D ESTIMATING PROBABILITIES OF HEDGE FUND LIQUIDATION

A failure of an individual hedge fund or a group of hedge funds can have adverse implications for financial stability, mainly through an impact on asset prices and market liquidity and through potential losses for the hedge funds' creditors. Therefore, it is important to understand the underlying reasons behind hedge fund failures and to create indicators that would allow strains in the hedge fund sector to be monitored. To this end, this special feature focuses on cases of hedge fund liquidation and estimates the main factors that could point to a higher liquidation risk, using a panel logit analysis. On the basis of the estimation results, a composite indicator is proposed, which shows that the probabilities of hedge fund liquidation increased substantially in 2008 and remained elevated at the beginning of 2009.

INTRODUCTION

This special feature represents a continuation of the work on hedge fund failures that was presented in several previous issues of the Financial Stability Review (FSR).[1] Its purpose is to gauge the factors that are useful in predicting hedge fund failures and to create, on the basis of the results of such analysis, a composite indicator of hedge fund liquidation risk.

A hedge fund failure is a relatively broad term. For investors and creditors, it constitutes a loss on their investments and credit exposures, whereas it represents a failed asset management venture for the hedge fund manager. However, a failure may not necessarily involve the loss of all investor capital or losses for the hedge fund's creditors. Therefore, it is important to distinguish between different types of hedge fund closures.

Owing to the lack of good data and the frequent interplay of several factors behind hedge fund failures, any classification and ranking of the main underlying causes is somewhat arbitrary. Nevertheless, the majority of hedge funds probably close primarily because they are losing investors, money or both. However, start-up hedge funds may opt to discontinue their operations predominantly on account of unsuccessful fund-raising efforts, since too small an investor capital base does not yield a sufficient flow of fee income and the benefits of economies of scale cannot be reaped.

In addition to such business-driven reasons, there is some evidence that hedge funds also often shut down on account of operational risk factors, such as the misrepresentation of investments, a misappropriation of funds/general fraud, unauthorised trading and style breaches, or inadequate resources and infrastructure.[2] The departure of key managers may also lead to the eventual liquidation of a fund.

Finally, there are hedge fund collapses, such as those of LTCM in September 1998, or Amaranth Advisors in September 2006, that may or may not have systemic implications and are of particular relevance for financial stability analysis. The results of a forensic-style ex post examination of such collapses can provide useful lessons for various market participants, but predicting them ex ante using commercially available hedge fund databases, which are the main source of quantitative data on large samples of hedge funds, is a very difficult task.

Whereas exits from databases that are driven by business considerations are more traceable, closures due to operational risk factors or collapses are very hard to identify and predict, not least because of the inadequate scope, quality and completeness of data reported to databases by hedge fund managers. Identifying and predicting such failures may also require some form of indirect, i.e. regression-based, analysis of hedge funds' investment portfolios, which is beyond

1 See Box 6 in ECB, *Financial Stability Review*, June 2007, and ECB, "Net asset value triggers as early warning indicators of hedge fund liquidation", *Financial Stability Review*, December 2007.

2 See S. Feffer and C. Kundro, "Understanding and Mitigating Operational Risk in Hedge Fund Investments", *Capco Institute White Paper Series*, March 2003.

the scope of this study. Nonetheless, some information on, for example, the risk profiles of individual hedge funds might provide useful warning signals of potential problems ahead.

DATA AND SAMPLE SELECTION

The empirical panel logit analysis of hedge fund closures presented in this special feature is based on information available in the Lipper TASS database, which is probably the most frequently used database for hedge fund attrition analysis, partly because it assigns a status code to hedge funds in its "graveyard" module that is based on attrition types. There are eight status codes: fund liquidated, no longer reporting, unable to contact the fund, fund closed to new investment, merged into another entity, program closed, fund dormant, and unknown.

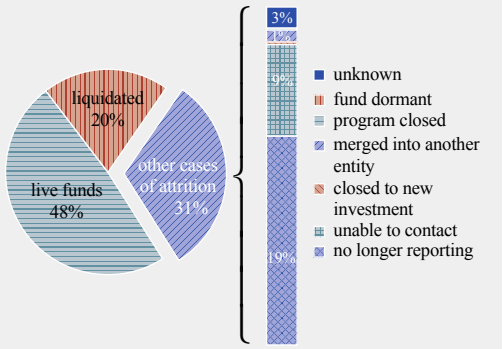
As shown in Chart D.1, liquidation was the most frequent reason why hedge funds had exited the database as at 30 March 2009. The destiny of most other hedge funds that left the database is not known and may not necessarily be linked to the respective fund's closure. Moreover, there is some evidence that survival and hazard functions of liquidated hedge funds differ from those of hedge funds that have stopped reporting for other reasons.[3] Therefore, further analysis is focused on cases of hedge fund liquidation only.

The data sample that was used for the estimation begins in January 1994, because the reasons why hedge funds left the database started to be tracked in that year and because it is also the starting date of the Credit Suisse/Tremont hedge fund indices that were used to benchmark hedge funds' returns. The monthly time series span 14 years and end in December 2007, 15 months before the date on which the database was downloaded (30 March 2009). Hedge funds that had no return data at the end of the sample and that had no graveyard status at the time of the download were treated as non-liquidation exits, and were thus excluded from the analysis.

The details of data filtering steps are depicted in Charts D.2.a and D.2.b, which show that the

Chart D.1 Distribution of single-manager hedge fund attrition cases

(percentage of total investment records in the database as at 30 March 2009)



Sources: Lipper TASS database and ECB calculations.
Note: Excluding funds of hedge funds. Numbers do not add up due to rounding.

final unbalanced sample consisted of 1,365 live and liquidated single-manager hedge funds, or 11% of all return time series in the database.[4] Chart D.2.a shows that the isolated impact of some filters was quite considerable. The cumulative impact of all filters applied in the selected sequence is illustrated in Chart D.2.b.

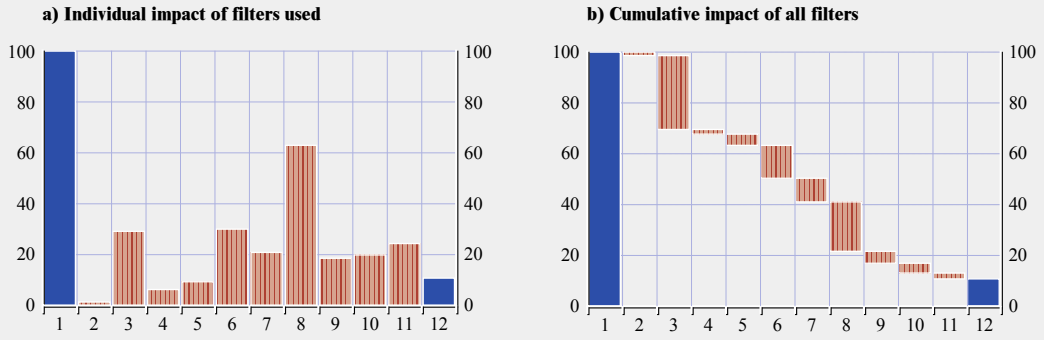
The sample was also cleansed of multiple sub-fund structures that typically represent onshore and offshore versions or separate classes of hedge fund shares (usually differing in the currency of denomination), which basically correspond to the same pool of money managed in highly correlated or nearly identical ways. Taking multiple sub-fund structures into account should yield more robust estimates that would not be biased as a result of varying numbers of sub-funds or their selective listing in the database by hedge fund managers.

Where several sub-fund structures, instead of one fund or sub-fund, were listed in the database, the structure with the largest capital under management was chosen, as measured by the 75th percentile of historical data on the amount of capital under

3 See N. Baba and H. Goko, "Survival Analysis of Hedge Funds", *Bank of Japan Working Paper Series*, No 06-E-05, March 2006.
4 There were 295 (22% of selected funds) liquidation events within the sample period and 81 (6%) took place after the sample period.

Chart D.2 Data filtering results

(percentage of investment return time series in the database)



1 12,656 investment records.
2 Undefined strategy, quarterly and other than net-of-fees returns.
3 Fund of funds.
4 Missing or illogical information on management and incentive fees, high-watermark provisions, use of leverage, co-investment.
5 Incomplete information on redemption restrictions.
6 No information on the use of derivatives.
7 Fewer than 18 monthly investment return observations.
8 Insufficient capital-under-management data.
9 Capital under management less than USD 10 million.
10 Non-liquidation exits.
11 Sub-fund structures.
12 Final sample, 1,365 single-manager hedge funds.

Sources: Lipper TASS database and ECB calculations.
Note: "Insufficient capital data" means that were fewer than 13 consecutive capital observations before the fund's last reported returns and, as a result, some fund-specific capital-based variables could not be computed at least once.

management. Sub-funds were identified by an automatic procedure that involved comparing the names of funds within the same investment strategy and the names of their management firms (investment advisors), as well as checking the correlation between their historical returns.

It is also important to note that it was assumed that liquidations took place immediately after the last reported returns, since there is no way of accounting for a possible liquidation bias, i.e. the fact that hedge fund managers can stop reporting to a database before the final liquidation value of a fund has been determined.[5] Hence, the forecast window within which a hedge fund's liquidation could occur was set to the next month.

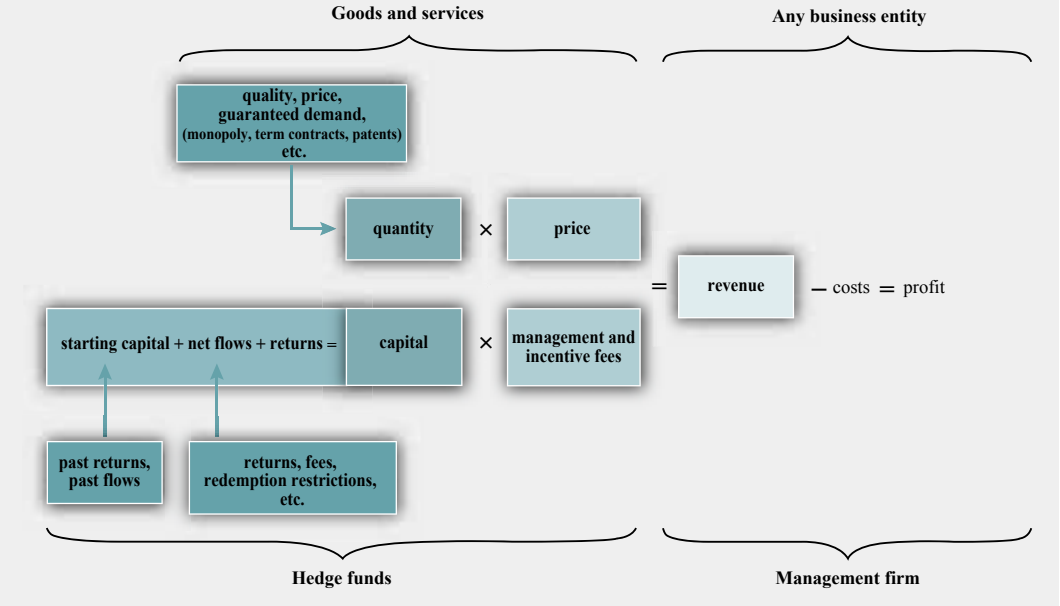
EXPLANATORY VARIABLES

Before proposing a list of variables that might be good predictors of cases of hedge fund liquidation, it is useful to compare hedge funds with other business entities. Such a comparison is depicted in Chart D.3 and highlights how various aspects of hedge funds' activities are interconnected. This framework is particularly helpful for the selection of variables that may be good predictors of hedge fund liquidations due to business difficulties associated with an insufficient or declining capital base or poor investment returns.

From the asset management business point of view, the size of capital under management is equivalent to the sales volume, but there are also other reasons why it is such an important factor in hedge fund liquidation risk. For example, some investors have allocation limits, either absolute (minimum investment amount) or relative (as a maximum proportion of the hedge fund's total capital). Furthermore, a large volume of capital under management serves investors as a proxy for the quality of operational risk controls and the overall maturity of the hedge fund's management firm.

5 See Box 6 in ECB, *Financial Stability Review*, June 2007.

Chart D.3 A hedge fund as a business entity



The variables that might help to predict cases of hedge fund liquidation can be grouped into several sets that refer to specific aspects of hedge fund activities. These sets, as well as descriptions of the individual explanatory variables, are provided in Table D.1.

The first set of variables refers to investment performance, with a further split into historical and recent returns. This differentiation is due to the fact that investment and divestment decisions may be driven by different evaluation horizons.[6] A costly and time-consuming managerial due-diligence process may lead to lower responsiveness on the part of prospective investors to recent performance since more weight is likely to be attached to the historical track record. By contrast, active monitoring by existing investors may result in a higher sensitivity to weak recent returns. In addition, three subsets of return indicators were used: absolute returns, the performance relative to peers following the same investment strategy and the fund's strategy index performance relative to the return index of the hedge fund sector as a whole.

The second set of indicators aims to capture the risk profile of a hedge fund. It includes second and higher moments of hedge fund returns, information on the use of leverage and derivatives, as well as dummy variables for various investment strategies. In the list, there is also a volatility measure that was adjusted with the Cornish-Fisher expansion at a 99% confidence level. Moreover, in order to gauge the possible illiquidity of hedge fund investments or intentional return smoothing by a hedge fund manager, a first-order autocorrelation coefficient was used.[7]

The third set includes variables associated with the fee structure and incentives faced by a hedge fund manager. Quite often, incentive fees are accrued throughout the calendar year, but paid out only once, at the end of the year. The last

6 See G. Baquero and M. Verbeek, "A portrait of hedge fund investors: Flows, performance and smart money", *ERIM Report Series Research in Management*, August 2005.

7 See C. Asness, R. Krail and J. Liew, "Do Hedge Funds Hedge?", *The Journal of Portfolio Management*, Fall 2001, and M. Getmansky, A. W. Lo and I. Makarov, "An Econometric Model of Serial Correlation and Illiquidity in Hedge Fund Returns", *Journal of Financial Economics*, Vol. 74, 2004.

variable in this set captures the dynamics of this entitlement during a calendar year.[8]

Redemption restrictions comprise the fourth set of variables. All listed withdrawal constraints except the payout period serve as defenders of the hedge fund's capital base, which is equivalent to the sales volume from a business perspective (see Chart D.3).

Variables in the fifth group represent an attempt to check the impact of the competitive environment on liquidation risk by testing the importance of the level of, and changes in, the market share of the broad investment strategy which the hedge fund pursues. An increasing market share could be a sign of the strategy's attractiveness to investors. At the same time, such popularity might pull in new hedge fund managers and thereby intensify competition for profitable investment opportunities.[9]

The purpose of the sixth group is to account for a possible clustering of cases of hedge fund liquidation within the same investment strategy or spillover effects from other strategies. Such interdependence might arise from similar investment positions (crowded trades) or correlated shocks to the liability side of hedge funds' balance sheets stemming from prime brokers' actions or investors' redemptions.

The last set of variables is dedicated to various business-related issues. It includes a fund's age, capital under management, estimates of the US dollar amounts of management and incentive fee income, and monthly dummy variables. It is important to note that during the estimation sample period, the average size of a hedge fund increased, as did the general price level and the minimum size of a commercially viable hedge fund. To account for these factors, every monthly observation of capital under management and estimated US dollar fee income was divided by the median size of all hedge funds included in the estimation sample in that particular month.

ESTIMATION RESULTS

Given the set of explanatory variables, a panel logit model was estimated using a random effects specification with 63,554 observations.[10] The columns in the middle of Table D.1 report the estimation results for the baseline and for the final model specifications respectively. At the bottom of the table, the McFadden pseudo-R^2 and the Akaike and Bayesian information criteria provide information on the goodness of fit.

The baseline specification included all proposed explanatory variables, whereas the final specification was produced with the aim of finding a list of variables that would all be statistically significant. It was derived in the following way. In a first step, the dependent variable was regressed on a constant and all explanatory variables, thereby yielding the baseline model. In a second step, all explanatory variables with p-values above 0.4 were dropped, as were also all strategy and monthly dummy variables with p-values above 0.1. Then the model was re-estimated with the remaining list of variables, which were dropped one by one on the basis of the highest p-values until there were no more variables with p-values above 0.1. At this stage, variables with economically counterintuitive signs were removed and the one-by-one dropping procedure was run again to provide a final list of variables.

It should be noted, however, that – unlike what occurred in the baseline specification – the variable for the standard deviation of returns (volatility) was highly statistically significant (p-value close to zero) in all intermediate specifications until it

8 The fact that the amount of incentive fees is determined in January also explains the significance of November and December dummy variables. See also V. Agarwal, N. Daniel and N. Naik, "Why is Santa so kind to hedge funds? The December return puzzle!", March 2007, available at SSRN.

9 See also M. Getmansky, "The Life Cycle of Hedge Funds: Fund Flows, Size and Performance", *Working Paper*, Isenberg School of Management, University of Massachusetts, January 2005.

10 The specification was chosen on the basis of a Hausman test.

Table D.1 Explanatory variables and estimation results

	Baseline model		Final model		
	coefficient	p-value	coefficient	p-value	
Investment performance results					
Historical returns					
Historical return	-0.075	0.68			Compound monthly rate of return in the fund's reporting currency during the last 18 months.
Relative historical return	0.145	0.42			**Historical return** in US dollars minus the equivalent return of the respective Credit Suisse/ Tremont strategy index over the same period.
Relative historical strategy return	**0.400**	**0.03****			Compound monthly rate of return in US dollars of the respective Credit Suisse/Tremont strategy index during the last 18 months minus the equivalent return of the Credit Suisse/Tremont Broad Hedge Fund Index.
Relative 12-month return	-0.003	0.73			12-month return in US dollars minus 12-month return of the respective Credit Suisse/Tremont strategy index.
Latest returns					
R	-0.002	0.86			Current and lagged monthly net-of-fee returns in fund's reporting currency.
R(-1)	-0.013	0.40			
R(-2)	0.025	0.12			
R 6-month return	**0.030**	**0.07***			Latest 6-month **R**.
R current drawdown	**-0.029**	**0.09***			Current **R** drawdown based on the last 18 months.
Relative 6-month return	**-0.046**	**0.01*****	**-0.022**	**0.00*****	**R 6-month return** in US dollars minus 6-month return of the respective Credit Suisse/Tremont strategy index.
Relative strategy return	0.027	0.44			Current, lagged and 6-month returns in US dollars of the respective Credit Suisse/Tremont strategy index minus the equivalent return of the Credit Suisse/Tremont Broad Hedge Fund Index.
Relative strategy return (-1)	**0.058**	**0.09***			
Relative strategy return (-2)	0.033	0.37			
Relative 6-month strategy return	**-0.050**	**0.02****			
Risk profile					
Historical volatility	**-0.143**	**0.09***			Standard deviation of **R** during the last 18 months.
Historical skewness	-0.061	0.51			Skewness of **R** during the last 18 months.
Historical kurtosis	0.045	0.20			Kurtosis of **R** during the last 18 months.
Historical Cornish-Fisher volatility	-0.007	0.78			**Historical volatility** adjusted with the Cornish-Fisher expansion at a 99% confidence level (z = -2.33; if both skewness and kurtosis are zero, the adjustment will yield negative **historical volatility**).
Leverage	0.013	0.94			Dummy variable, 1 if the fund uses leverage and zero otherwise.
Derivatives	**0.342**	**0.02****	**0.323**	**0.02****	Dummy variable, 1 if the fund uses derivatives and zero otherwise.
Autocorrelation of returns	**0.093**	**0.74**			First-order autocorrelation coefficient of **R** during the last 18 months.
Strategy [1,9]	[–0.13, 0.89]	[0.35, 0.93]			Dummy variables, 1 if coincides with the fund's investment strategy and zero otherwise. No dummy variable for the dedicated short bias strategy.
Fees and incentives					
Personal capital	0.102	0.43			Dummy variable, 1 if the manager co-invested own money and zero otherwise.
High watermark	**-0.452**	**0.00 *** **	**-0.479**	**0.00 *** **	Dummy variable, 1 if a high-watermark provision applies and zero otherwise.

Table D.1 Explanatory variables and estimation results (continued)

	Baseline model		Final model		
	coefficient	p-value	coefficient	p-value	
Management fee	-0.145	0.19	**-0.220**	**0.01****	Annual management fee as a proportion of average CUM.
Incentive fee	**0.020**	**0.06***	**0.017**	**0.08***	Annual performance fee as a proportion of returns above a high watermark and a hurdle rate, if any.
Non-negative YTD HWM incentive fee	**-0.004**	**0.00*****	**-0.003**	**0.00*****	Either zero or positive year-to-date return above a high watermark, if any, that was valid at the end of December the previous year multiplied by the **incentive fee**.
Redemption restrictions					
Lockup period	-0.020	0.15			Minimum investment holding period in months.
Redemption frequency	0.029	0.37			In months.
Notice period	**-0.421**	**0.00*****	**-0.366**	**0.00*****	In months.
Payout period	-0.201	0.15	**-0.239**	**0.08***	In months.
Competitive environment					
Strategy share	-2.400	0.14			Total CUM in US dollars of all funds belonging to the same broad strategy group as the fund in question as a proportion of total CUM in US dollars of all hedge funds in the sample.
1-month change in strategy share	-3.025	0.63			1, 3, 6 and 12-month changes in **strategy share**.
3-month change in strategy share	-1.833	0.78			
6-month change in strategy share	0.769	0.90			
12-month change in strategy share	**-7.058**	**0.08***			
Correlation of liquidations					
Liquidations within strategy	7.980	0.13	**9.234**	**0.05****	Current and lagged ratios of liquidated funds within the fund's strategy to all funds within the fund's strategy at the end of the previous month.
Liquidations within strategy (-1)	-4.272	0.56			
Liquidations within strategy (-2)	5.933	0.29			
Liquidations in all other strategies	2.703	0.90			Current and lagged ratios of liquidated funds outside the fund's strategy to all funds outside the fund's strategy at the end of the previous month.
Liquidations in all other strategies (-1)	**38.305**	**0.04****			
Liquidations in all other strategies (-2)	14.645	0.43			
Business-related issues					
Age	**-0.012**	**0.01*****	**-0.007**	**0.00*****	The current age of the fund in months.
Age^2	0.000	0.25			The squared **age**.
Capital	**-0.325**	**0.00*****	**-0.223**	**0.00*****	CUM in US dollars divided by the median CUM in that month.
1-month change in capital	0.050	0.61			1, 3, 6 and 12-month change in CUM in US dollars divided by the median CUM in that month.
3-month change in capital	-0.030	0.86			
6-month change in capital	-0.048	0.41			
12-month change in capital	0.013	0.81			
1-month percentage change in capital	-0.006	0.25			1, 3, 6 and 12-month percentage change in CUM in the fund's reporting currency.
3-month percentage change in capital	**-0.009**	**0.03****	**-0.011**	**0.00*****	
6-month percentage change in capital	**0.001**	**0.00*****			
12-month percentage change in capital	**-0.008**	**0.00*****	**-0.008**	**0.00*****	

Table D.1 Explanatory variables and estimation results (continued)

	Baseline model		Final model		
	coefficient	p-value	coefficient	p-value	
Capital x non-negative YTD HWM incentive fee	4.433	0.10*			CUM in US dollars at the end of December the previous year multiplied by **non-negative YTD HWM incentive fee** and divided by the median CUM in that month.
Capital x management fee	4.627	0.72			Manager's **management fee** income over the last 3 months divided by the median CUM in that month.
Quarterly change in capital x management fee	65.396	0.13			Difference between manager's **management fee** income over the last 3 months and the same income a quarter ago divided by the median CUM in that month.
Months Jan.-Oct., excluding Mar.	[–0.29, 0.46]	[0.13, 0.91]			Dummy variable for each month from January to October, except March.
November	0.603	0.04**	0.490	0.01***	Dummy variable, 1 if the current month is November and zero otherwise.
December	0.812	0.01***	0.686	0.00***	Dummy variable, 1 if the current month is December and zero otherwise.
Constant	-4.190	0.00***	-3.819	0.00***	
McFadden pseudo-R^2	15.96		13.34		
Akaike information criterion	3,299		3,275		
Bayesian information criterion	4,006		3,429		

Notes: CUM stands for capital under management. ***, ** and * denote statistical significance at the 1%, 5% and 10% levels respectively.

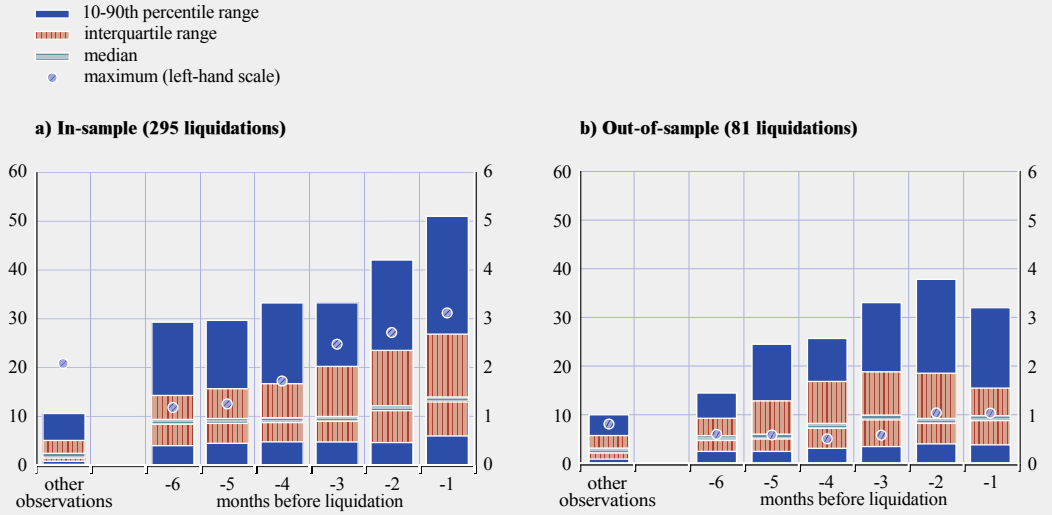
was dropped together with some other variables owing to a counterintuitive sign, suggesting that higher return volatility means lower liquidation risk. The Madoff fraud case, in which smooth and consistent returns should have raised a red flag, immediately comes to mind, but it is nevertheless quite likely that a self-selection bias might play a role here too. One could speculate that when a hedge fund with an attractive and smooth investment record self-selects to report to a database, it has not yet experienced a serious market shock and therefore remains vulnerable to a "black swan", "time bomb" or "left tail" event. The same could be said about hedge funds that pursue primitive "leveraged carry", out-of-the-money option-selling and other low-volatility but potentially devastating investment strategies, which have also often been likened to the collection of nickels in front of a steamroller.

The resulting final specification includes 15 variables and a constant. As expected, variables based on capital under management clearly dominate and there is at least one variable from each set of indicators except for the competitive environment group. Three and twelve-month percentage changes in, as well as the minimum level of, capital under management regularly feature in banks' credit agreements with hedge funds as net asset value-based triggers (see also Chart 4.20 in Section 4.2), and these estimation results confirm their importance. Even though there is one variable relating to relative returns in the final specification, the lack of absolute return variables could be explained by the fact that changes in the capital under management combine the impact of both net flows and returns, and thus seem to outperform pure return variables.

The presence of other variables in the final specification is more or less intuitive, although the November dummy has not been commonly found significant in similar studies. Moreover, the reasons for the importance of the payout period variable are not straightforward. One explanation could be that the longer the time after redemption that redeeming investors receive their money, the more they are discouraged from submitting withdrawal requests as a result of short-term factors. As regards the correlation

Chart D.4 Estimated probability of hedge fund liquidation before liquidation based on the estimation sample data

(in-sample period: Jan. 1994 – Dec. 2007; out-of-sample period: Jan. 2008 – Feb. 2009; percentage probability of liquidation)



Sources: Lipper TASS database and ECB calculations.
Note: In the out-of-sample analysis, the last six monthly observations before cases of non-liquidation attrition or last reported returns were excluded from computations. In the latter case, the destiny of a hedge fund after its last reported returns was not known, and therefore its last six monthly observations were excluded in order to ensure comparability.

between cases of hedge fund liquidation, it seems that contagion-like effects are present only among hedge funds belonging to the same broad investment strategy group.

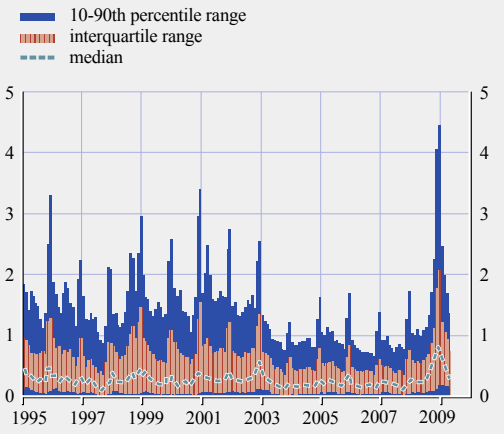
In addition to the statistical measures of the goodness of fit reported in Table D.1, Chart D.4 provides an illustration of model performance both within and outside the estimation window for the selected sample of hedge funds. In both cases, estimated probabilities of liquidation tended to increase as a liquidation event approached, and were also generally higher than probabilities estimated for the periods that were more than six months before a liquidation event (see the bars designated "other observations").

COMPOSITE INDICATOR

In order to derive an aggregate indicator of liquidation risk in the hedge fund sector, the coefficients obtained in the final specification could be used to compute a probability of liquidation for every hedge fund in the database that has enough information for the minimum set of required variables. Since the final specification includes only 15 variables, the number of eligible hedge funds increases in comparison with the

Chart D.5 Composite indicator of single-manager hedge fund liquidation risk

(Jan. 1995 – Apr. 2009; distribution of percentage probability of liquidation)



Sources: Lipper TASS database and ECB calculations.
Notes: Based on 2,152 single-manager hedge fund investment records. The most recent data are subject to incomplete reporting.

number of hedge funds used in the estimation sample, which was obtained after a conservative filtering procedure that is necessary to estimate the baseline specification. The distribution of these individual probabilities for each point in time is shown in Chart D.5, which represents the proposed composite indicator of liquidation risk.

CONCLUDING REMARKS

The proposed composite indicator of hedge fund liquidation risk confirms that the liquidation risk had increased markedly in the hedge fund sector by the end of 2008, and remained high thereafter. It is important to note, however, that the indicator reports the estimated risk of liquidation, which may not necessarily signify a collapse with the complete loss of investors' capital and large losses for creditor banks. Many hedge funds that close seem to do so for business reasons. Therefore, in order to better capture the risk of a hedge fund collapse, it would be desirable to have more variables related to the risk profile of a hedge fund, particularly as regards leverage, on which information is very scarce.

The current version of the indicator may undergo further modifications, as is common for such relatively complex indicators. Nevertheless, it will serve as a useful tool for monitoring developments in the hedge fund sector from a financial stability perspective.