II	-0.012	-0.006	-0.011	-0.020	0.040
1998-III	-0.049	-0.049	-0.048	-0.059	-0.138
1998-IV	0.051	0.061	0.057	0.000	0.251
1999-I	0.031	0.039	0.037	-0.022	0.056
1999-II	0.078	0.086	0.084	0.015	0.071
1999-III	0.005	0.007	0.006	-0.007	-0.068
1999-IV	0.129	0.136	0.135	0.002	0.138
2000-I	0.060	0.063	0.063	-0.065	0.038
overall	0.033	0.038	0.037	0.005	0.056

Table 2: Average quarterly returns of US hedge funds 1994-2000. The column labelled 'all funds' refers to all funds that were present in a certain quarter, the column labelled 'active' refers to funds that are still active in the first quarter of 2000, the column labelled 'non-liquidated' refers to all funds that were present in a certain quarter and have not been liquidated during the sample period, the column labelled 'liquidated' refers to funds that had left the database by the end of the sample period due to liquidation.

sample period due to liquidation. Clearly, the table indicates that average returns of liquidated funds are substantially below those of non-liquidated funds. For example, the average return in the first quarter of 1995 for non-liquidated funds is 4.0%, while the average return is only 2.0% for funds that have been liquidated by 2000. Combining both subsets produces an average quarterly return in the first quarter of 1995 of 3.4%. A striking result is that the difference in mean over the entire sample period between non-liquidated and liquidated funds is about 3.2% per quarter with a t-value of 2.89. Over the entire sample period, average returns of active funds are about 2.11% (per annum) above the average returns of all funds, a number which Malkiel (1995), Liang (2000) and others refer to as the "survivorship bias". Note that the average returns of non-liquidated funds (the combination of the subset of active funds with the funds that have been self-selected during the sample period) are about 1.52% (per annum) above the average of all funds, a number one could refer to as "liquidation bias". Both estimates are between the 1.5% of Fung and Hsieh (2000) and the numbers presented by Brown, Goetzmann and Ibbotson (1999) [3%] and Liang (2000) [2.24%]. There is no clear indication of a "self-selection bias" in average returns.

While it is commonly accepted that funds with a relatively bad performance are more likely to be dissolved, it is not clear a priori over which period historical returns are important to explain liquidation. To obtain some insight into this question, Figure 1 presents conditional liquidation rates (hazard rates) by performance decile over the next eight quarters. That is,

in each quarter funds are ranked on the basis of (gross, raw) returns and divided into 10 deciles. Next, for each decile, the average liquidation rate is determined for one up to eight quarters after the ranking period.[2] It is clear from the figure that in the first four quarters conditional liquidation rates for loser funds (decile 1) are much higher than for winner funds (decile 10), while for the last two or three quarters the relationship is almost flat. This seems to indicate that quarterly returns are important determinants of subsequent liquidation rates over the next four or so quarters, while at 8 quarters conditional liquidation rates are basically the same, independent of initial returns.

There are a number of classification methods for hedge funds' investment styles commonly used by data vendors, although none appears to be universally accepted. The TASS database employs two different classifications. The classification we use initially contains 17 styles which are mutually exclusive and closely correspond to the commonly used Tremont hedge fund style indices. It takes into account different dimensions simultaneously: asset class, geographical focus and investment bias (i.e. US equity hedge funds; European equity hedge funds; Asian equity hedge funds; pure leveraged currency; fixed income directional; convertible fund (long only); etc.). However, this investment style is not available for 269 funds (of which 242 are dead funds).

[2] The conditional attrition rate (hazard rate) corresponds to the probability of attrition in quarter $t + S$ conditional upon not being dissolved in the preceding quarters $t + 1$ to $t + S - 1$, and conditional upon its performance rank in quarter t.

In each quarter from Q2/1994 to Q1/2000, funds are ranked into decile portfolios based on their previous one-quarter net excess returns. For the quarter subsequent to initial ranking and for each of the next 8 quarters after formation, the rate of liquidated funds as a percentage of the total number of funds still existing at the beginning of each period is determined. Thus, the bar in cell (i,j) represents the conditional probability of being liquidated in the post-formation period *i* given an initial ranking of decile *j*.

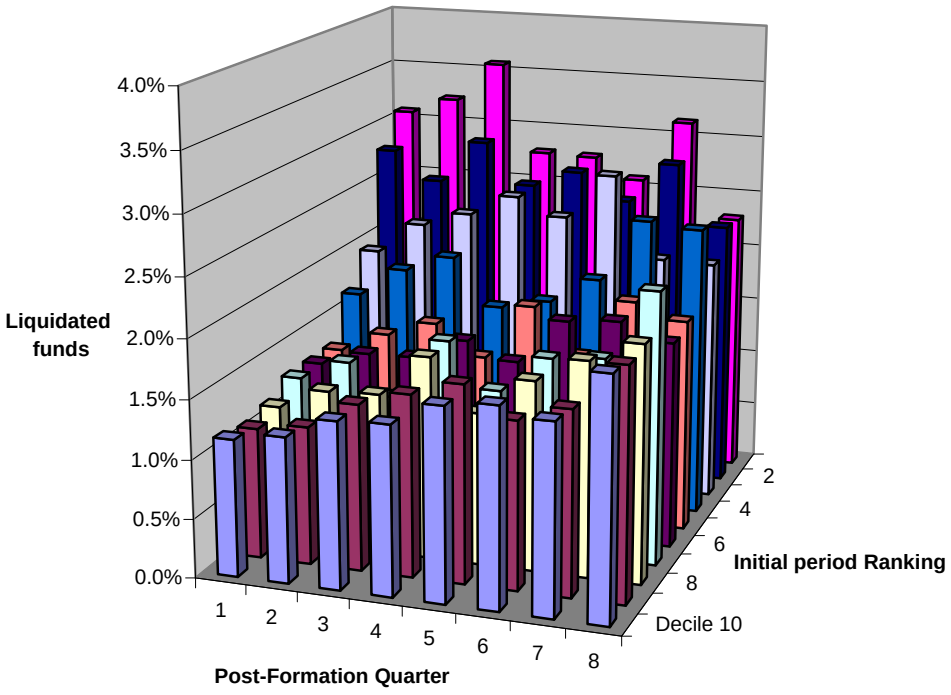

Figure 1: Conditional liquidation rates, 1 to 8 quarters after initial rank

This represents a major drawback since we intend to study survival-related biases by investment style. In order to determine the style of this subsample of funds, we apply multiple discriminant analysis.

For all funds in the TASS database, we observe indications of their investment style through a set of 15 *overlapping* style indicators (e.g. bottom up, market neutral, fundamental, ...). On average, each fund is characterized by at least four of these styles. The subsample of funds for which we also observe a unique style classification according to the 17 styles distinguished above, is used to determine a set of discriminant functions. These discriminant functions provide a set of scores for each of the 17 styles.[3] Subsequently, the discriminant functions are used to determine the scores for the subsample of funds for which the appropriate style classification is missing, after which each fund is allocated to its "most likely" style. While such a procedure necessarily is subject to classification error, its within sample performance is rather well, with 52.3 % of the funds classified correctly in one of 17 investment styles.

As mentioned above, these 17 styles closely correspond to the Tremont hedge fund benchmarks. Tremont offers a series of nine hedge fund indices, computed on a monthly basis and constructed out of hedge funds that have at least $10 million under management and provide audited financial statements (see, e.g. Lhabitant, 2001). In Table 3 we report the number of

[3]In fact, one of these 17 style categories (pure property) contained only one fund and was not used in the discriminant analysis.

	onshore			offshore		
Investment Style	non liquidated	dead	total	non liquidated	dead	total
Convertible Arb.	5	0	5	4	2	6
Dedicated Short Bias	6	0	6	6	0	6
Emerging Markets	23	9	32	139	43	182
Equity Market Neutral	46	15	61	76	23	99
Event Driven	65	5	70	78	8	86
Fixed Income Arb.	7	1	8	14	6	20
Global Macro	3	1	4	21	6	27
Long/Short Equity	158	19	177	154	33	187
Managed Futures	100	41	141	123	92	215
Hedge Fund Index	118	15	133	263	69	332
All styles	531	106	637	878	282	1160

Table 3: Numbers of liquidated (referred to as "dead") and non-liquidated US hedge funds, by investment style

non-liquidated and liquidated funds assigned to a Tremont index. The investment style "Hedge Fund Index" is a general hedge fund index and does not refer to a particular investment style. We assigned funds without a clear investment style, like fund-of-funds, to this category. In addition, we distinguish between offshore and onshore funds.

It appears that "Long/Short equity" and "Managed Futures" are the most popular investment styles, with 364 and 356 funds, respectively. Furthermore, the majority of the funds can be classified as offshore. A large proportion of about 37.4% of the funds with investment style "Managed Futures" have been liquidated by 2000. For "Emerging Markets", this percentage is about 24.3%, while for "Dedicated Short Bias" this percentage is 0%. Clearly, this indicates that investment style might be a significant factor

in explaining fund survival. We do not observe striking differences between liquidation rates of offshore and onshore funds, although the first group has a somewhat larger proportion of dissolved funds.

In the next section, we present a model that explains liquidation of hedge funds as a function of historical returns as well as a number of fund characteristics, including investment style.

3 Modelling the liquidation process

Variables that are likely to affect liquidation rates of hedge funds are historical returns over a number of previous quarters, fund size, age of the fund, fund risk, an underwater indicator reflecting negative returns over a predetermined period, and the fund's investment style. To describe our liquidation model, let y_{it} be an indicator variable that indicates whether or not fund i has liquidated in quarter t. Our specification describes the probability of fund liquidation ($y_{it} = 0$) using a longitudinal probit model, such that a fund does not liquidate if an underlying latent variable, y^*_{it} is positive. That is,

$$\begin{aligned} y^*_{it} &= \alpha + \sum_{j=1}^{J} \gamma_{ij} r_{i,t-j} + \beta' x_{i,t-1} + \lambda_t + \eta_{it} \qquad (1) \\ y_{it} &= 0 \text{ if fund } i \text{ is liquidated in quarter } t \ (y^*_{it} \leq 0) \\ y_{it} &= 1 \text{ otherwise} \end{aligned}$$

where $r_{i,t-j}$ is the return of fund i in quarter $t-j$, $x_{i,t-1}$ is a vector of fund-specific characteristics, including a set of style dummies, and λ_t denote fixed time effects describing economy wide effects. The coefficients γ_{ij} indicate how non-liquidation (survival) is affected by the fund's returns, lagged j quarters. Compared to Liang (2000), who includes the average monthly return over the fund's history, this allows us to analyze the dynamic impact of historical returns upon fund survival. For the moment, we fix the maximum lag J at 6. The γ_{ij} coefficients are assumed to be equal across funds, with the exception of those cases in which less than J historical returns are available. In such a case, the γ_{ij} coefficients are set to zero if the corresponding return is unobserved (which is typically the case for funds with a recent inception date). To reduce the effect of a potential backfill bias on our estimates, information on a fund is only taken into account in the estimation of (1) at the moment its age exceeds 4 quarters.

In Table 4 we present some summary statistics of the fund-specific variables ($x_{i,t-1}$) that were included in the liquidation model (1). These descriptive statistics are based on 19245 fund/period observations, while 10 of the fund-specific variables are dummies. It appears that 59% of the observations are from offshore hedge funds. These funds, while reporting in US$, are located in tax-havens like the Virgin Islands. The average incentive fee of the fund manager is about 16%, but can be as high as 50% of realized performance. Note that these incentive fees are only obtained when the fund has recovered past losses (high water-mark). The annual management fee

Variable	mean	std.dev	min	max
offshore	0.59	0.49	0.00	1.00
Incentive Fees	15.93	7.90	0.00	50.00
Mng. Fees	1.62	1.06	0.00	8.00
ln(NAV)	16.72	1.77	7.58	23.30
ln(Age)	3.80	0.66	2.57	5.62
$\ln(\text{Age})^2$	14.94	5.09	6.58	31.55
StDev	0.08	0.08	0.00	2.19
Underwater	0.17	0.38	0.00	1.00
Emerging Markets	0.10	0.30	0.00	1.00
Equity Market Neutral	0.07	0.26	0.00	1.00
Event Driven	0.10	0.30	0.00	1.00
Fixed Income Arb.	0.01	0.11	0.00	1.00
Global Macro	0.02	0.15	0.00	1.00
Long/Short Equity	0.19	0.39	0.00	1.00
Man. Futures	0.22	0.41	0.00	1.00
Fund of Funds	0.20	0.40	0.00	1.00

Table 4: Summary statistics fund-specific variables.

varies from 0% to 8% (of net asset value) and has an average of 1.6%. The age of the funds varies between 13 months and 275 months (about 23 years), while the average age is about 45 months. The average size of the hedge funds, measured by their log net asset value is 16.72, corresponding to about 18.3 million US$. Total risk is measured by the standard deviation of the previous six quarterly returns (StDev). The underwater indicator is equal to one if a fund has a negative cumulative return over the past eight quarters[4], which occurs in 17% of the cases. About 20% of the observations belong to so-called funds-of-funds, while only 1% corresponds to hedge funds with a

[4]The cumulative return is determined over at least five quarters with a maximum of eight quarters.

Parameters	Estimate	Std.error	Parameters	Estimate	Std. Error
intercept	2.171	0.857	StDev	1.676	0.404
$r1$	0.913	0.229	ln(Age)	-1.001	0.438
$r2$	0.820	0.246	$\ln(\text{Age})^2$	0.142	0.058
$r3$	1.153	0.251	Underwater	-0.387	0.070
$r4$	0.290	0.252	Emerging Markets	-0.137	0.089
$r5$	0.101	0.234	Equity Market Neutral	-0.219	0.101
$r6$	-0.384	0.203	Event Driven	0.165	0.131
offshore	-0.136	0.057	Fixed Income Arb.	-0.194	0.223
Incentive Fees	-0.007	0.004	Global Macro	-0.145	0.206
Mng. Fees	-0.021	0.026	Long/Short Equity	-0.083	0.088
ln(NAV)	0.171	0.017	Man. Futures	-0.076	0.078
Loglikelihood: -1358.2194			Chi-squared test: 548.25 (DF = 42)		
pseudoR^2: 0.1679			($p = 0.0000$)		

Table 5: Estimation results liquidation model, including net asset value (size). Coefficient estimates for the time dummies are not reported.

"fixed income arbitrage" investment style.

We estimate (1) using all investment styles, while including style dummies to capture the possibility, as suggested by the summary statistics in Table 3, that different investment styles are associated with different overall liquidation rates. Given the limited number of funds with investment styles "convertible arbitrage" or "dedicated short bias", no dummies are included for these styles and the funds are allocated to the general hedge fund index (reference category). In addition, the model includes time dummies to capture aggregate shocks to the liquidation rates. Because fund size (NAV) is not available for each period for all funds in our sample, we use the most recent observation of net asset value available from the TASS database. However, there remain some observations for which NAV is missing and cannot

Parameters	Estimate	Std.error	Parameters	Estimate	Std. Error
intercept	4.189	0.797	StDev	0.735	0.377
$r1$	1.052	0.218	ln(Age)	-0.599	0.414
$r2$	1.044	0.236	$\ln(\text{Age})^2$	0.098	0.055
$r3$	1.374	0.243	Underwater	-0.453	0.068
$r4$	0.447	0.235	Emerging Markets	0.031	0.086
$r5$	0.307	0.225	Equity Market Neutral	-0.184	0.096
$r6$	-0.065	0.194	Event Driven	0.245	0.126
offshore	-0.104	0.055	Fixed Income Arb.	-0.066	0.219
Incentive Fees	-0.008	0.003	Global Macro	0.089	0.208
Mng. Fees	-0.031	0.025	Long/Short Equity	-0.054	0.084
			Man. Futures	-0.284	0.073
Loglikelihood: -1452.3809			Chi-squared test: 455.82 ($DF = 41$)		
pseudoR^2: 0.1356			($p = 0.0000$)		

Table 6: Estimation results liquidation model, excluding net asset value (size). Coefficient estimates for the time dummies are not reported.

be imputed. This occurs in 7% of the cases. Because we do not want to eliminate these observations from our persistence analysis in Section 4, we also estimated a second liquidation model from which ln(NAV) is excluded. This model, based on a smaller information set, is used to correct for look-ahead bias whenever information on net asset value is missing. The estimation results, based on either 19245 or 20413 fund/period observations, are presented in Table 5 and Table 6, respectively[5].

The results show that the impact of historical returns upon fund survival is positive and significant: funds with high returns are much less likely to liquidate than funds with low returns. The impact of the individual quarters decreases with each lag. Consistent with Brown, Goetzmann and Park

[5]The estimates for the time dummies are available upon request.

(2001), the underwater indicator has a highly significant and negative impact upon survival, indicating that a negative aggregated return over the previous two years increases the probability that a fund will liquidate. A comparison with the results for mutual funds in ter Horst, Nijman and Verbeek (2001) suggests that hedge fund survival is more strongly related to historical performance, both economically, as measured by the coefficient magnitudes, and statistically, as reflected by the corresponding t-ratios. As indicated by the Chi-squared test, the variables in the models are jointly highly significant, while many of the variables are also individually significant. For example, fund size has a strong negative impact upon liquidation: smaller funds are, ceteris paribus, much more likely to be liquidated than large funds. Surprisingly, the magnitude of the incentive fee for a manager affects the probability of survival in a negative and significant way, i.e. the higher the incentive fee, ceteris paribus, the more likely it is that the fund will liquidate in the next quarter. Age has a significant nonlinear effect: young hedge funds have a high probability to disappear, but when funds become more mature, the liquidation probability decreases. Most investment style dummies have a significant impact on survival probabilities. The funds with style "event driven" have, ceteris paribus, the highest probability to survive, while funds classified as "equity market neutral" have the lowest survival probability. Interestingly, no significant effect is found for the "managed futures" style when fund size is included in the specification, while it is highly significant and negative when size is dropped.

The results of Brown, Goetzmann and Park (2001), who estimate several alternative models for hedge fund failure, indicate a positive and statistically significant impact of style adjusted return risk upon fund failure. This is consistent with the idea that high risk funds are more likely to experience extreme returns and therefore more likely to be terminated (compare Brown et al, 1992). However, in the current specifications explaining fund liquidation, standard deviation is statistically insignificant when fund size is excluded (Table 6), and becomes significant and positive when fund size is added (Table 5). This suggests that, with a given return history and fund size, high risk funds experience a somewhat lower liquidation probability.[6] This is not inconsistent with the finding that high-risk funds are more likely to liquidate, but it does indicate that high-risk funds are allowed to have more extreme negative returns than low-risk funds before they decide to liquidate.

The specification reported in Table 5 is tested against a number of more general alternatives. For example, we test whether the model is significantly improved when returns lagged 7, 8 and 9 quarters are added. The value of the likelihood ratio test statistic is 4.82, which is insignificant at the 10% level.[7] Furthermore we tested the logarithmic specification in size against a more general alternative. The likelihood ratio test on the inclusion of $\ln(NAV)^2$ produces an insignificant value of 0.09. In summary, the results of these tests

[6] The results in Tables 5 and 6 are not driven by outliers. Moreover, the results are similar if alternative measures for standard deviation are used (e.g. based on monthly returns).

[7] The asymptotic distribution is Chi-squared with 3 degrees of freedom.

do not indicate serious shortcomings of the current specification.

In order to obtain an indication of the probability that an arbitrary hedge fund will liquidate in the next quarter given its past record of returns and its age, we use the estimates of (1) to compute the probability of liquidation. In Figure 2 the liquidation probabilities are reported for funds with different ages, with a minimum of 5 quarters, where historical returns vary from -10% to $+10\%$ for each of the last six quarters. The underwater indicator is set equal to one if the cumulative return over the previous six quarters is negative. All other variables are fixed at their sample average. It appears that for a fund with an age of 12 quarters and a return record of -10% for each of the last six quarters, the probability to liquidate in the next quarter is about 4.6%, while for a fund with the same age but a return record of $+10\%$ for each of the last six quarters the liquidation probability is only 0.5%. Note that the underwater indicator has a strong impact on the probability of liquidation. If a fund is underwater, implying that the manager will not receive the incentive fee, the probability that a fund will disappear increases from almost 1% to about 2.5% for a fund at an age of 12 quarters and a past average return around 0%. It is clear that fund age affects liquidation nonlinearly. Apparently, liquidation rates of funds that recently started are less affected by a poor historical performance than those of funds that are around for several years, while older funds are also less likely to liquidate. These results are consistent with Boyson (2003), who investigates the relationship between survival, past performance and manager tenure. According to her results,

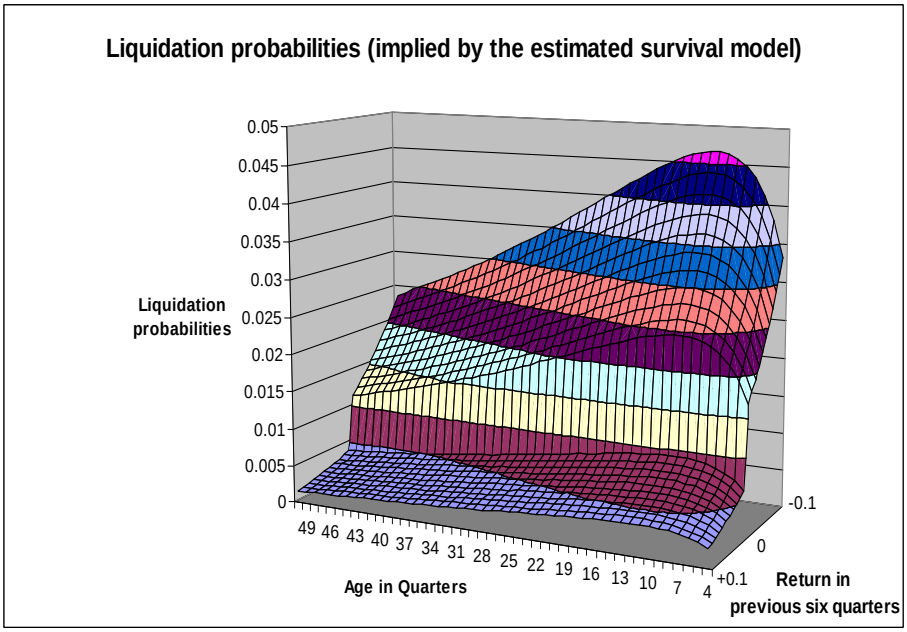

Figure 2: Liquidation probabilities by fund age and previous six quarters' returns (as implied by the estimated liquidation model).

young managers are much more likely than old to be terminated for poor performance.

4 Estimating Persistence in Performance

The question whether hedge funds show persistence in their performance has received much attention in the recent literature. For example, Brown, Goetzmann and Ibbotson (1999) use annual returns of offshore hedge funds and do not find persistence in their sample. Agarwal and Naik (2000) use quarterly, half-yearly and annual (post-fee and pre-fee) returns and examine

short-term as well as long-term persistence. They find that persistence is highest at the quarterly horizon and decreases when moving to a yearly horizon. However, persistence in quarterly returns could be affected by the fact that most hedge funds only report on an annual basis. The investment style of the hedge funds is not relevant for the persistence pattern found by Agarwal and Naik (2000).

In this section, we will first examine whether there is performance persistence in raw returns. Basically, we examine whether 'winning' funds are more likely to be winners in the next period. To obtain some indications about the probabilities that hedge funds from the top deciles remain in the top deciles, Figure 3 reports a contingency table of quarterly performance. Each quarter all funds are ranked in ten deciles, and this is compared with their ranking in the previous quarter. The table also incorporates liquidated funds and new funds that enter the database (after a backfill period of four quarters) and is therefore not affected by look-ahead bias. Funds that are in the top decile (decile 10) have a probability of about 20% of being a top performer in the next quarter again. They have a probability of about 17% of ending up in the loser decile (decile 1). The funds that performed worst (decile 1) in the ranking period, have the highest probability of being a loser again (about 24%), but also a probability of about 4% of being liquidated in the next quarter. Moreover, these funds have a high probability of more than 16% to end up in the winner decile. The most likely explanation for this finding is that funds in the extreme deciles (deciles 1 and 10) are more risky

than those in the other deciles. More risk is associated with higher average returns, but also with bigger chances of extremely good and extremely poor outcomes. Such funds are more likely to move from the winner to the loser decile or vice versa. In line with this, we observe that funds from the middle deciles are more likely to remain in the middle deciles than to move to one of the extreme deciles. The probability of being liquidated in the next quarter is relatively high for the lower deciles.

The previous analysis does not provide information about the levels of average returns across the different deciles. To investigate this, we rank the funds in the so-called ranking period on the basis of past average returns over the previous quarter, the previous year or the previous two years. This ranking is broken down into ten deciles. To avoid double counting, fund-of-funds are excluded from this exercise. In the subsequent evaluation period we calculate the average returns for each of these deciles. For instance, for the one year ranking period this implies that the first ranking is based on returns over the year 1994 (i.e. the first year of our sample), while the evaluation period is the year 1995. The procedure is repeated over the entire sample period, moving forward by one quarter at the time and adjusting the sample to include those funds that have a sufficiently long return history. As a result these rankings are conditional upon survival over the ranking and evaluation periods. Multi-period selection bias or look-ahead bias may thus distort the empirical results. As before, we take account of potential backfill biases by only using information on a fund once its age exceeds four quarters.

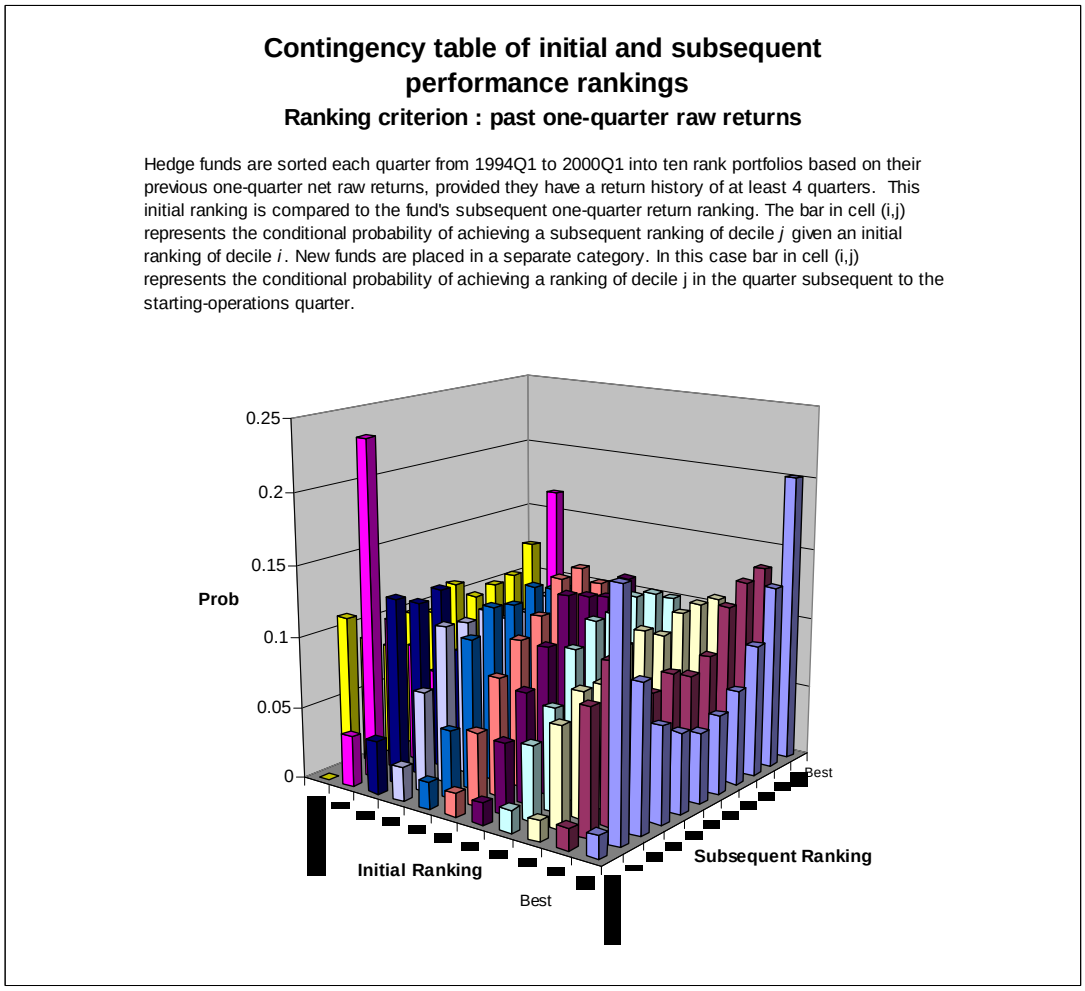

Figure 3: Contingency table of quarterly performance

As is well known by now, spurious performance persistence patterns might arise that are due to look-ahead bias (Carpenter and Lynch, 1999). Following the correction procedure introduced by ter Horst, Nijman and Verbeek (2001), we also present persistence results that are corrected for look-ahead bias. Basically, the correction method implies a multiplication of the performance measure (e.g. the average return over the ranking period) with a weight factor, which is the ratio of an unconditional non-liquidation probability in the numerator and a conditional non-liquidation probability in the denominator. The latter one can be obtained from the estimated liquidation process that is reported in Section 3, while the unconditional probability can be estimated by the ratio of the funds that were not liquidated during the ranking period and the number of funds present in the sample at the beginning of the ranking period. The correction for the average returns over the evaluation period is similar, except that the unconditional probabilities are conditional upon the fund's decile during the ranking period (but not upon the entire return history).[8]

Consider the case that we are interested in persistence in raw returns at an annual horizon. This implies that we can only use information on funds that have reported returns for at least four consecutive quarters. Let $Y_{it} = 1$ if fund i has survived during quarters t to $t + 3$ (and $Y_{it} = 0$ otherwise) and let R_i denote the entire vector of fund returns. The probability that a fund is observed in quarters t to $t + 3$, after a backfill period of 4 quarters,

[8]The correction assumes that self-selection is determined exogenously.

and given its returns and given its characteristics X_{it} (age, management fees, investment style, net asset value), can be obtained from the liquidation model. Assuming that liquidation is independent of current or future returns, this probability is

$$P\{Y_{it} = 1|R_i, X_{it}\} = \prod_{t=s}^{s+3} P\{y_{it} = 1|r_{i,t-1,\ldots,}x_{i,t-1}\}. \tag{2}$$

Estimates for the probabilities at the right-hand side are directly obtained from the probit model. The unconditional non-liquidation probability can easily be estimated by the ratio of the appropriate number of funds that did not liquidate between quarter t and $t + 3$ and the number of funds that was in the sample in quarter $t - 1$. As shown by ter Horst, Nijman and Verbeek (2001), multiplying the returns for funds used in the analysis by the resulting weight factors provides the unconditional distribution of returns we are interested in.

In Table 7 we report empirical persistence of raw returns at quarterly and annual horizons, with and without correcting for look-ahead bias. The results for the annual horizon are also represented graphically in Figure 4. All estimates are based on the full sample of hedge funds, excluding fund-of-funds. The results in Table 7 show some interesting patterns. At the annual level, we see that the persistence pattern without corrections is slightly J-shaped. Given the results of Hendricks, Patel and Zeckhauser (1997), Brown, Goetzmann, Ibbotson and Ross (1997), and ter Horst, Nijman and Verbeek

(2001), a pattern like this may be attributable to look-ahead bias. Correcting for look-ahead bias flattens the J-shaped pattern. Without corrections, average returns may be overestimated by as much as 3.8% (decile 1), which is statistically significant with a t-value of 2.59. This shows that the impact of look-ahead bias upon persistence measures may be quite severe. In contrast, ter Horst, Nijman and Verbeek (2001), studying persistence in performance of 'growth' and 'income' mutual funds, report only slightly different estimates after correcting for look-ahead bias. These findings show that the impact of look-ahead bias in persistence estimates is much larger for hedge funds than it is for mutual funds. The most likely explanation for this is the stronger relationship between hedge fund survival and historical performance. The corrections for look-ahead bias are most pronounced for the extreme deciles, which is to be expected given that these deciles typically contain the more risky funds. The finding that look-ahead bias has a U-shaped pattern is due to the cross-sectional dispersion in fund specific risk. Funds ranked in one of the extreme deciles are more likely to be 'high risk' funds and thus less likely to survive. Conditional upon the fact that they have not been liquidated during the evaluation period, they will have made better returns than average; see ter Horst, Nijman and Verbeek (2001) for additional discussion.

At the quarterly horizon, we clearly observe positive persistence in hedge fund returns, particularly for the best four deciles. For example, the top decile provides an average return over the next quarter of 20.4% (annualized) while the bottom decile provides only about 8.3%. This corresponds to the

Table 7: **Persistence Estimates (Raw returns)**

	Average performance (raw returns)			
	One-Quarter		Four-Quarters	
Decile	non corrected	corrected	non corrected	corrected
1 (losers)	0.092	0.083	0.159	0.121
	(0.076)	(0.077)	(0.097)	(0.099)
2	0.116	0.117	0.164	0.143
	(0.048)	(0.047)	(0.064)	(0.056)
3	0.124	0.124	0.146	0.131
	(0.034)	(0.033)	(0.048)	(0.045)
4	0.118	0.115	0.142	0.131
	(0.030)	(0.029)	(0.041)	(0.037)
5	0.121	0.124	0.141	0.143
	(0.021)	(0.021)	(0.027)	(0.029)
6	0.131	0.126	0.134	0.131
	(0.024)	(0.024)	(0.034)	(0.035)
7	0.143	0.140	0.139	0.135
	(0.025)	(0.025)	(0.041)	(0.042)
8	0.165	0.168	0.159	0.159
	(0.034)	(0.034)	(0.034)	(0.035)
9	0.196	0.196	0.192	0.191
	(0.045)	(0.045)	(0.051)	(0.050)
10 (winners)	0.206	0.204	0.208	0.202
	(0.067)	(0.066)	(0.109)	(0.110)
winners - losers	0.115	0.120	0.049	0.082
	(0.076)	(0.079)	(0.074)	(0.080)

Each quarter, funds are sorted into ten rank portfolios based on their previous one-quarter or four-quarter returns, respectively. Next, average returns over the next one or four quarters are computed, for each decile. Using returns from 1994-2000, this produces a time-series for each decile of 22 average one-quarter returns, and 16 (overlapping) average four-quarter returns. The numbers in the table are the annualized time-series averages and their standard errors in parentheses. The standard errors are corrected for autocorrelation based on the Newey-West approach. The corrected figures employ a weighting procedure to eliminate look-ahead bias.

Table 8: **Persistence Estimates (Raw returns), continued**

	Average performance (raw returns)		
		Eight-Quarter	
Decile	non corrected	corrected	corrected (robust estimates)
1 (losers)	0.039	-0.021	0.020
	(0.041)	(0.046)	(0.024)
2	0.076	0.050	0.044
	(0.096)	(0.093)	(0.059)
3	0.116	0.112	0.102
	(0.059)	(0.063)	(0.045)
4	0.110	0.106	0.105
	(0.021)	(0.029)	(0.030)
5	0.121	0.116	0.113
	(0.033)	(0.038)	(0.040)
6	0.131	0.115	0.115
	(0.042)	(0.043)	(0.044)
7	0.159	0.160	0.145
	(0.057)	(0.052)	(0.041)
8	0.174	0.162	0.153
	(0.068)	(0.052)	(0.033)
9	0.152	0.155	0.156
	(0.047)	(0.055)	(0.049)
10 (winners)	0.082	0.050	0.064
	(0.082)	(0.100)	(0.082)
winners - losers	0.044	0.070	0.044
	(0.095)	(0.104)	(0.079)

Each quarter, funds are sorted into ten rank portfolios based on their previous eight-quarter returns. Next, average returns over the next eight quarters are computed, for each decile. Using returns from 1994-2000, this produces a time-series for each decile of 8 (overlapping) average eight-quarter returns. The numbers in the table are the annualized time-series average returns and their standard errors in parentheses. The standard errors are corrected for autocorrelation based on the Newey-West approach. The corrected figures employ a weighting procedure to eliminate look-ahead bias. The robust estimates give zero weight to the 1% lowest and 1% highest returns.

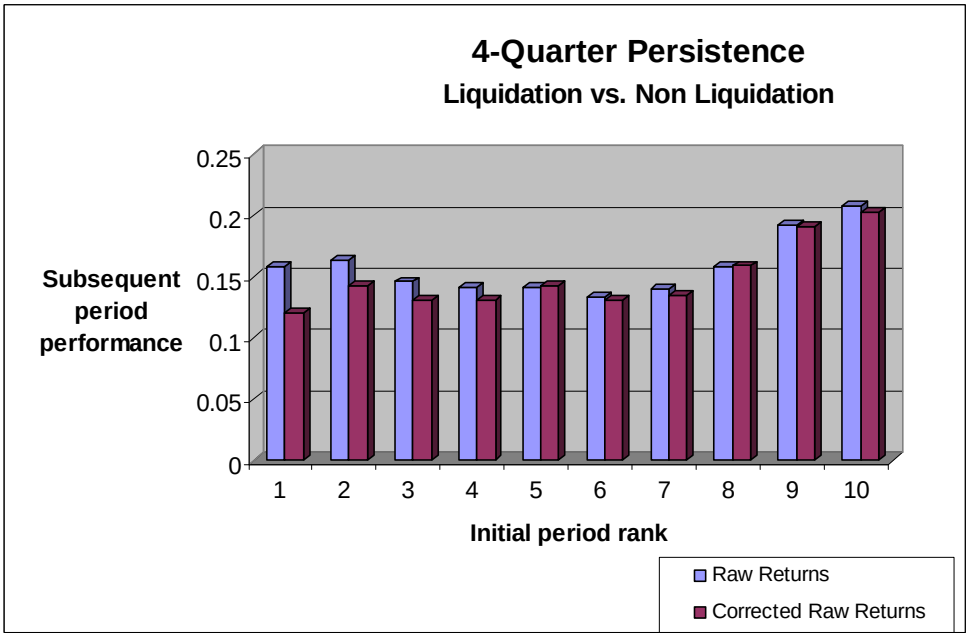

Figure 4: Annual persistence in raw returns.

findings of Agarwal and Naik (2000), who also find strong persistence at a quarterly horizon over the period 1982 - 1998. However, in their study the issue of look-ahead bias is not taken into account. The corrections for look-ahead bias reduce most of the averages somewhat, although the bias is much less than in case of an annual horizon. Because these estimates refer to only one quarter, it is not surprising that the look-ahead bias is less severe.

The results for a two-year horizon are reported in Table 8. Compared to Table 7, the number of funds that can be used to estimate persistence is substantially reduced. Both the corrected and uncorrected persistence estimates show an increasing pattern over the deciles, with the exception of the

top decile. Nevertheless, the winners outperform the losers by a statistically insignificant 7%. To investigate the impact of the extreme observations, we also computed average returns in the evaluation period giving zero weight to the 1% lowest and 1% highest returns. This is expected to result in more robust estimates for the expected returns during the evaluation period. The results are reported in the last column of Table 8 and reduce the performance of the winner-loser portfolio to 4.4%.

One explanation for positive persistence in raw returns, after correcting for look-ahead bias, is the presence of cross-sectional variation in expected fund returns due to heterogeneous style or (systematic) risk characteristics. As argued by Boyson (2003), controlling for style is important in an analysis of performance persistence among hedge funds. Therefore, we also examine persistence in risk-adjusted returns. For hedge funds this is somewhat more complicated than for mutual funds. Hedge fund returns typically have low correlations with returns on standard asset pricing factors like the return on the market portfolio. This is an important feature of hedge funds and makes them an interesting investment vehicle for diversification opportunities. The reason for the low correlation is that hedge funds often follow highly dynamic investment styles, and are allowed to invest in derivatives, to take short positions or to make use of leverage. The question how to obtain risk-adjusted returns of hedge funds receives a lot of attention in the current literature. Basically, two approaches can be found, the first approach makes use of indices that have option like pay-off structures (see, e.g. Fung and Hsieh,

1997, 2001, and Agarwal and Naik, 2004), while the second approach uses peer group hedge fund indices (see, e.g. Lhabitant, 2001). The idea behind the first approach is that hedge fund strategies generate option-like returns that should be reflected in the benchmark indices. The second approach avoids the problem and simply makes use of indices constructed out of other hedge funds with the same reported style as the funds under consideration. The first approach is only suitable for very specific trading strategies, while the second approach is much more general. However, it is more appropriate to denote the obtained returns from the second approach as style-adjusted or relative returns instead of risk-adjusted returns. Given that in our study the focus is on persistence in hedge fund returns in general, and not for a specific investment style, we decided to follow the second approach, and examine whether hedge funds show persistence in style-adjusted or relative returns. The style benchmarks we employ are the Tremont hedge fund style indices, and correspond to the investment styles of the hedge funds in our sample (see Table 3). Basically, we subtract from the raw return of a hedge fund the return on the style benchmark the fund belongs to. Similarly to the procedure followed in case of raw returns, we examine whether there is persistence in relative returns.

In Table 9 we report persistence of relative returns at quarterly and annual horizons, with and without corrections for look-ahead bias, while Figure 5 presents a visual representation of the results at the annual frequency. The results for the biannual horizon are reported in Table 10. At the annual hori-

Table 9: **Persistence Estimates (Style-adjusted returns)**

	Average performance (style-adjusted returns)			
	One-Quarter		Four-Quarter	
Decile	non corrected	corrected	non corrected	corrected
1 (losers)	-0.029	-0.033	-0.007	-0.036
	(0.042)	(0.043)	(0.069)	(0.063)
2	-0.021	-0.018	-0.019	-0.028
	(0.022)	(0.022)	(0.043)	(0.042)
3	-0.034	-0.036	-0.010	-0.010
	(0.015)	(0.016)	(0.029)	(0.029)
4	-0.022	-0.020	–0.014	-0.018
	(0.011)	(0.011)	(0.022)	(0.021)
5	-0.001	-0.003	-0.015	-0.020
	(0.012)	(0.012)	(0.014)	(0.016)
6	-0.002	-0.002	-0.010	-0.012
	(0.014)	(0.014)	(0.010)	(0.011)
7	0.020	0.020	-0.006	-0.007
	(0.013)	(0.013)	(0.014)	(0.014)
8	0.038	0.040	0.016	0.010
	(0.021)	(0.021)	(0.013)	(0.014)
9	0.052	0.047	0.018	0.014
	(0.025)	(0.025)	(0.016)	(0.014)
10 (winners)	0.065	0.067	0.066	0.062
	(0.037)	(0.037)	(0.053)	(0.054)
winners - losers	0.094	0.100	0.073	0.099
	(0.066)	(0.068)	(0.090)	(0.083)

Each quarter, funds are sorted into ten rank portfolios based on their previous one-quarter or four-quarter style-adjusted returns, respectively, where style-adjusted returns are raw returns in deviation of the returns on an appropriate style index. Next, average style-adjusted returns over the next one or four quarters are computed, for each decile. Using returns from 1994-2000, this produces a time-series for each decile of 22 average one-quarter returns, and 16 (overlapping) average four-quarter returns. The numbers in the table are the annualized time-series averages and their standard errors in parentheses. The standard errors are corrected for autocorrelation based on the Newey-West approach. The corrected figures employ a weighting procedure to eliminate look-ahead bias.

Table 10: **Persistence Estimates (style-adjusted returns), continued**

	Average Performance (style-adjusted returns)		
		Eight-Quarter	
Decile	non corrected	corrected	corrected (robust estimates)
1 (losers)	-0.039	-0.116	-0.050
	(0.099)	(0.095)	(0.068)
2	0.008	0.004	-0.013
	(0.064)	(0.062)	(0.040)
3	0.001	-0.007	-0.014
	(0.050)	(0.048)	(0.040)
4	-0.004	-0.009	-0.007
	(0.034)	(0.028)	(0.026)
5	-0.009	-0.015	-0.012
	(0.042)	(0.041)	(0.038)
6	-0.016	-0.016	-0.016
	(0.032)	(0.027)	(0.027)
7	0.005	-0.002	-0.004
	(0.051)	(0.050)	(0.025)
8	0.025	0.025	0.017
	(0.037)	(0.038)	(0.019)
9	0.017	0.005	0.002
	(0.030)	(0.041)	(0.036)
10 (winners)	-0.027	-0.047	-0.053
	(0.040)	(0.052)	(0.036)
winners - losers	0.012	0.069	-0.003
	(0.136)	(0.139)	(0.102)

Each quarter, funds are sorted into ten rank portfolios based on their previous eight-quarter returns. Next, average returns over the next eight quarters are computed, for each decile. Using returns from 1994-2000, this produces a time-series for each decile of 8 (overlapping) average eight-quarter returns. The numbers in the table are the annualized time-series averages and their standard errors in parentheses. The standard errors are corrected for autocorrelation based on the Newey-West approach. The corrected figures employ a weighting procedure to eliminate look-ahead bias. The robust estimates give zero weight to the 1% lowest and 1% highest returns.

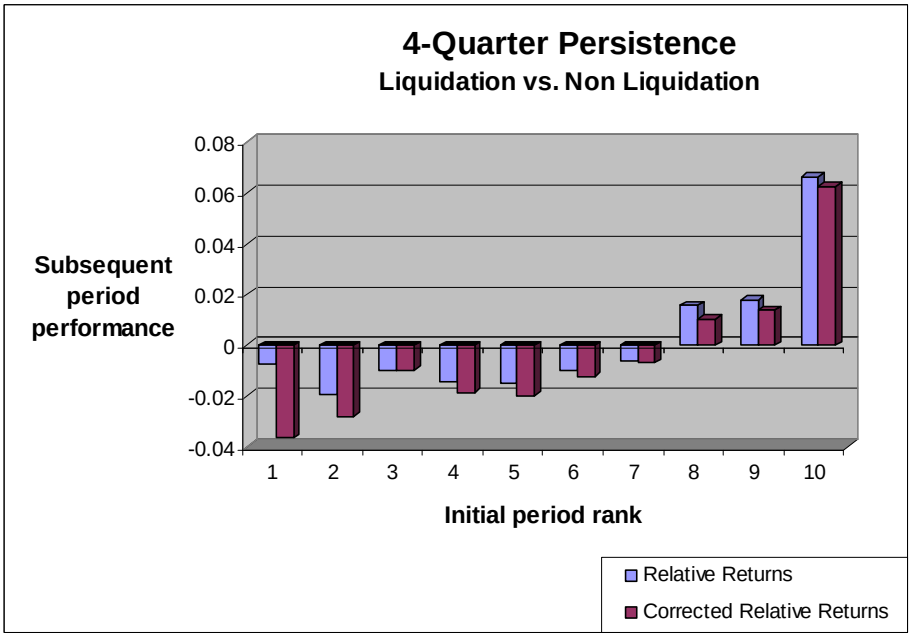

Figure 5: Annual persistence of style adjusted, relative returns.

zon we find that the top three deciles (decile 8, 9 and 10) outperform their style benchmark. The outperformance, although statistically insignificant, increases from about 1% (decile 8) to somewhat more than 6% for decile 10 at an annual basis (corrected relative returns). For the remaining deciles we find underperformance and insignificant persistence of negative relative returns. The effect of look-ahead bias is most severe for decile 1, where the bias is about 3%. At a quarterly horizon the persistence of relative returns is stronger. For decile 7 this outperformance is about 2% and increases to about 6.7% for decile 10. Similarly to the results of the raw returns, the effect of look-ahead bias is much smaller at a quarterly horizon than at an annual

horizon. At a biannual horizon, reported in Table 10, we do not observe any persistence of relative returns. Almost all funds show, on average, underperformance with respect to their corresponding style benchmark. When the 1% highest and lowest observations are omitted from the evaluation period, we find qualitatively similar results.

A major explanation for the fact that we observe more persistence in hedge fund returns than is usually found for mutual fund returns, is that liquidity in the hedge fund industry is severely restricted. While Berk and Green (2004) argue that past performance is unable to predict future returns of mutual funds due to the fact that mutual fund investors chase performance by investing more in funds that recently performed well (see, e.g. Chevalier and Ellison, 1997, Sirri and Tufano, 1998), hedge funds are characterized by lockup periods and redemption notice periods. Moreover, regulatory restrictions may limit the growth of (on-shore) hedge funds. When investment strategies employed by hedge fund managers cannot be scaled up without limit, performance fees and high-water mark contracts provide incentives to the manager to close the fund for new investors or otherwise limit the inflow of new money (see Goetzmann, Ingersoll and Ross, 2001). However, the persistence found above may not be exploitable if the funds in the top deciles are closed for new investments. To address this issue[9], we analyze the subsequent performance of the top three deciles, while concentrating only on those funds that are actually taking new money. While our database pro-

[9] We are grateful to the referee for this suggestion.

Table 11: **Persistence Estimates of the top three deciles (raw returns)**

	Average raw returns of the three top deciles			
	One-Quarter		Four-Quarter	
Decile	all funds	open funds	all funds	open funds
8	0.168	0.177	0.159	0.154
	(0.034)	(0.036)	(0.035)	(0.038)
9	0.196	0.219	0.191	0.190
	(0.045)	(0.050)	(0.050)	(0.049)
10 (winners)	0.204	0.218	0.202	0.217
	(0.066)	(0.073)	(0.110)	(0.116)
winners - losers	0.120	0.135	0.082	0.096
	(0.079)	(0.083)	(0.080)	(0.079)

Each quarter, funds are sorted into ten rank portfolios based on their previous one-quarter or four-quarter raw returns, respectively. Next, average raw returns over the next one or four quarters are computed, for each decile. Using returns from 1994-2000, this produces a time-series for each decile of 22 average one-quarter returns, and 16 (overlapping) average four-quarter returns. The numbers in the table are the annualized time-series averages and their standard errors in parentheses. The standard errors are corrected for autocorrelation based on the Newey-West approach. The columns labelled "open funds" are based on average returns across the subset of funds in that decile that are classified as open for investment. The figures employ a weighting procedure to eliminate look-ahead bias.

vides information about whether or not a fund is closed for investment, this applies only at the time the data were purchased. To solve this problem, we use money flows during the evaluation period to classify funds as closed or open for investment. In particular, we define funds as being "closed for investment" if average cash flows during the four quarters before the end of the evaluation period are less than 1%[10].

Table 11 presents the estimated average returns for the top three deciles when we exclude funds that are classified as closed for investment and con-

[10]Experimenting with alternative cut off rates led to very similar results.

strasts them with the corresponding figures based on the entire sample of funds. In case of decile 10, the average return increases from 20.4% to 22.2% at a quarterly horizon, while in case of an annual horizon, the average return increases from 20.2% to 21.7% (corrected returns). From this table we conclude that the persistence results are robust for excluding funds that are classified as closed for new investments. Apparently, the persistence is not driven by well performing funds that are closed for new money, suggesting that it might be exploitable for investors.

5 Concluding remarks

Empirical studies analyzing the performance of hedge funds are hampered by high attrition rates, due to fund liquidation and the possibility that funds stop reporting to the database vendor. The results in this paper clearly indicate that fund liquidation is driven by historical returns, attrition rates being higher for funds that perform poorly. Given endogenous liquidation, standard ways of analyzing persistence in performance are affected by look-ahead bias, as one is implicitly conditioning upon the fund having observed returns for a number of consecutive quarters. To eliminate such biases, it is possible to use a weighting procedure, which requires an appropriate model that relates fund survival to fund performance and other observables.

The empirical model for hedge fund liquidation estimated in this paper indicates that historical performance is an important factor explaining fund

liquidation, where performance in the more distant past is of smaller importance. Moreover, if the aggregated return over a previous predetermined period is negative, implying that it is unlikely for the manager to receive the incentive fee, a hedge fund has a much higher probability to liquidate. Other significant factors explaining survival are fund age, net asset value, investment style and the magnitude of the incentive fee. The impact of age is nonlinear, with lower attrition rates for young and mature funds. Using the empirical liquidation model, we determined the persistence in fund returns with and without correcting for look-ahead bias, using a simple weighting procedure. The results indicate that look-ahead bias is quite severe. While ter Horst, Nijman and Verbeek (2001) find that look-ahead bias is of minor importance for mutual funds, this paper finds that it can be quite important for hedge funds, whose attrition rates are higher. For example, without correcting for look-ahead bias, expected future returns of poorly performing funds may be overestimated by as much as 3.8% per year, a number which is statistically significant and higher than the typical 2% per year that is associated with survivorship bias. This stresses the importance in empirical studies of correcting for look-ahead bias in addition to survivorship bias. The finding that the greater total risk of hedge funds over their mutual fund counterparts exacerbates look-ahead bias confirms the results in Brown et al. (1992) who introduce the idea that look-ahead bias is a theoretical result of the cross-sectional dispersion of volatility across funds.

For the one quarter horizon, the corrected results indicate a clear pattern

of positive persistence in raw fund returns. That is, the best 20 to 30% of the funds are expected to provide above average returns in the subsequent evaluation period too. For the annual horizon, the pattern is also consistent with positive persistence, but statistically insignificant. In order to check whether the presence of cross-sectional variation in expected returns due to style or risk characteristics explains the observed persistence patterns in raw returns, we also examined persistence in style-adjusted returns. By subtracting from the raw hedge fund returns the return of the corresponding style benchmark, and following the same procedure as in case of raw returns, we determined the persistence in relative returns with and without correcting for look-ahead bias. At a quarterly and annual horizon the graphs show that, on average, the top deciles outperform their style benchmark. For the top 10% of the hedge funds this outperformance is around a statistically insignificant 6% for an annual horizon, and around 6.7% (annualized) for a quarterly horizon. At a biannual horizon we mainly found underperformance of the hedge funds with respect to their style benchmark. Interestingly, persistence in hedge fund performance seems to be located in both the top and bottom parts of the distribution. That is, poorly performing funds tend to underperform during the next 12 months, while the best performing funds tend to outperform.

The average excess returns on a winner-loser strategy at the annual horizon during the period 1994-2000 are 8.2% and 9.9%, based on raw and style-adjusted returns, respectively. Despite the lack of statistical significance,

these numbers are potentially economically important. A major explanation for the fact that we observe more persistence in hedge fund returns than is usually found for mutual fund returns, is that liquidity in the hedge fund industry is severely restricted. While Berk and Green (2004), argue that much of the persistence in mutual fund returns is competed away by mutual fund investors rationally shifting their capital in search of superior investments, hedge funds are characterized by lockup periods and redemption notice periods. Regulatory restrictions may limit the growth of (on-shore) hedge funds. Further, when investment strategies employed by hedge fund managers cannot be scaled up without limit, performance fees and high-water mark contracts provide incentives to the manager to close the fund for new investors or otherwise limit the inflow of new money (see Goetzmann, Ingersoll and Ross, 2001). A robustness check, where we consider funds with very low or negative cash flows as "closed for investment", shows very similar returns for the top three deciles. This suggests that the persistence results are robust, and that they might be exploitable for investors.

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