# Fund liquidation, self-selection and look-ahead bias in the hedge fund industry

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# Fund liquidation, self-selection and look-ahead bias in the hedge fund industry[1]

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**Abstract**

A wide range of empirical biases hampers hedge fund databases. In this paper we focus upon survival-related biases and disentangle look-ahead biases due to self-selection of funds and due to fund termination. Self-selection arises because funds voluntarily report their information to data vendors and may decide to stop doing so. By extending existing methodology, we analyze persistence in hedge fund performance over the period 1994-2000, taking into account the above biases. The results show that look-ahead biases due to liquidation and self-selection enforce each other and may lead to overestimating expected returns by as much as 8% per year. Overall, the results are consistent with positive persistence in hedge fund returns at horizons of two and four quarters.

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# 1 Introduction

During the last decade, the hedge fund industry has grown enormously. Hedge funds differ from mutual funds and other investment vehicles by their lack of regulation[1], with limited transparency and disclosure, and by their internal structure (see, e.g., Fung and Hsieh, 1997). For example, most hedge funds try to achieve an absolute return target, irrespective of global market movements, while hedge fund managers typically have incentive-based contracts. Accordingly, hedge funds have a broad flexibility in the type of securities they hold and the type of positions they take. On the other hand, 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.

Their non-standard features make hedge funds an interesting investment vehicle for investors with potential diversification benefits. A wide range of academic papers examines hedge fund performance and its persistence (see, e.g., Brown, Goetzmann and Ibbotson, 1999, Agarwal and Naik, 2000, Boyson, 2003, Capocci and Hübner, 2004, Baquero, Ter Horst and Verbeek, 2004). Both for the mutual fund industry (Sirri and Tufano, 1998) and the hedge fund industry (Agarwal, Daniel and Naik, 2003), it is reported that money flows chase past performance. Berk and Green (2004) present a theoretical model that explains that persistence can be competed away by investors rationally shifting their money in search for superior investments. In the hedge fund industry, however, the presence of liquidity restrictions that prevent investors to quickly shift their money from one fund to the other, may result in genuine (short-run) persistence even if investors allocate their money according to past performance (see Baquero, Ter Horst and Verbeek, 2004).

In this paper we analyze the persistence in hedge fund performance taking into account a number of potentially important biases that are present in hedge funds databases (see Fung and Hsieh, 1997, or Ackermann, McEnally and Ravenscraft, 1999) or are induced by the employed methodology. One of these biases is self-selection bias that arises due to the fact that hedge

[1]U.S. hedge funds are defined by their freedom from regularity controls of the Investment Company Act of 1940.

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. Self-selection bias exists either because underperformers 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.

In addition to self-selection bias another better-known bias, survivorship bias, also significantly affects standard measures of performance persistence of hedge funds (see, e.g. Brown, Goetzmann and Ibbotson (1999)). This bias is more severe than in the mutual fund industry due to the much higher attrition rate (about 14% per year for hedge funds versus about 5% per year for mutual funds). Attrition of hedge funds is due to a number of reasons, such as liquidation, closed to new investments or because the manager voluntarily decides to stop reporting. This in contrast to mutual funds where attrition is usually related to fund termination (liquidation or merger with other funds). Ackermann, McEnally and Ravenscraft (1999) argue that the previously mentioned self-selection bias and the survivorship bias offset each other. While it may be the case that, e.g., average fund returns are more or less unaffected by the joint operation of endogenous self-selection and liquidation, it is not possible, in general, that these two processes leave the cross-sectional and time-series distributions of returns unaffected. A final issue is backfilling bias, which arises because hedge funds are typically added to a database with an instant history.

While most studies attempt to correct for 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 (see, e.g. Carhart, 1997, and Ter Horst, Nijman and Verbeek, 2001). Look-ahead bias (or multi-period sampling bias) arises because persistence studies require returns to be observed during a number of consecutive periods. A recent study of persistence in performance of hedge funds of Baquero, Ter Horst, and Verbeek (2004) finds that look-ahead bias seriously affects the results and that correcting for look-ahead bias is essential. For instance, without correcting for look-ahead bias due to fund liquidation, average raw returns (within a given ranking decile) might be overestimated by as much as 5% when persistence is analyzed at an annual level. However, in Baquero, Ter Horst and Verbeek (2004) it is assumed that self-selection is exogenous. If self-selection would be mainly driven by good performing funds that are closed to new investment, this may have a compensating impact upon performance and persistence measures, such that liquidation bias and self-selection bias offset each other. On the other hand, if self-selection is negatively related to past performance, correcting for self-selection bias may exacerbate the liquidation bias corrections and thus strengthen the reported persistence patterns in hedge fund performance. Consequently, it is an interesting question to separately identify the impact of liquidation bias and self-selection bias in hedge fund persistence.

In this paper we analyze the persistence in hedge fund performance taking into account both liquidation and self-selection bias. The question whether past performance is indicative of future performance has been extensively studied for mutual funds. The results are somewhat mixed, but in general it can be concluded that there is little evidence of performance persistence of mutual funds (see, e.g., Carhart, 1997, Ter Horst and Verbeek, 2000, Wermers, 2003, Bollen and Busse, 2004). For hedge funds recent studies show some evidence of short term performance persistence (see, e.g. Agarwal and Naik, 2000, Bares, Gibson and Gyger, 2002) while at longer horizons the results are more ambiguous (see, e.g., Brown, Goetzmann and Ibbotson, 1999, Brown and Goetzmann, 2003). None of these studies corrects for the possibility of look-ahead bias. Baquero, Ter Horst and Verbeek (2004) correct for look-ahead bias due to fund liquidation and find exacerbated persistence patterns in hedge fund performance, particularly at the annual horizon.

In this paper we make a number of contributions to the hedge funds literature. First, we empirically examine the factors that affect self-selection bias by identifying variables from reports supplied by data vendors. Interestingly, past performance appears to have a significant and negative impact upon the probability that a fund decides to stop reporting. That is, poorly performing funds are more likely to disappear from the TASS database at their own request. Second, we propose a method that will correct for self-selection bias separately from the look-ahead bias due to fund liquidation. Finally, while disentangling the effects of liquidation bias and self-selection bias, we analyze the persistence in hedge fund performance over various horizons, using the TASS database of hedge funds over the period 1994-

2000. The results indicate that, in addition to liquidation bias, correcting for self-selection bias is important. Both biases work in the same direction and their combined impact may result in overestimating expected returns within a given decile by as much as 7.6% per year.

The structure of this paper is as follows. In Section 2 we discuss the TASS database, analyze fund attrition and relate it to liquidation and self-selection. Moreover, we estimate probit specifications for both the liquidation and the self-selection decisions. Section 3 explains how one can correct for look-ahead bias due to liquidation and self-selection when analyzing persistence in hedge fund performance and how these two biases can be disentangled. Empirical results concerning persistence at different horizons are presented in Section 4, while Section 5 concludes.

# 2 Liquidation and Self-selection

The data used in this paper are from TASS Management Limited and contain information of 1797 hedge funds over the period 1994-2000, where we restrict attention to funds reporting in US$. Although the TASS database contains information of hedge funds since 1979, we focus on the period 1994-2000 for several reasons. First, information on "dead" funds is available only for funds that disappeared since 1994, and second, the number of funds before 1994 is very small. As mentioned above, whether or not we observe returns for a given fund depends upon two main issues. First, the fund may be liquidated. Second, if the fund is not liquidated, its management may prefer to not report returns and other information to TASS. We refer to this second decision as self-selection. Another potential problem is backfilling bias or instant history bias, which arises because when funds are included in the TASS database for the first time, they come with a history of several quarters. We take backfilling bias into account by only using information on a fund once its age exceeds one year.

In the TASS database, some information on the reason why a fund disappeared form the sample is provided. For example, we find explanations like "This fund liquidated end of August 1996.", "Due to the Fund Managers request this fund has been taken off the database.", or "This fund is closed for new investments.". In order to disentangle the different selection processes, we construct a variable that contains a code for the disappearance

| disappearance reason | number of funds | year preceding disappearance average return | average net money flow |
|---|---|---|---|
| 1: liquidated or closed down | 316 | −1.7% | −3.7% |
| 2: at fund manager's request | 177 | 0.2% | 9.4% |
| 3: closed to new investors | 32 | 0.7% | 15.8% |
| 4: closed (unknown) | 77 | −0.9% | 0.6% |
| 5: matured | 10 | −0.1% | −4.8% |

Table 1: Reasons of Disappearance. For each disappearance code, the table lists the number of funds that during 1994-2000 dropped from the TASS database due to this reason, the average quarterly return and net money flows over the preceding four quarters.

reason. We used the following codes and scanned the reported disappearance record for the following expressions: 1. liquidated or closed down, 2. at fund manager's request, 3. closed to new investors, 4. closed (unknown), and 5. matured. We consider reasons 2, 3 and 5 as self-selection, while reason 1 is considered as liquidation. In order to classify funds that disappeared due to an unknown reason (reason 4), we estimate the quarterly money flows of the funds following the procedure mentioned in Agarwal, Daniel and Naik (2003). We aggregated these money flows over the four quarters preceding fund attrition. Using this information, funds with disappearance reason 4 (unknown) are classified as liquidated if the cumulative net money flows over the final year are negative, while otherwise it is considered as self-selected. In Table 1 we report the number of funds that disappeared, the reason of disappearance, and we report the average quarterly net money flow[2], and the average quarterly return over the year preceding disappearance

From Table 1 we observe that a total of 612 hedge funds disappear from the data set during the period 1994-2000. Moreover, for the funds that liquidated or closed down the average quarterly return in the year preceding the disappearance is −1.7%, while for the funds that disappeared at the fund manager's request or are closed to new investors this average quarterly return is 0.2% and 0.7%, respectively. A similar pattern is observed for the average net money flow, which is negative for the funds that liquidated (−3.7%) while it is strongly positive (9.4% and 15.8%) for the funds that

[2] Quarterly net money flows are defined as $[NAV_{i,t} - NAV_{i,t-1}(1 + r_{i,t})]/NAV_{i,t-1}$, where $NAV_{i,t}$ denotes the size of the fund (net asset value) at the end of quarter $t$ and $r_{i,t}$ is the return for fund $i$ during quarter $t$.

self-selected. Apparently, low past returns combined with a net money outflow increase the likelihood that a fund will liquidate. After classifying the different disappearance reasons, we identify 360 funds that disappear from the database due to liquidation, while 210 funds self-select themselves out of the database.

In Table 2 we report the average quarterly returns and the average quarterly net money flows for funds that self-select, liquidate or survive during the sample period 1994 - 2000. For example, the first row indicates that, in the first quarter of 1994, the average return of funds that liquidated before the end of our sample period is $-2.61\%$, while it is $-1.83\%$ for funds that survived until 2000. The table clearly shows that funds that liquidate during the sample period have substantial lower average returns and net money flows than funds that self-select or survive. The average return for funds that liquidate is about 0.50% per quarter, while funds that self-select or survive have an average quarterly return of 2.04% and 3.59%, respectively. The average quarterly net money flows exhibit a similar pattern. Funds that liquidate have an average quarterly net money flow of only 2.49%, while funds that self-select or survive have an average net money flow of 7.47% and 9.07%, respectively. Combining the three subsamples gives an average quarterly return and net money flow of 3.06% and 7.78% (not reported). Note that the average returns of the surviving funds are about 2.1% (per annum) higher than the average return of the combined samples. This number is usually referred to as survivorship bias (see, e.g. Malkiel, 1995 and Liang, 2000). The liquidation bias is defined as the difference between the average returns of the combination of the subsamples of self-selected and surviving funds and the combination of all three subsamples. This bias is about 2.2% (per annum) (see, e.g. Baquero, Ter Horst and Verbeek, 2004). Finally, we can define self-selection bias as the difference between the subsamples of liquidated and surviving funds and the combination of all three subsamples. This bias is about 1.2% (per annum).

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). Consequently, we also analyze liquidation and self-selection at the quarterly level. In the remainder of the paper liquidation

| **Quarter** | self-selected | | liquidated | | survivors | |
|---|---|---|---|---|---|---|
| | return | net flow | return | net flow | return | net flow |
| 94-I | −1.39% | 6.47% | −2.61% | 8.59% | −1.83% | 6.33% |
| 94-II | 0.43% | 1.57% | 2.64% | 10.12% | 0.97% | 8.71% |
| 94-III | 1.60% | 8.85% | −0.46% | 3.55% | 2.27% | 8.54% |
| 94-IV | −1.63% | −0.89% | −1.06% | 1.78% | −0.73% | 2.40% |
| 95-I | 3.31% | 8.07% | 2.40% | 3.24% | 4.47% | 12.92% |
| 95-II | 3.59% | 11.48% | 0.90% | 1.32% | 5.11% | 6.83% |
| 95-III | 3.56% | 1.21% | 0.48% | 1.01% | 4.71% | 7.18% |
| 95-IV | 2.32% | 3.28% | 2.94% | 2.26% | 3.64% | 1.60% |
| 96-I | 3.44% | 7.81% | 0.90% | −0.66% | 3.32% | 8.39% |
| 96-II | 8.20% | 9.48% | 3.48% | 12.50% | 6.06% | 11.40% |
| 96-III | 1.18% | −1.01% | 1.07% | 0.47% | 2.25% | 14.04% |
| 96-IV | 4.47% | 7.90% | 3.69% | 7.70% | 6.68% | 14.63% |
| 97-I | 4.45% | 23.39% | 4.27% | 11.09% | 4.32% | 13.79% |
| 97-II | 4.59% | 4.78% | 2.60% | 3.13% | 5.35% | 12.14% |
| 97-III | 5.40% | 11.12% | 5.94% | 13.48% | 7.83% | 15.64% |
| 97-IV | −2.83% | −6.56% | −2.12% | −2.30% | −0.50% | 5.75% |
| 98-I | 2.81% | 9.73% | 0.53% | 3.63% | 5.73% | 19.48% |
| 98-II | −5.64% | 16.47% | −2.24% | 0.80% | −0.66% | 9.76% |
| 98-III | −2.77% | 6.68% | −6.63% | 0.25% | −4.98% | 2.63% |
| 98-IV | 0.64% | 9.00% | −0.33% | 2.40% | 5.85% | 9.14% |
| 99-I | 1.13% | 35.39% | −2.25% | −8.82% | 3.70% | 2.96% |
| 99-II | 4.19% | −3.48% | 1.45% | −3.28% | 8.45% | 9.48% |
| 99-III | −3.38% | −0.49% | −1.14% | −9.41% | 0.69% | −3.29% |
| 99-IV | 11.38% | 9.01% | −2.36% | −3.06% | 13.36% | 17.20% |
| 00-I | − | − | − | − | 5.96% | 0.81% |
| average (unweighted) | 2.04% | 7.47% | 0.50% | 2.49% | 3.59% | 9.07% |
| average (weighted) | 2.15% | 7.35% | 1.03% | 3.03% | 4.14% | 7.78% |

Table 2: Average quarterly returns and net money flows of US hedge funds in the TASS database that self-select, liquidate or survive during the sample period 1994-2000. The row labeled 'average (weighted)' reports the weighted averages (weighted by the number of funds per quarter) over the sample period, while the row 'average (unweighted)' reports the unweighted averages.

will be denoted by an indicator variable $L$, such that $L_{it} = 0$ if fund $i$ has liquidated in quarter $t$ ($L_{it} = 1$ otherwise). Given that a fund is not liquidated, returns may not be available due to self-selection, and we let $S_{it} = 0$ if fund $i$ attrited the database because of self-selection ($S_{it} = 1$ otherwise). This implies that a return $r_{it}$ is observed only if $L_{it}S_{it} = 1$.

For both decisions we specify a binary choice model. First, the liquidation decision is modelled by means of a binary probit model, with latent variable equation

$$L^*_{it} = \alpha_{10} + \sum_{j=1}^{6} \gamma_{1j} r_{i,t-j} + x'_{it}\beta_1 + \varepsilon_{1,it}, \tag{1}$$

where $x_{it}$ denotes a vector of fund characteristics that affect liquidation. The observed indicator satisfies $L_{it} = 0$ (liquidation) if $L^*_{it} < 0$ and 1 otherwise. The specification allows fund returns up to six quarters ago to affect the liquidation decision. It is assumed that $\varepsilon_{1,it}$ is $IIN(0,1)$, independent of the explanatory variables. We expect that $\gamma_{1j} > 0$ for several of the lags, so that the better performing funds are, ceteris paribus, less likely to liquidate.

Similarly, we specify a process for the self-selection decision as a probit model based on

$$S^*_{it} = \alpha_{20} + \sum_{j=1}^{6} \gamma_{2j} r_{i,t-j} + x'_{it}\beta_2 + \varepsilon_{2,it}, \tag{2}$$

with $S_{it} = 0$ (self-selection) if $S^*_{it} < 0$ and 1 otherwise. While the set of conditioning variables $x_{it}$ in both equations is in principle the same, a priori exclusion restrictions may be imposed.

In Table 3 we present some summary statistics of the fund-specific variables ($x_{it}$) that were included in the liquidation and self-selection models. Most of these variable also appear in related specifications of Brown, Goetzmann and Park (2001) and Baquero, Ter Horst and Verbeek (2004). Summary statistics are based on 20138 fund/period observations. 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).

| Variable | mean | std.dev | min | max |
|---|---|---|---|---|
| offshore | 0.59 | 0.49 | 0 | 1 |
| Incentive Fees | 15.87 | 7.82 | 0 | 50 |
| Mng. Fees | 1.63 | 1.08 | 0 | 8 |
| Underwater | 0.14 | 0.34 | 0 | 1 |
| ln(NAV) | 16.73 | 1.79 | 7.58 | 23.30 |
| ln(Age) | 3.80 | 0.66 | 2.56 | 5.62 |
| $\ln(\text{Age})^2$ | 14.89 | 5.09 | 6.58 | 31.55 |
| StDev | 0.08 | 0.08 | 0.00 | 1.63 |

Table 3: Summary statistics fund-specific variables. (20138 fund/period observations)

The annual management fee varies between 0% and 8% (of net asset value) and has an average of 1.6%. The underwater indicator is equal to one if a fund has a negative cumulative return over the past eight quarters[3], which occurs in 14% of the cases. 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 corresponds to about 18 million US$. Total risk is measured by the standard deviation of the previous six quarterly returns (StDev).

Fund size (NAV) is not available for each quarter for all funds in our sample. Therefore, 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 be imputed. This occurs in 7% of the cases. Because we do not want to eliminate these observations, we estimated the liquidation and self-selection model using two specifications, one including size (based on 20138 fund/period observations) and one excluding size (based on 21297 fund/period observations). In Table 4 we report the estimation results based on 20138 fund/period observations for the probit specification for liquidation versus non-liquidation (including size). Note that non-liquidation means that it is still possible that the fund self-selected during the sample period. Therefore, we subsequently remove all the fund/period observations where a fund liquidated (321 fund/period observations) and estimate the probit specification to explain self-selection versus survival (including size), where survival implies that the fund did not

[3]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 | 1.839 | 0.796 | StDev | 1.855 | 0.401 |
| $r1$ | 1.049 | 0.227 | ln(Age) | $-0.764$ | 0.418 |
| $r2$ | 0.687 | 0.235 | ln(Age)$^2$ | 0.111 | 0.055 |
| $r3$ | 1.039 | 0.240 | offshore | $-0.143$ | 0.055 |
| $r4$ | 0.192 | 0.249 | Incentive Fees | $-0.009$ | 0.003 |
| $r5$ | 0.239 | 0.229 | Mng. Fees | $-0.033$ | 0.022 |
| $r6$ | 0.406 | 0.247 | underwater | $-0.278$ | 0.069 |
| ln(NAV) | 0.156 | 0.015 | time | $-0.028$ | 0.004 |
| Loglikelihood: $-1417.524$ | | | Chi-squared test: 459.00 $(DF = 15)$ | | |
| pseudo$R^2$: 0.139 | | | $(p = 0.000)$ | | |

Table 4: Estimation results liquidation model, including net asset value (size) variable (20138 fund/period observations).

| Parameters | Estimate | Std.error | Parameters | Estimate | Std. Error |
|---|---|---|---|---|---|
| intercept | 2.475 | 0.890 | StDev | 0.530 | 0.410 |
| $r1$ | 1.195 | 0.240 | ln(Age) | $-0.722$ | 0.458 |
| $r2$ | 0.668 | 0.250 | ln(Age)$^2$ | 0.097 | 0.060 |
| $r3$ | 0.634 | 0.247 | offshore | $-0.006$ | 0.059 |
| $r4$ | 0.140 | 0.264 | Incentive Fees | $-0.010$ | 0.004 |
| $r5$ | $-0.335$ | 0.234 | Mng. Fees | 0.029 | 0.027 |
| $r6$ | $-0.028$ | 0.263 | underwater | $-0.024$ | 0.088 |
| ln(NAV) | 0.113 | 0.016 | time | $-0.024$ | 0.005 |
| Loglikelihood: $-1100.890$ | | | Chi-squared test: 171.05 $(DF = 15)$ | | |
| pseudo$R^2$: 0.072 | | | $(p = 0.000)$ | | |

Table 5: Estimation results self-selection model, including net asset value (size) variable (19817 fund/period observations).

liquidate and still prefers to report their performance to the data vendor. The estimation results are reported in Table 5. The estimation results for both specifications excluding size are reported in the appendix (Table 8 and Table 9). All models include a linear time trend to take account of aggregate shocks to the probabilities of liquidation and self-selection.

From an inspection of Tables 4 and 5, it appears that the impact of historical returns is somewhat stronger for the liquidation decision than for the self-selection decision. For both specifications, only the first three past quarterly returns have a significant impact on the self-selection decision. In the liquidation model, positive coefficients indicate that higher historical returns imply a lower probability to liquidate. In the self-selection model, they indicate that funds with high historical returns are more likely to survive, where surviving means that the fund did not liquidate and decides to keep reporting to the data vendor. However, in the liquidation model an additional impact of historical returns is captured by the underwater indicator, which is highly significant. The negative coefficient implies that if a fund has a negative aggregate return over the most recent eight quarters, it is significantly more likely to liquidate. That is, if a fund is underwater, implying that the manager will not receive the incentive fee, the probability of liquidation increases substantially, potentially due to excessive risk-taking (compare Goetzmann, Ingersoll and Ross, 2003). For self-selection, the impact of being underwater seems negligible, both economically and statistically. The impact of size (ln(NAV)) is significantly positive, i.e. smaller funds have a higher probability to liquidate or self-select than larger funds (ceteris paribus).

The results for the self-selection model are clearly at odds with the idea that good performing funds are more likely to stop reporting because they no longer wish to attract new investors. Also, it does not appear to be the case that large funds, which may suffer most from decreasing returns to scale of their investment strategies, are more likely to voluntary stop reporting because managers are unwilling to attract new money. Total risk, as measured by the standard deviation over the past six quarters, does not significantly affect the self-selection decision, while it significantly affects the liquidation decision, implying that high risk hedge funds have a higher probability to not-liquidate. This seems a counterintuitive result, and apparently contradicts the findings of Brown, Goetzmann and Park (2001) who find that high risk funds have a higher probability to liquidate. However, our results suggest that high risk funds experience a somewhat lower liquidation probability, given the return history and fund size. It indicates that high risk funds are allowed to have more extreme negative returns than low risk funds before they decide to liquidate (see Baquero, Ter Horst and Verbeek, 2004)

In both specifications, age has significant nonlinear impact, indicating that old funds with past poor performance are less likely to disappear than young funds with a similar poor performance. This finding corresponds to the results of Boyson (2003a, 2003b) who performs unconditional and conditional survival tests, and finds that age and manager ability are positively related to the likelihood of a manager's survival. Offshore funds have a larger probability to liquidate than onshore funds, while given that the fund did not liquidate, being an offshore fund does not significantly affect the self-selection decision. The impact of the incentive fee on the non-liquidation probability or survival probability is significantly negative, i.e. a higher incentive fee, ceteris paribus, increases the probability that a fund will liquidate or self-select.

Although it is suggested in the literature that self-selection bias and survivorship or look-ahead bias will offset each other, our results show that most of the factors in our specifications affect the liquidation and self-selection decisions in the same direction. The magnitudes of the estimated coefficients in the self-selection model are typically smaller than those in the liquidation model. The management fee has a different sign across the two models, but is insignificant in both models. On the basis of the estimation results of these two models, we conclude that self-selection is not exogenous, and we expect that look-ahead biases due to self-selection and liquidation will not offset, but even strengthen each other, and correcting for both biases will be necessary. In the next section, we describe how both biases can be disentangled and how persistence analysis can be corrected for these biases. This can be achieved using an extension of the methodology reported in Ter Horst, Nijman and Verbeek (2001).

# 3 Disentangling look-ahead bias and self-selection bias

Suppose interest lies in analyzing fund performance over the period $t+1$ to $t+s+1$, conditional upon a given information set $\Omega_t$. In some applications, this information set may be empty. In others, $\Omega_t$ will contain indicators for the fund's investment style and its previous performance (e.g. its performance decile during a ranking period). This means that interest lies in the conditional distribution of returns $r_{i,t+1}, ...r_{i,t+s+1}$ given $\Omega_t$, which we denote by

$$f(r_{i,t+1}, ..., r_{i,t+s+1}|\Omega_t), \tag{3}$$

where $f$ is generic notation for a (conditional) density function. Empirically, we can only obtain full information about this joint distribution if the fund has not liquidated or self-selected during the period $t+1$ to $t+s+1$. Let us denote this by $Y_{it} = 1$. This means we can empirically identify

$$f(r_{i,t+1}, ..., r_{i,t+s+1}|\Omega_t, Y_{it} = 1). \tag{4}$$

If (3) and (4) are identical, liquidation and self-selection is exogenous and no biases arise if the sample selection process is ignored. However, as we have seen in the previous sections, it is likely that both liquidation and self-selection are determined by historical performance and other characteristics that may have a relation with returns during period $t+1$ to $t+s+1$. For example, funds that have high levels of (idiosyncratic) risk are more likely to have extreme returns and are typically less likely to survive (see Brown et al., 1992, or Hendricks, Patel and Zeckhauser, 1997). The difference between (3) and (4) drives the look-ahead bias in performance measures.

A first step in solving this identification problem is obtained by writing (compare Ter Horst, Nijman and Verbeek, 2001)

$$f(r_{i,t+1}, ...r_{i,t+s+1}, z_{it}|\Omega_t) = w_{it} f(r_{i,t+1}, ...r_{i,t+s+1}, z_{it}|\Omega_t, Y_{it} = 1), \tag{5}$$

where

$$w_{it} = \frac{P\{Y_{it} = 1|\Omega_t\}}{P\{Y_{it} = 1|r_{i,t+1}, ...r_{i,t+s+1}, \Omega_t, z_{it}\}}. \tag{6}$$

is a weight factor. In this expression, $z_{it}$ denotes a vector of observable fund characteristics and other variables that are relevant for fund liquidation and self-selection from $t+1$ to $t+s+1$. The weight factor $w_{it}$ indicates how the distribution, conditional upon $Y_{it} = 1$ can be adjusted to recover the distribution of returns unconditional upon $Y_{it} = 1$, which is what we are really interested in. If we are willing to assume that the denominator of (6) does not depend upon $r_{i,t+1}, ..., r_{i,t+s+1}$ directly, but only through the history of returns and other fund characteristics (contained in $z_{it}$), the weights can be identified and estimated empirically.

This approach to correct for sample selection bias is different from the econometric approaches to these problems based upon the work of Heckman (1979) and Hausman and Wise (1979), because the latter approaches assume that the model of interest is conditional upon the same set of variables as the selection processes. In our case, this is inappropriate. Instead, we assume that the set of (observable) explanatory variables $z_{it}$ can be chosen such that, conditional upon $z_{it}$, selection is independent of current and future, potentially unobserved, returns. This approach is referred to as "selection upon observables" and is employed in, e.g., Fitzgerald, Gottschalk and Moffitt (1998) to correct for attrition bias from the Panel Study of Income Dynamics.

In the current application, $Y_{it} = 1$ implies that the fund has not liquidated during $t+1$ to $t+s+1$ and has not stopped reporting due to self-selection. Let us refer to these two conditions as $Y_{1,it} = 1$ and $Y_{2,it} = 1$, respectively, so that $Y_{it} = Y_{1,it}Y_{2,it}$. Referring to the two binary choice models specified above, it holds that

$$Y_{1,it} = \prod_{\tau=t+1}^{t+s+1} L_{i\tau}$$

and

$$Y_{2,it} = \prod_{\tau=t+1}^{t+s+1} S_{i\tau}.$$

Then $Y_{1i} = 0$ says that fund $i$ is not used in the analysis because of fund liquidation, while $Y_{2i} = 0$ says that it is not used because of self-selection. To disentangle the impact of these two processes, first note that we can write

$$\begin{aligned} w_{it} &= \frac{P\{Y_{2,it} = 1|\Omega_t, Y_{1,it} = 1\}}{P\{Y_{2,it} = 1|r_{i,t+1}, ...r_{i,t+s+1}, z_{it}, \Omega_t, Y_{1,it} = 1\}} \\ &\quad \times \frac{P\{Y_{1,it} = 1|\Omega_t\}}{P\{Y_{1,it} = 1|r_{i,t+1}, ...r_{i,t+s+1}, z_{it}, \Omega_t\}} \\ &= w_{2,it}w_{1,it}. \end{aligned} \tag{7}$$

If $w_{2,it} = 1$ for all $i, t$, then self-selection is exogenous and does not lead to look-ahead bias in measures for performance (persistence). In this case, liquidation implies look-ahead bias if $w_{1,it} \neq 1$ and this is the case analyzed by Baquero, Ter Horst and Verbeek (2004). In this paper, we disentangle the two sources of bias by identifying both sets of weights and applying corrections with one weight or their product. The correction for self-selection is conditional upon the fund not liquidating. The application of the above correction weights allows us to determine to what extent we get different results if we only correct for selection bias due to liquidation, assuming self-selection is random.

To identify the weights we need to assume that the probabilities do not depend upon future, potentially unobserved returns. Further, we assume that self-selection and fund liquidation are mutually exclusive events, and both describe "absorbing states". That is, once a fund stops reporting to TASS, it will not return in the database at a later stage. Then the denominator of $w_{1,it}$ can be determined from the binary choice model as

$$P\{Y_{1,it} = 1 | r_{i,t+1}, ...r_{i,t+s+1}, z_{it}, \Omega_t\} = \tag{8}$$

$$P\{L_{i,t+1} = 1 | r_{it}, r_{i,t-1}, ..., x_{i,t+1}\}...P\{L_{i,t+s+1} = 1 | r_{i,t+s}, r_{i,t+s-1}, ..., x_{i,t+s+1}\}$$

and similarly for $w_{2,it}$. The right hand side probabilities are described by the probit model in (4) provided the appropriate functional form (and conditioning variables) are chosen in $x_{it}$. Consequently, consistent estimation of the binary choice models for liquidation and self-selection allows us to obtain consistent estimators for the two sets of weights, which enables us to correct for look-ahead bias due to these two processes and separate their effects upon performance measures and their persistence. To estimate the numerator in (7) when $\Omega_t$ takes on a limited number of different values (e.g. past performance decile), it is most convenient to use a simple nonparametric approach (see below).

# 4 Persistence in Hedge Fund Performance

Empirical studies on the behavior of investors in hedge funds have shown that money-flows chase past performance (see, e.g., Agarwal, Daniel and Naik, 2003, or Baquero and Verbeek, 2004). Moreover, several recent studies document some evidence of persistence in hedge fund performance at quarterly horizons (see, e.g., Agarwal and Naik, 2000, Bares, Gibson and Gyger, 2002), while at longer horizons the results are more ambiguous (see, e.g., Brown, Goetzmann and Ibbotson, 1999, Brown and Goetzmann, 2003). Apparently, if investors take into account that persistence is mainly a short term phenomenon, looking at past performance provides potentially valuable information for investing in hedge funds. However, while all the above mentioned studies on performance persistence of hedge funds control for the effects of survivorship bias, none of them corrects for look-ahead bias due to fund liquidation or self-selection. Baquero, Ter Horst and Verbeek (2004) correct for look-ahead bias due to liquidation and find positive persistence at horizons of one and four quarters, although the statistical significance is weak. In the previous section we extended the methodology of the latter paper to allow us to disentangle the effects of look-ahead bias and self-selection bias. In this section we will apply this method on analyzing performance persistence of hedge funds, and examine whether it is indeed the case that self-selection bias and survivorship effects offset each other, as claimed by Ackermann, McEnally and Ravenscraft (1999).

First, we will examine performance persistence in raw returns by examining whether winning funds over the last two or four quarters are more likely to be top performers in the next two to four quarters. We follow a similar procedure as Baquero, Ter Horst and Verbeek (2004), by distinguishing a ranking period of two or four quarters and an evaluation period of two or four quarters. The ranking based on past performance is broken down into ten deciles (decile 10 contains the past winners), and in the subsequent evaluation period we calculate the average returns of each of these deciles. The procedure is repeated over the entire sample period, moving forward by one quarter at the time and adjusting the sample by including the funds that have a sufficiently long return history. Fund-of-funds are excluded to avoid double counting. To avoid backfilling bias, returns are only used in this exercise if the fund has a history of at least four quarters.

First of all, in order to prevent spurious performance persistence patterns that are due to look-ahead bias (see, e.g. Carpenter and Lynch, 1999), we apply the correction method as introduced by Ter Horst, Nijman and Verbeek (2001). Basically, we repeat the analysis of Baquero, Ter Horst and Verbeek (2004) by multiplying the performance measure (e.g. average return over the ranking period) with a weight factor $w_{1,it}$ which is the ratio of an unconditional non-liquidation probability and a conditional non-liquidation probability. This conditional probability can be obtained from our estimated liquidation process reported in Section 3, while the unconditional probability is equal to the ratio of funds that were not liquidated during the ranking period and the number of funds present at the beginning of the ranking period. In a similar way we correct the average returns over the evaluation period, where the unconditional probabilities are conditional upon the fund's decile during the ranking period.

Second, we correct for self-selection bias by multiplying the performance measure with a second weight factor $w_{2,it}$. This factor is the ratio of the conditional probability of non-self-selection (conditional upon not being liq-

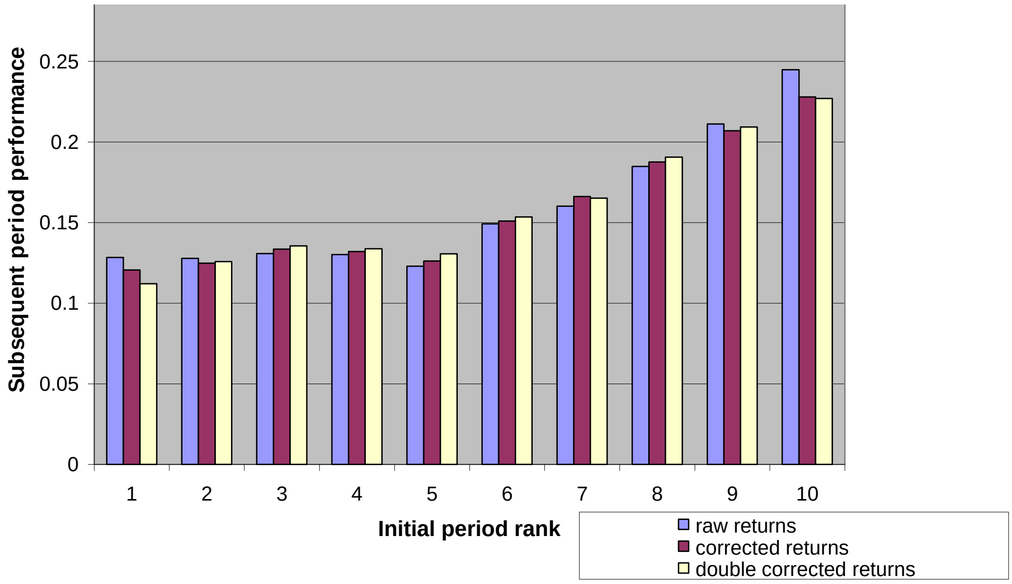


Figure 1: Bi-quarterly persistence in raw returns.

uidated), and an unconditional non-self-selection probability (conditional upon not being liquidated). This conditional probability can be obtained from the estimated self-selection process of Section 3. The unconditional probability is now equal to the ratio of funds that were not self-selected minus the ones that were liquidated during the ranking period, and the number of funds present at the beginning of the ranking period minus the ones that were liquidated during the ranking period. Similarly, we correct the average returns over the evaluation period once more, but adjusting for the fact that the unconditional probabilities are now conditional upon the fund's decile during the ranking period.

The results of the above exercises are provided in Tables 6 and 7 for the two-quarter and four-quarter horizon, respectively, and summarized in Figures 1 and 2. We report the empirical persistence of raw returns at bi-quarterly and annual horizons, without any correction (raw returns), with a correction for look-ahead bias due to liquidation (corrected returns) and with a correction for look-ahead bias due to both liquidation and self-selection (double corrected returns). All estimates are based on the full sample of hedge funds, excluding fund-of-funds.

Table 6: **Persistence Estimates (Raw returns)**

| | Average performance (raw returns) | | | |
|---|---|---|---|---|
| | Two-Quarters | | | |
| | (1) | (2) | (3) | (1) - (3) |
| Decile | non corrected | corrected | double corrected | |
| 1 (losers) | 0.1284 | 0.1206 | 0.1122 | 0.0162 |
| | (0.0794) | (0.0865) | (0.0953) | (0.0200) |
| 2 | 0.1278 | 0.1248 | 0.1258 | 0.0020 |
| | (0.0335) | (0.0367) | (0.0379) | (0.0068) |
| 3 | 0.1308 | 0.1336 | 0.1356 | -0.0048 |
| | (0.0291) | (0.0297) | (0.0302) | (0.0038) |
| 4 | 0.1302 | 0.1320 | 0.1338 | -0.0036 |
| | (0.0242) | (0.0244) | (0.0247) | (0.0028) |
| 5 | 0.1230 | 0.1262 | 0.1306 | -0.0076 |
| | (0.0218) | (0.0239) | (0.0257) | (0.0062) |
| 6 | 0.1492 | 0.1510 | 0.1536 | -0.0044 |
| | (0.0255) | (0.0262) | (0.0260) | (0.0055) |
| 7 | 0.1602 | 0.1662 | 0.1652 | -0.0050 |
| | (0.0296) | (0.0289) | (0.0291) | (0.0069) |
| 8 | 0.1848 | 0.1876 | 0.1906 | -0.0058 |
| | (0.0416) | (0.0439) | (0.0448) | (0.0076) |
| 9 | 0.2112 | 0.2070 | 0.2094 | 0.0018 |
| | (0.0529) | (0.0494) | (0.0525) | (0.0055) |
| 10 (winners) | 0.2448 | 0.2280 | 0.2270 | 0.0178 |
| | (0.0810) | (0.0806) | (0.0785) | (0.0115) |
| winners - losers | 0.1164 | 0.1072 | 0.1148 | 0.0016 |
| | (0.0918) | (0.0939) | (0.0997) | (0.0232) |

Each quarter, funds are sorted into ten rank portfolios based on their previous two-quarters. Next, average returns over the next two quarters are computed, for each decile. Using returns from 1994-2000, this produces a time-series for each decile of 21 average two-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 liquidation bias, and the double corrected employ a weighting procedure to eliminate liquidation and self-selection bias.

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

| | Average performance (raw returns) | | | |
|---|---|---|---|---|
| | Four-Quarters | | | |
| | (1) | (2) | (3) | (1) - (3) |
| Decile | non corrected | corrected | double corrected | |
| 1 (losers) | 0.1601 | 0.1108 | 0.0838 | 0.0763 |
| | (0.0911) | (0.0924) | (0.0956) | (0.0203) |
| 2 | 0.1658 | 0.1503 | 0.1367 | 0.0291 |
| | (0.0600) | (0.0566) | (0.0537) | (0.0144) |
| 3 | 0.1459 | 0.1297 | 0.1211 | 0.0248 |
| | (0.0455) | (0.0415) | (0.0400) | (0.0013) |
| 4 | 0.1451 | 0.1369 | 0.1320 | 0.0130 |
| | (0.0387) | (0.0378) | (0.0356) | (0.0073) |
| 5 | 0.1418 | 0.1383 | 0.1338 | 0.0080 |
| | (0.0252) | (0.0244) | (0.0257) | (0.0550) |
| 6 | 0.1342 | 0.1314 | 0.1273 | 0.0069 |
| | (0.0318) | (0.0333) | (0.0356) | (0.0072) |
| 7 | 0.1403 | 0.1369 | 0.1328 | 0.0075 |
| | (0.0381) | (0.0393) | (0.0390) | (0.0087) |
| 8 | 0.1565 | 0.1536 | 0.1573 | -0.0008 |
| | (0.0325) | (0.0317) | (0.0333) | (0.0071) |
| 9 | 0.1900 | 0.1853 | 0.1823 | 0.0076 |
| | (0.0468) | (0.0505) | (0.0485) | (0.0094) |
| 10 (winners) | 0.2029 | 0.1888 | 0.1825 | 0.0204 |
| | (0.1016) | (0.0971) | (0.0975) | (0.0147) |
| winners - losers | 0.0428 | 0.0781 | 0.0987 | -0.0559 |
| | (0.0693) | (0.0718) | (0.0745) | (0.0207) |

Each quarter, funds are sorted into ten rank portfolios based on their previous four-quarter returns, respectively. Next, average returns over the next four quarters are computed, for each decile. Using returns from 1994-2000, this produces a time-series for each decile of 17 (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 liquidation bias, and the double corrected employ a weighting procedure to eliminate liquidation and self-selection bias.

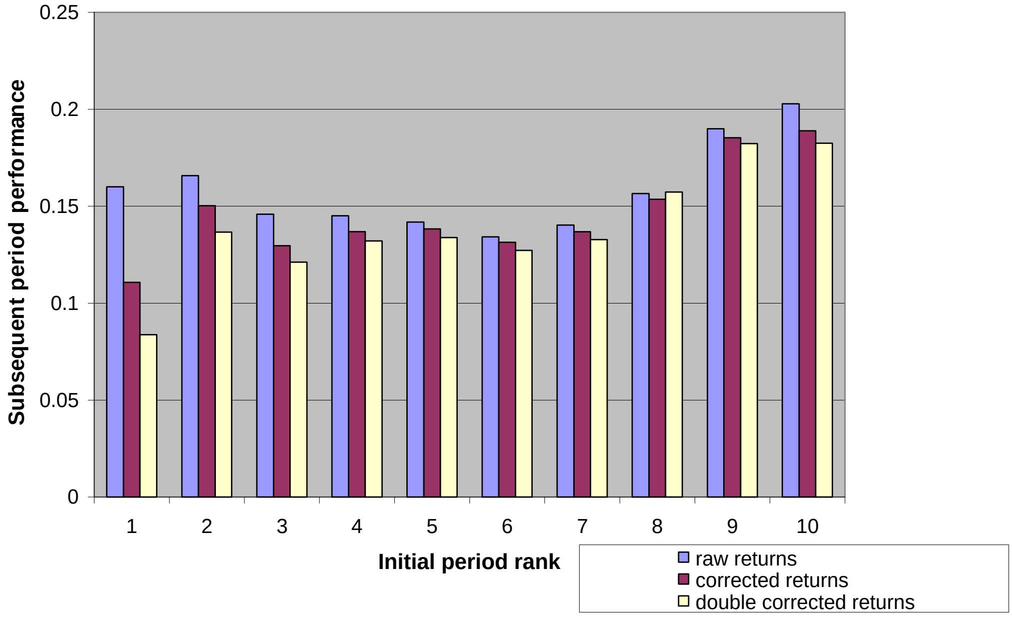


Figure 2: Four-quarterly persistence in raw returns.

The results are remarkable. First of all at a bi-quarterly as well as an annual horizon we observe evidence of a persistence pattern which is without corrections (raw returns) slightly $J$-shaped. As discussed in Hendricks, Patel and Zeckhauser (1997) and Ter Horst, Nijman and Verbeek (2001) such a pattern could be explained by look-ahead bias. If we correct for look-ahead bias the $J$-shape flattens, and we find positive persistence in performance. The expected return on a zero investment portfolio that is long in winners (decile 10) and short in losers (decile 1), is approximately 9.9% at the annual horizon and 11.5% and the bi-quarterly horizon. The persistence pattern is much stronger for the bi-quarterly horizon, and this corresponds to the findings of Brown, Goetzmann and Ibbotson (1999), Agarwal and Naik (2000), and Bares, Gibson and Gyger (2002), who also find evidence of a persistence pattern at a short term horizon, while the pattern is less stronger at longer horizons. However, note that these studies do not correct for look-ahead bias, and that without corrections, average returns may be overestimated by as much as 4.9% (decile 1, annual horizon). For additional discussion on correcting for look-ahead bias we refer to Baquero, Ter Horst and Verbeek (2004).

The most striking result is that when we also correct for self-selection bias the positive persistence pattern is further strengthened. The persistence pattern at an annual horizon is even much stronger than before. This contradicts the claim of Ackermann, McEnally and Ravenscraft (1999), and shows that self-selection bias does not offset liquidation bias. For most of the deciles we see that liquidation bias and self-selection bias have the same sign. For decile 1 at an annual horizon it even has an impact of an additional 2.7%, which implies that average returns may be overestimated by as much as 7.6% if no correction for look-ahead bias due to liquidation and self-selection is employed. At a bi-quarterly level, the impact of self-selection bias is somewhat less, but for decile 1 until decile 4 the impact is statistically significant at an annual level.

# 5 Concluding remarks

When analyzing hedge fund performance and its persistence, a multi-period sampling bias or look-ahead bias may arise if funds attrite from the available databases due to reasons that relate to their performance. In this paper, we consider two important reasons why funds may disappear from hedge fund databases. First, funds may liquidate or close down due to their poor performance, and, second, hedge fund managers may voluntary stop reporting to a database vendor (self-selection). In this paper we empirically investigate the determinants of fund liquidation and self-selection, and analyze the impact of these two process upon persistence measures of hedge fund performance.

Using information from the TASS database, covering the period 1994-2000, we find that both liquidation and self-selection are more likely for hedge funds that have a poor return history. While the relationship is somewhat stronger for the liquidation process, this implies that look-ahead bias due to self-selection affects persistence measures in the same direction as does look-ahead bias due to fund liquidation. Consequently, double correcting persistence tables leads to a stronger persistence pattern than obtained in Baquero, Ter Horst and Verbeek (2004), where look-ahead bias due to liquidation is the focus of interest. At the annual horizon, the expected excess return on a winner minus loser portfolio, based upon previous year returns, is close to 10% when both biases are taken into account, while it is only 4% if no correction is employed. These biases are almost entirely located in the bottom decile, where expected returns may be overestimated by almost 8% per year. The difference is statistically significant. These results are in conflict with the suggestion in Ackermann, McEnally and Ravenscraft (1999) that positive and negative survival-related biases may cancel out.

# Appendix

| Parameters | Estimate | Std.error | Parameters | Estimate | Std. Error |
|---|---|---|---|---|---|
| intercept | 3.729 | 0.750 | StDev | 1.247 | 0.381 |
| $r1$ | 1.035 | 0.211 | ln(Age) | $-0.413$ | 0.398 |
| $r2$ | 0.892 | 0.225 | ln(Age)$^2$ | 0.072 | 0.053 |
| $r3$ | 1.236 | 0.231 | offshore | $-0.086$ | 0.052 |
| $r4$ | 0.464 | 0.240 | Incentive Fees | $-0.011$ | 0.003 |
| $r5$ | 0.358 | 0.218 | Mng. Fees | $-0.085$ | 0.020 |
| $r6$ | 0.061 | 0.169 | underwater | $-0.392$ | 0.067 |
| | | | time | $-0.026$ | 0.004 |
| Loglikelihood:-1509.352 | | | Chi-squared test: 344.93 ( $DF = 14$) | | |
| pseudo$R^2$: 0.103 | | | ($p = 0.000$) | | |

Table 8: Estimation results liquidation model, excluding net asset value (size) variable (21297 fund/period observations).

| Parameters | Estimate | Std.error | Parameters | Estimate | Std. Error |
|---|---|---|---|---|---|
| intercept | 3.869 | 0.839 | StDev | 0.040 | 0.375 |
| $r1$ | 1.371 | 0.234 | ln(Age) | $-0.500$ | 0.443 |
| $r2$ | 0.748 | 0.241 | ln(Age)$^2$ | 0.076 | 0.058 |
| $r3$ | 0.770 | 0.240 | offshore | 0.042 | 0.057 |
| $r4$ | 0.216 | 0.237 | Incentive Fees | $-0.011$ | 0.004 |
| $r5$ | $-0.028$ | 0.184 | Mng. Fees | $-0.019$ | 0.025 |
| $r6$ | 0.278 | 0.266 | underwater | $-0.078$ | 0.085 |
| | | | time | $-0.023$ | 0.004 |
| Loglikelihood: -1153.794 | | | Chi-squared test: 135.32 ($DF = 14$) | | |
| pseudo$R^2$: 0.055 | | | ($p = 0.000$) | | |

Table 9: Estimation results self-selection model, excluding net asset value (size) variable (20972 fund/period observations).

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