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The Evolving Beta-Liquidity Relationship of Hedge Funds

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Abstract

Using an optimal changepoint approach, we find a structural change in the relation between hedge funds' stock market exposure and aggregate stock market liquidity that takes place in the period 2000 to 2002. Before the structural break, market betas have no relation to liquidity and only a few style categories of hedge funds show increased market presence when liquidity is low. After the break, the relationship is inverted, pointing towards an increased liquidity timing ability of hedge funds, as users of liquidity. We relate our findings to best execution rules and decimalization in the US stock market that were introduced in that period and impacted aggregate liquidity conditions. Furthermore, the returns to a momentum strategy display a similar structural break and momentum-loading funds constitute a sizeable proportion of hedge funds that manifest a distinct beta-liquidity evolution with a structural break in that period.

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1 Introduction

Hedge funds are sophisticated investors and their share of market volume has grown enormously in the past decade. Hedge funds claim to have lower or alternative risk exposures than traditional mutual funds, which makes them attractive to investors. In this paper, we raise the question of whether there is a systematic pattern in the US-stock market exposure of hedge funds that is related to market liquidity. This is relevant from the perspective of understanding the sources of performance of hedge funds and at the same time gives insight into the role that hedge funds play in market liquidity.

Hedge funds make use of the constantly changing investment opportunity set to deliver returns that are attractive to investors who might lack the sophistication to do this themselves. As a consequence, the returns of hedge funds display non-standard and dynamic risk exposures, see Fung and Hsieh (1997), Agarwal and Naik (2004) and Bollen and Whaley (2009). Also, increases in technology and automation of stock trading venues have made it possible to implement and execute ever faster and more sophisticated trading algorithms. This is visible in the type of dynamics observed in hedge fund exposures, see Patton and Ramadorai (2013).

Liquidity conditions affect the profit opportunities for hedge funds, as liquidity impacts the speed by which private information is incorporated in prices and the profitability of trading on anomalies, see Chordia et al. (2008), Chordia et al. (2014). Further, Ben-Rephael et al. (2010) find that the profitability of trading on the liquidity premium has declined markedly over the years. Consequently, if markets have become more liquid and efficient, and the returns to arbitrage trading have diminished, this should have had an impact on hedge fund returns. In this paper, we address the question of whether variations in the market exposure of hedge funds are related to aggregate market liquidity.

In addition, Chordia et al. (2014) identify distinct regimes in market efficiency related to the exogenous decreases in market liquidity that were caused by the consecutive reductions in the minimum tick size.¹ To account for the potential effect of such structural breaks, we adopt an optimal changepoint model for the stock market exposure of hedge funds which allows for breaks in the linear relation between hedge fund market betas and the level of aggregate market liquidity.

We find consistent evidence of a structural break in the beta-liquidity relationship that is predominantly located in the years 2000 and 2001. Moreover, there is a marked change in the direction and the level of exposures in relation to liquidity around the break: before the break, the stock market exposure of hedge funds and liquidity have no or little relationship. The exception is Global Macro and Equity-focused

¹ The minimum tick size on the NYSE was reduced from \$1/8 to \$1/16 in 1997 and it was reduced further to one cent in 2001.

hedge funds, for which a significant negative relationship is found. This is evidence of liquidity provision for hedge funds in some style categories. After the break, the relation between exposure and liquidity becomes strongly positive for all hedge fund strategies. In other words, the stock market exposure of hedge funds becomes significantly increasing with the liquidity of the market.

We conjecture that the location of a breakpoint at the beginning of the century and the direction of the shift in market exposures are related to the institutional changes of tick size decimalization and disclosure of execution quality in 2000 and 2001. The changes had the intention of improving market quality, but they had more widespread ramifications than just lower spreads. For example, they were partly response to and partly facilitation of the advent of automated and high-frequency trading. The effects have found to be large and measurable in spreads, market efficiency and the returns to anomaly-based strategies, see Chordia et al. (2008), Chordia et al. (2014).

Our paper suggests a consequence to what is known about the effects, which is that the role that hedge funds play in the market has changed because of it: before 2000, the presence of hedge funds in the stock market was relatively insensitive to liquidity conditions. After 2002, market presence is more tuned to periods of high liquidity.

The exact month in which the break occurs depends on the hedge fund portfolio composition and the specification for the time-varying market exposure. The result is robust to other specifications of the market index, choice of hedge fund portfolio and liquidity measure.

If hedge funds' market exposure is positively related to liquidity, their activities are not necessarily beneficial for other stock market participations, as their exposure is at its lowest when liquidity is most needed. A similar finding is in Lewis (2014), who finds that the recent activities of high-frequency traders in the US-stock market are not beneficial for other stock market participants. This contributes to the debate on whether the role of hedge funds in financial markets is beneficial at all times, see Eichengreen et al. (1998), Stiglitz (2000), Brown et al. (2000), Fung and Hsieh (2000) and Brav et al. (2008).

To discover the sources of the specific relation between liquidity and market exposure, we compute the returns to several dynamic strategies often employed by hedge funds and estimate the same breakpoint model. The strategies are pairs trading, momentum, reversal and a long-short liquidity strategy. From these, only momentum has a high number of funds that load on it and a similar changepoint in the beta-liquidity relation as hedge funds. With the evidence that momentum has a time-varying beta, see Daniel and Moskowitz (2013), there are broadly two ways to interpret our finding in the context of hedge funds. First, it could be that hedge funds are active and important momentum-traders, and that the amount of hedge fund capital dedicated to momentum is driving the momentum betas. This would be a more

widespread effect of hedge fund activities on markets, of which a few studies already point towards, see Aragon and Strahan (2011) and Franzoni and Plazzi (2013). Alternatively, it could be that time variation in momentum betas is driven by factors which have impacted hedge funds in a similar fashion. Both explanations could fit our findings.

We contribute to the literature on whether hedge funds and algorithmic traders add or demand liquidity. From the perspective of market efficiency, having sophisticated investors who trade on information improves the informational content of prices. But if this means that liquidity is absorbed in good times and not supplied in bad times, this makes the US-equity market less attractive as a source of funding. From analysis of actual trading patterns, Jylhä et al. (2014) find that hedge funds demand or supply liquidity, based on the absolute level of liquidity in the market. They find a significant change in behavior around the introduction of Autoquote on the NYSE in 2003. Autoquote enabled algorithmic trading, which is known to have led to a significant improvement in trading costs, see Hendershott et al. (2011). Further evidence on the impact of hedge funds and algorithmic traders on the microstructure level is presented in Hendershott and Riordan (2009) and Franzoni and Plazzi (2013). Aragon and Strahan (2011) find that forced selling of hedge fund positions has a direct impact on stock prices. In this paper we document a change in the relation between hedge fund exposure to the US stock market and market liquidity that occurs around 2000-2002. This finding points towards a changing role of hedge funds in the market, potentially due to technological and institutional changes.

Several recent studies explore the systematic linkages between hedge funds and the financial system, as in Adrian and Brunnermeier (2011) and Billio et al. (2012). Our results suggest that hedge funds' role in systemic risk might have increased in the years after 2000. It is possible that changes in trading structures and platforms have improved market liquidity, but have also facilitated market participants in leaving the market when volatility spikes coincide with liquidity dry-ups. This is evidence of good risk management from the perspective of a single institution, but a negative externality for the market.

Finally, our paper is related to the literature of the time-varying risk exposures of momentum trading. Momentum profits are found over long periods, and across diverse markets and asset classes and have been found to arise as a compensation for increased crash risk, liquidity, or due to limits to arbitrage, see Jegadeesh and Titman (1993), Grundy and Martin (2001), Chabot et al. (2009), Vayanos and Woolley (2013), Daniel and Moskowitz (2013) and Asness et al. (2013). Our results on the beta-liquidity relation of momentum profits add to the evidence that buying winners and selling losers is a strategy with a specific time-varying risk profile, the dynamics of which are closely linked with market liquidity.

The paper proceeds as follows. Section 2 introduces the model. Section 3 describes the data. Section 4 presents the results. Section 5 provides robustness analyses and Section 6 concludes.

2 A Model for Structural Changes in Risk Exposures

To test for structural breaks in hedge fund exposures to the stock market, we model the hedge fund return as the result of a dynamically changing set of factor exposures over time. We focus on the optimal timing of the fund's stock market exposure as driven by the liquidity conditions on the market. A similar approach is taken by Busse (1999) who analyzes volatility timing by mutual funds.

2.1 Optimal Liquidity Timing of the Market Exposure of a Hedge Fund

A general model for the return of hedge fund i given N risk factors is given by

$$r_{i,t+1} = \alpha_{i,t} + \beta_{m,i,t} \cdot r_{m,t+1} + \sum_{j=1}^2 \beta_{m,i}^{(j)} \cdot r_{m,t+1-j} + \sum_{k=1}^{N-1} \beta_{k,i,t} \cdot r_{k,t+1} + \varepsilon_{i,t+1}, \quad (1)$$

where $r_{i,t+1}$ is the excess return of fund i at time $t + 1$, $r_{m,t+1}$ is the excess return of the market at time $t + 1$, $r_{k,t+1}$ are the returns of $N - 1$ factors, $\beta_{m,i,t}$ is the sensitivity of fund i 's return to the contemporaneous market return, set at time t , $\beta_{k,i,t}$ is the sensitivity of fund i to factor k , determined at time t , $\alpha_{i,t}$ is the abnormal return of the fund, and $\varepsilon_{i,t+1}$ is the error term. To account for serial correlation in hedge fund returns, generally linked with illiquid holdings (see Getmansky et al. (2004)), we add two terms that involve lagged market returns, and $\beta_{m,i}^{(j)}$, $j = 1, 2$ correspond to the sensitivities of fund i to the lagged market returns.

We are interested in the optimal market beta of hedge fund i at time t , given liquidity conditions at time t . Dropping the subscript i and assuming that $E_t[\varepsilon_{t+1}] = 0$, $E_t[r_m, \varepsilon_{t+1}] = 0$ and $E_t[r_{k,t+1}, \varepsilon_{i,t+1}] = 0$, we can express the expected return at $t + 1$ conditional on the information at time t as:

$$E_t[r_{t+1}|I_t] = \alpha_t + \beta_{m,t} E_t[r_{m,t+1}|I_t] + \sum_{j=1}^2 \beta_m^{(j)} \cdot r_{m,t+1-j} + \sum_{k=1}^{N-1} \beta_{k,t} E_t[r_{k,t+1}|I_t], \quad (2)$$

where I_t is the information set available to the hedge fund manager at time t and our focus is on the information contained in the aggregate stock market liquidity which we denote by L_t .

Our motivation to consider aggregate liquidity as the most important information variable comes from several sources in the literature. Regarding expected returns, Amihud (2002) and Acharya and Pedersen (2005) find that in the cross-section of US-stocks, the conditional expected return is inversely related to liquidity. Bekaert et al. (2007) find a similar result for emerging markets. Jones (2002) finds a relation between the annual stock market return and previous year's bid-ask spread and turnover. The optimal

timing of stock market beta also depends on next period's volatility. There is evidence that the relation between next period's volatility and the current level of liquidity is inverse, see Benston and Hagerman (1974), Grossman and Miller (1988), Farmer et al. (2004), Grossman and Miller (1988), Mike and Farmer (2008). Brunnermeier and Pedersen (2009) model an interaction between market and funding liquidity that arises from the behavior of leveraged investors. The resulting dynamics are such that market liquidity declines as volatility increases. An example is the collapse of Long Term Capital Management in 1998, which was a liquidity event for the market, but led to a spike in (global) market volatility that lasted for several months.

From Equation (2) we can derive the optimal time-varying beta as a trade-off between the expected return and risk of next period's return, and liquidity, L_t , at time t . Appendix A derives the relation between beta and liquidity in the optimum as a function of the sensitivities of expected returns and volatility to liquidity. As argued in the Introduction, it is these sensitivities of expected returns and volatility to liquidity that were potentially affected by the institutional changes of 2000 and 2001 and the advent of modern trading technologies that took place around the same time. There is evidence that after 2001, stock market illiquidity and subsequent volatility have become more related. This could have changed the behavior of sophisticated investors such as hedge funds. For example, Huang (2012) finds that mutual fund managers tilt their holdings more heavily toward liquid stocks when the market is expected to be more volatile. The same could be at work with hedge funds.

We proceed to test for the relation between hedge fund betas and aggregate liquidity by assuming a linear structure between liquidity and the optimal beta, allowing for structural breaks.

2.2 Detecting Structural Breaks in Hedge Fund Betas

To detect structural breaks in the relation between hedge fund betas and liquidity, we consider the following linear specification for hedge fund returns and risk factors with a time-varying beta for the stock market return $r_{m,t}$, consistent with the general model in Equation (1):

$$R_t = \alpha_i + \beta_t \cdot r_{m,t} + \sum_{j=1}^2 \beta^{(j)} \cdot r_{m,t-j} + \sum_k \gamma_k \cdot F_{t,k} + \varepsilon_t, \quad (3)$$

where R_t is the hedge fund portfolio return in month t , $r_{m,t}$ the return on the market, $F_{t,k}$ a set of risk factors and ε_t an error term. β_t is the time-varying market beta, β^j are the lagged market betas and γ_k , $k = 1 \dots 7$, are the exposures to the other six hedge fund risk factors of Fung and Hsieh (2004), and an innovation in liquidity to account for priced liquidity risk. The Fung and Hsieh-factors include linear and

option-like factors and are given by a size factor, the monthly change in 10-year Treasury yields, the change in the yield spread between a 10-year Treasury bond and Moody's Baa bonds, as well as three trend-following factors represented by the return of a portfolio of lookback straddles on bond, currency and commodity futures. Unless noted otherwise, the market return $r_{m,t}$ is the return on the S&P 500 stock index.

We model the time-variation in β_t as being linearly dependent on market liquidity $L_{m,t}$ and market volatility $\sigma_{m,t}$. By including volatility we account for any volatility timing ability of hedge funds. We allow for a change in the relation between beta and liquidity via changepoints τ_i within the optimal changepoint regression framework of Andrews et al. (1996). Changepoint regressions for capturing time-varying hedge fund risk exposures have been previously used in literature (see Bollen and Whaley (2009) and Patton and Ramadorai (2013)). Our setting is different in that we model variations in market betas via observable variables, while allowing for a structural change in the interaction between those variables and the risk exposure. Specifically, with n possible changepoints, the model for β_t becomes

$$\beta_t = \beta_0 + \sum_{i=1}^n \left(\delta_0^i + \delta_1^i \cdot 1_{\{t > \tau_i^*\}} \right) L_{m,t} + \lambda \sigma_{m,t}, \quad (4)$$

where $L_{m,t}$ is the liquidity variable, $\sigma_{m,t+1}$ is market volatility, $1_{\{A\}}$ is the indicator function for event A and τ_i^* is the optimal location in time of the i -th changepoint. The formulation in Equation (4) allows for separate responses of β_t to liquidity, before and after the changepoint. The parameter δ_1^i measures the change in the sensitivity of beta to liquidity after changepoint τ_i^* . In the case of the S&P 500, the liquidity variable $L_{m,t}$ is an aggregate measure of the liquidity of the S&P 500-stocks. If we use other stock market aggregates, the liquidity variable changes as well.

In our baseline specification we use one changepoint τ^* . Section 5 tests for the robustness of our results when using two changepoints. Using more than two changepoints would improve the fit of the model at the cost of losing economic interpretation (i.e., data mining). An alternative would be to estimate a stochastic (latent) process for beta, but this leads to less powerful tests given the short time span of individual hedge funds, see Bollen and Whaley (2009).

Substituting Equation (4) into (3), we obtain the following partial structural change model for a single changepoint τ^* :

$$R_t = \alpha_i + \beta_0 r_{m,t} + (\delta_0^1 + \delta_1^1 \cdot 1_{\{t > \tau^*\}}) L_{m,t} r_{m,t} + \lambda \sigma_{m,t} r_{m,t} + \sum_{j=1}^2 \beta^{(j)} \cdot r_{m,t-j} + \sum_k \gamma_k \cdot F_{t,k} + \varepsilon_t, \quad (5)$$

Our specification in (5) nests the case of constant risk exposures (obtained by setting the parameters δ_0^1 , δ_1^1 and λ to zero), as well as the model of time-varying betas and constant liquidity interaction (for which $\delta_1^1 = 0$), considered in Cao et al. (2013).

The optimal changepoint τ^* is the one that maximizes the fit, i.e. the change-date that minimizes the sum of squared errors. The details on determining the significance of a changepoint are provided in Appendix B.

2.3 Measuring Market Liquidity

Our measure of market liquidity is the Amihud (2002) ILLIQ-measure. ILLIQ measures stock market *illiquidity* as the average daily ratio of absolute stock return to dollar volume. This can be seen as the average price impact of a given dollar volume of a transaction. Among daily proxies, the Amihud liquidity measure is the most strongly correlated measure with intra-day measures of the price impact of trading, see Goyenko et al. (2009), De Jong and Driessen (2006), Hasbrouck (2009) and Korajczyk and Sadka (2008).

We measure overall stock market illiquidity as the average of the individual ILLIQ-measures across all stocks for each month, weighted by market capitalization:

$$ILLIQ_t = \frac{1}{N_t} \sum_{i=1}^{N_t} ILLIQ_{i,t} \cdot M_{t-1} / M_0, \quad (6)$$

where N_t is the number of stocks in month t , M_t is the market capitalization at the end of month t and M_0 is the market cap at the beginning of the sample period. $ILLIQ_{i,t}$ is the ILLIQ measure for stock i in month t and is estimated as

$$ILLIQ_{i,t} = \frac{1}{D_t} \sum_{d=1}^{D_t} \frac{|r_{i,t}^d|}{V_{i,t}^d}, \quad (7)$$

where D_t denotes the number of trading days in month t , $r_{i,t}^d$ denotes the return on stock i in the d^{th} day of month t , and $V_{i,t}^d$ denotes the dollar trading volume for stock i in the d^{th} day of month t .

The illiquidity variable picks up predicted changes in liquidity, such as tick-size changes and time trends in liquidity. To correct for this, we follow Hameed et al. (2010) and adjust ILLIQ for predicted changes in

liquidity. This boils down to regressing $ILLIQ_{i,t}$ on (i) tick change dummies to capture the tick change from 1/8 to 1/16 on June 24, 1997 (ii) the change from 1/16 to the decimal system on January 29, 2001, and (iii) two time trend variables equal to the difference between the current year and the year 1994 and 1997, respectively, or the first year when the stock is included in the S&P 500 index if that is later than 1994 or 1997. The adjusted ILLIQ is denoted as $\varepsilon(ILLIQ)$.

3 Data

For the hedge fund returns we use monthly returns and asset values of individual hedge funds from the Lipper TASS database as provided by Thomson Reuters. The database contains both live and graveyard funds, however it starts retaining dead funds only after 1994 and the data from earlier periods is subject to survivorship bias, see Fung and Hsieh (2002). We thus follow the conventional approach in the hedge fund literature and start our sample period from January 1994. Our database runs until December 2008.

We apply the following filter to the individual funds. We discard funds that do not report on a monthly basis or have less than 24 consecutive months of data. We convert the assets of non-USD funds to US-dollars, using the exchange rate at the end of the month. We include only funds that report net-of-fee returns on a monthly basis. In some of our analyses we also control for backfill bias and fund size by discarding the first 12 months of data for each fund and consider only funds with average Assets under Management of \$10 million or more.

We exclude hedge funds that have no exposure to the US stock market, classified as either Fixed Income Arbitrage or Managed Futures. Also, to ensure good coverage over time we collapse the self-reported style classifications Long Short Equity Hedge and Equity Market Neutral into one category. We add a category of hedge funds called ‘Primary Focus on Equities’ which consists of all hedge funds who report to have US-equities as their primary focus.

Table 1 summarizes the descriptive statistics of the monthly hedge fund returns in our sample. It contains a total of 8,943 hedge funds divided over 8 style classifications. Our custom category Primary Focus on Equities contains 3,162 funds. The most populous styles are Long/Short Equity Hedge and Equity Market Neutral (3,322 funds) and Fund-of-Funds (3,018 funds). They jointly account for roughly 70% of the sample.

INSERT TABLE 1 HERE

For stock market index-returns we use the monthly total return on the S&P 500 (large cap), S&P 400 (mid cap), and S&P 600 (small cap), as provided by Datastream. We summarize the market factors in panel A of Table 2.

INSERT TABLE 2 HERE

For the construction of ILLIQ we use individual stock returns from the Center for Research in Security Prices (CRSP). To construct the monthly ILLIQ measure for each stock, we use daily data (returns, volume and market capitalization) for the constituents of each of the S&P indices (small cap S&P 600, mid cap S&P 400 and large cap S&P 500) for the 1994 - 2008 period. To obtain a market-wide illiquidity measure for each index, we take the mean of the individual ILLIQ-measures across all stocks that constitute the index in a given month, scaled by the market capitalization of the index portfolio following (6). Panel B of Table 2 gives the summary statistics of the liquidity measures.

The risk factors used in the changepoint regressions are the seven factors from Fung and Hsieh (2004), as provided on the website of David Hsieh. These include a size factor, the monthly change in 10-year Treasury yields, the change in the yield spread between a 10-year Treasury bond and Moody's Baa bonds, as well as three trend-following factors represented by the return of a portfolio of lookback straddles on bond, currency and commodity futures. For the volatility measure we take the CBOE VIX index, which is commonly used to capture volatility timing (see Chen and Liang (2007)).

4 Results

We estimate hedge fund market betas and the potential changepoints in the interaction term of market beta and liquidity. Unless noted otherwise, the S&P 500 serves as the market index and the monthly aggregate of Amihud's ILLIQ-measure is the liquidity measure computed as outlined in Section 3 and using the stocks in the S&P 500.

4.1 Structural Breaks in the beta-liquidity relation for hedge funds

We estimate the partial structural change model for a single changepoint as given in Equation (5), with value-weighted portfolio returns of hedge funds. Table 3 reports the coefficient estimates for the beta specification for a single changepoint.

INSERT TABLE 3 HERE

Panel A of Table 3 has the results for the ILLIQ measure given in Equation (7) as a proxy for the aggregate market illiquidity. Panel B uses the ILLIQ measure that is corrected for predictable changes in

liquidity, as in Hameed et al. (2010). We control for the interaction of the VIX-measure times the market return, to capture the impact of liquidity crises that go together with spikes in the VIX, or simple volatility timing.

What becomes immediately clear from Table 3 is that all strategies show a significant breakpoint in the interaction term of the market return times ILLIQ. Most interaction terms are negative and significant at the 99%-level after the breakpoint. They are positive only for Dedicated Short Bias and for the residual ILLIQ-measure (Panel B) for Dedicated Short Bias and Convertible Arbitrage. The fact that the changepoint effect is the exact opposite for Dedicated Short Bias suggests that the change in time-variation is related to the market exposure of hedge funds, and that we are not measuring an effect that is orthogonal to it. The breakpoint for Global Macro is the earliest, in September 1998. This could be an effect of the LTCM-crisis in that month, which was itself a Global Macro hedge fund (although not in our sample). After LTCM, the US-stock market exposure of Global Macro hedge funds has become sensitive to the liquidity conditions of the stock market, as measured by ILLIQ.

In Panel A, the breakpoints for the other hedge funds styles are significant and between April 2000 and January 2002. The predominantly negative sign for the changepoint term is related to the findings of Cao et al. (2013) who find evidence of liquidity timing for individual hedge funds. However, our estimates show that liquidity timing has only started after a breakpoint. The styles Long/Short Equity and Fund of Funds, to which 70% of hedge funds belong in our sample, have a breakpoint in September 2000. For the two panels together, 13 out of 18 regressions have a changepoint in the period from April 2000 to February 2001.

The years 2000 and 2001 are well known for the institutional changes that took place. In addition, the literature documents a drastic change in liquidity conditions following the changes.

The first institutional change is the mandatory disclosure of execution quality, by virtue of Act 11Ac1-5, adopted in November 2000 and later redesignated as rule 605, by the U.S. Securities and Exchanges Commission (SEC). Under Rule 605, any exchanges on which US stocks are traded are required to publish a monthly report of execution quality on a per-stock basis. The introduction of the rule was a response to increased market fragmentation: increase in electronic trading and trading venues meant that consumers and traders could not be sure that their trades were executed at the best available price. In some markets, 50% of trades were executed at better prices than the public quotes, see Securities and Exchanges Commission (2000). Several studies suggest that the rule had its intended effect: The increase in transparency led to more competition between exchanges and execution quality in US equities improved dramatically in the years after the introduction of the rule, see Zhao and Chung (2007) and O'Hara and Ye (2011).

The second institutional change is the decimalization of quotes, which is the reduction of the minimum tick size from 1/16 to one cent, which took place in January 2001 for the New York Stock Exchange (NYSE) and in April 2001 for NASDAQ. As a result, the liquidity of the US stock market has increased across all commonly used determinants of liquidity, see Schapiro (2010) and Chordia et al. (2011). The average trade size and trading costs decreased sharply after 2001, see Bessembinder (2003), Gibson et al. (2003), Chakravarty et al. (2005), Bacidore et al. (2003). Doubts remain about whether this has benefited small stocks to the same extent as large stocks, see Hendershott et al. (2011) and Brennan et al. (2012). Ronen and Weaver (2001) find a significant reduction in volatility after AMEX's May 1997 tick size reduction. Chakravarty et al. (2004) find an initial increase in volatility after decimalization in 2001 but a decline over the longer term.

Our main results in Table 3 suggest that the change in liquidity conditions induced by the institutional changes have led hedge funds to change the way in which they adjust market exposures to liquidity conditions. A case in point is Chordia et al. (2011), who note that, due to decimalization and SEC rule 605, best execution has become a source of outperformance for hedge funds.

The horizons of investors might be different for small and large stocks. Also, there is evidence that most illiquid stocks are also the stocks with the smallest market capitalization, see Acharya and Pedersen (2005). To check whether our results are confined to a segment of hedge funds and/or market indices of particular size, we condition our sample of hedge funds on the exposure to small, medium and large-sized stock-indices. We determine the relevant index for each fund by applying the AIC information criterion from a multivariate regression of individual hedge fund returns on the Fung and Hsieh (1997) 7-factor model, augmented with contemporaneous AR(2) residuals of the Amihud ILLIQ measure, computed on the respective indices. Then, we perform a similar set of regressions as in Table 3 but with the ILLIQ-measure computed for the respective index, i.e., for the portfolio of hedge funds selected on the S&P 400 Midcap index, we use the ILLIQ-measure computed based on the stocks in the S&P 400 as well. It turns out that 33% of hedge funds have the S&P 500 as the appropriate market index. For 53% of funds the S&P 400 is selected. The remainder, 14% has the S&P 600 as market index. The regression results are in Table 4.

INSERT TABLE 4 HERE

Table 4 shows that the coefficient for the interaction term with changepoint is again negative and significant. The significant changepoints are at similar dates as before, with most of them lying between February 2000 and July 2001. There are some exceptions: Convertible Arbitrage has a changepoint in November 2004 for the S&P 400-selection. Global Macro (with S&P 500) and Multi-strategy (with S&P

400) have a changepoint in September 1998. Event Driven (S&P 500) has July 1999 as a significant changepoint.

An interesting observation is that for Global Macro in Panel A and C, the interaction term of the market times ILLIQ (without changepoint) is positive and significant. This is also the case for the hedge funds with Primary focus on Equity in Panel A. This suggests that these funds have a role in the liquidity supply for the US-stock market before their respective break points. Separate split-sample regressions (not reported) that allow all coefficients to change over the breakpoint show this effect as well.

To analyze the location and significance of changepoints, Figure 1 plots the F-statistic for the significance of a changepoint in each month for two portfolios and three market indices. The construction of the F-statistic is given in Appendix B. We use value-weighted portfolios and the three stock indices as market indices, i.e., each panel shows three different portfolios based on the exposure to the small, medium and large-cap indices.

INSERT FIGURE 1 HERE

In both panels corresponding to LSEH/EMN funds and funds with a primary focus on equities, we observe that the F-statistics peak around 2001 with the exception of the portfolio of hedge funds that load on the S&P 600 Small caps. For the latter portfolio, the highest F-statistics are spread out over a longer period peaking around 2000.

As further evidence for a changepoint in 2000/2001, we estimate the changepoint regression for individual funds. We only take hedge funds with Primary Focus on Equities and at least 36 months of return-data. The outcomes are in Table 5 grouped by the optimal changepoint year, if significant. That is, only hedge funds that have a significant changepoint in any year are reported.

INSERT TABLE 5 HERE

Table 5 shows that the years in which the most changepoints occur are 2000, 2001, and 2007, with 18%, 16% and 22% of hedge funds having an optimal changepoint in those years, respectively. Only for 2000 and 2001, however, do the average t-statistic and cross-sectional t-statistic point at a significant negative sign for the interaction of beta and liquidity after the breakpoint. The year 2007 clearly had a large market disturbance, for example in August 2007 with the start of the 2007/2008 credit crisis, see Khandani and Lo (2007) and Brunnermeier and Pedersen (2009). However, Table 5 shows that, consistent with the absence of an institutional change in these years, there is no respective change in the relation between market exposure and liquidity.

4.2 Characteristics of funds with structural breaks

Our results might be driven by a subset of hedge funds that have specific features related to funding and redemption constraints. Funds that use leverage or funds that are more exposed to investor withdrawals might be faced with forced liquidations after a liquidity event. This offers an alternative mechanism through which fund market exposures could vary over time. To address such potential concerns, we re-estimate our model for portfolios of hedge funds that are less likely to be affected by the above mentioned constraints. For brevity we restrict the analysis to hedge funds that belong to the categories Primary Focus on Equities, Long-Short Equity Hedge/Equity Market Neutral and Fund-of-Funds

We form value-weighted portfolios using hedge funds that (1) do not employ leverage, (2) have a low redemption frequency, (3) have redemption notice periods of 60 days or more, (4) have lock-up periods of more than 3 months, and (5) have a below-median fund-flow volatility, computed as in Sirri and Tufano (1998). A similar approach is used in Cao et al. (2013). The results, with the prevalence of each statistic, are in Table 6.

INSERT TABLE 6 HERE

Table 6 shows significant change dates for all five portfolios, all located in the year 2000. The reversal in the beta-liquidity relationship remains strongly significant, even when hedge funds are less likely to be impacted by external funding constraints.

4.3 Detecting Structural Breaks in Dynamic Strategies

The relation between hedge fund betas and liquidity could be due to a specific trading strategy or systematic exposure that is common among hedge funds and that was particularly affected by the institutional changes in 2000 and 2001. Thus, we analyze several dynamic strategies with the potential to generate the beta-liquidity relation that we observe in the data. One of the candidate strategies we consider is designed to earn the liquidity premium. For three other strategies we have prior evidence of a time-varying beta. They are pairs trading, momentum trading and reversal trading. We describe them below.

Trading on Liquidity

A liquidity trading strategy is designed to capture the liquidity premium of US-stocks, by buying and selling similar stocks with different systematic liquidity exposures, as in Ben-Rephael et al. (2010). Stocks are sorted on size into three groups. Within each size tercile, stocks are sorted within five portfolios, based on their previous-year illiquidity, as measured by Amihud's (2002) ILLIQ measure. The

long-short liquidity portfolio per size-tercile consists of a long position in the least liquid quintile and a short position in the most liquid quintile.

Sadka (2010) finds that the returns on a liquidity factor can explain a large part of the variation in hedge fund returns. Moreover, Ben-Rephael et al. (2010) show that the liquidity premium that is earned in this way, has decreased markedly over the past two decades. If the size of the liquidity premium is an input for hedge fund strategies, the decline might be a reason for a change in the beta-liquidity relationship that we observe.

Pairs trading

Pairs trading is a Wall Street quantitative investment strategy that is a statistical arbitrage between stocks with statistically similar price histories. The strategy is shown to deliver persistent outperformance, correcting for the standard risk factors, see Gatev et al. (2006) and Engelberg et al. (2009). The beta of pairs trading is not necessarily zero, as the widening of a gap between two similar stocks creates an exposure to systematic risk. Moreover, if price differences between two similar stocks are at least partly driven by liquidity, the dynamics in the market exposure of such a strategy might be related to liquidity.

We generate pairs trading-returns along the line of Gatev et al. (2006), as follows: At the beginning of each month, we rank pairs of stocks from the NYSE-Amex-NASDAQ universe based on the sum of squared deviations of the normalized price indices over the past 12 months (the formation period). Only stocks with a full price history over the formation period are considered. This list of pairs is monitored during a period of six months (trading period) to detect a widening between prices of more than two standard deviations. The day after such an event, the pair is 'opened' by going one dollar short in the higher-priced stock and one dollar long in the lower-priced stock. A pair is closed once the prices cross or at the end of a 6-month trading period. The return on a pair is computed as the reinvested payoffs during the trading interval. A pair can open and close several times during the trading period. Given that we take a six month trading period, it is assumed that six strategies (managers) are operating simultaneously, in overlapping (six month) periods. We follow Engelberg et al. (2009) in that we also consider a strategy that closes out pairs that do not converge after 10 days.

Momentum trading

The return on momentum is the return on a portfolio with a long position in past winners and a short position in past losers, see Jegadeesh and Titman (1993). Momentum is a strategy that is used by some directional hedge funds and its return is a common risk factor used in performance attribution, see Kosowski et al. (2007) and Griffin and Xu (2009). Relevant here is that momentum is shown to produce a

time-varying beta, see Daniel and Moskowitz (2013). For the return on momentum we take the monthly return of the Up-Minus-Down (UMD) factor from Kenneth French's website.

Reversal trading

Return reversal is known to capture systematic risk and there is some evidence that it might be related to liquidity, see Huang et al. (2010) and Da et al. (2012). We take the monthly Short-Term Reversal Factor from Kenneth French's website, which is the return on a portfolio strategy where the weights are determined by the inverse of the previous-month excess return over the market. It is a contrarian strategy in that it buys past losers and sells past winners.

For each of the strategies, we compute the monthly returns for the period 1994-2008 and estimate the changepoint model for the strategy return. The results are in Table 7

INSERT TABLE 7 HERE

Table 7 shows that only short-term reversal has a significant exposure to the market portfolio of -0.64. The interaction term $R^m \times ILLIQ$ is not significant for any strategy. The interaction term with a changepoint, however, is significant for all strategies. It is negative for the liquidity and momentum strategy, and positive for pairs trading and reversal. Based on the F-test for significance of the changepoint date, only the changepoint for the momentum strategy is significant and located in January 2001.

Additionally, for each strategy we sort hedge funds into loading and non-loading portfolios, based on their exposure to the strategy-return in portfolios and test for the changepoint. The non-loading portfolios are of interest for the contraposition of the reasoning that a dynamic strategy is the cause of a beta-liquidity relation. The results are in Table 8, with a separate panel for each dynamic strategy.

INSERT TABLE 8 HERE

Panel A of Table 8 has the regression results for portfolios of hedge funds that either load or do not load on the liquidity strategy. For convertible arbitrage, dedicated short bias and event-driven there are not enough loading funds to obtain a complete time series of returns. For the other style categories, a maximum of 9% of hedge funds from a strategy loads significantly on the liquidity strategy. Except for multi-strategy, all portfolios with funds loading on liquidity have a significant changepoint between April 2000 and July 2002, with a negative and significant sign.

Panel B has the results for portfolios of hedge funds loading on pairs trading. We observe that the percentage of funds loading on pairs trading is low, and apart from Primary Focus Equity, only three

strategies have enough funds to constitute a complete time series for the portfolio. Only Global Macro has a negative sign for the changepoint term, located in May 2004.

Panel C has the results for momentum. Here, the number of loading funds is high, reaching 33% for Long-short equity funds and 37% for fund-of-funds. Second, almost all loading portfolios (except for dedicated short bias) have a negative and significant sign for the changepoint. The portfolio with loading funds has an interaction term after the breakpoint that is higher in absolute terms than that of non-loading funds. Third, except for Dedicated Short Bias, the changepoints for loading funds are all located between February 2000 and July 2001.

Panel D has the results for short-term reversal. For long-short equity, the loading portfolio has a positive and significant sign for the changepoint term, which might reflect the negative beta of the strategy that we saw in Table 6. This is comparable to what we see for dedicated short bias in Table 3, i.e., for strategies that are on average short, the effects are opposite. Again, this suggests that the change in the timing of beta that we pick up is related to the overall exposure to the market.

In all, Tables 7 and 8 show that returns to momentum display a similar shift in market timing as what we find for hedge funds, and the large fraction of hedge funds that load on momentum display a stronger pattern. The liquidity strategy comes second, with less pronounced patterns and fewer funds that load on it. Pairs trading and reversal have little or no similarity with the timing effect we find for hedge funds.

Why momentum? Recent studies show that the excess return of momentum strategies has no obvious source of risk, see Cooper et al. (2004), Daniel and Moskowitz (2013) and Vayanos and Woolley (2013). Asness et al. (2013) find that, post-1998, Sharpe ratios of momentum have become more sensitive to changes in liquidity conditions. This corroborates with our finding of hedge fund betas becoming more sensitive to liquidity in the second half of the sample. Another explanation is that momentum profits pre-2000 reflect limits to arbitrage, due to high execution costs, see Lesmond et al. (2004). After the dramatic decline in execution costs, the time-varying beta of momentum has changed accordingly. From the data, we cannot rule out that the time-varying beta momentum has changed because of hedge funds trading on it. But it might also be the other way around: hedge fund betas have changed because they trade on momentum and the dynamics of momentum profits has changed.

Momentum returns are found to be related to value and size effects in stock markets, see Asness et al. (2013). Also, the effects of illiquidity on market exposure might be related to market crashes. In a bear market (or crash), volatility is typically high and liquidity is low. Following a market decline, portfolios based on momentum are likely to be long in stocks with low betas and short in stocks with high betas, see Daniel and Moskowitz (2013). To test for the influence of value, size and market timing effects, Table 9

has the changepoint results for portfolios of hedge funds with significant loadings on the momentum strategy when we control for these factors.

INSERT TABLE 9 HERE

In Panel A we correct for value and size when determining momentum loadings in the individual fund regressions. Results are shown for the changepoint in the interaction term, for three selections of hedge funds on the respective market indices (and associated liquidity measure). All long strategies have a negative and significant coefficient and a changepoint in 2000 or 2001.

In Panel B we correct for market timing with a bear-market indicator in the time-varying beta specification, as in Daniel and Moskowitz (2013). Compared to Panel A, results are similar, with a few exceptions. For example, Emerging markets and Event-driven are not significant anymore for S&P 500 as the market index. Also, Global Macro and Multi-strategy have a changepoint in 1997 and 1998, respectively.

Overall, momentum returns explain a large part of the variation in hedge fund returns, including the changepoint in the period 2000-2002. This holds for almost all hedge fund styles and across the relevant market indices.

5 Robustness

Our results might be affected by backfill bias, which is the problem that early observations of any hedge fund in a database as ours is the result of selective attrition: funds only enter the database when they have a string of relatively good results, which they offer as a return history, see Fung and Hsieh (2009), Aiken et al. (2013). To correct for this, we exclude observations before the month in which the fund was added to the database, using the field “Date added” that is provided by Lipper/TASS. The results are in Table 10 and remain qualitatively similar.

INSERT TABLE 10 HERE

As an alternative liquidity measure, we use Pastor and Stambaugh (2003)'s measure of one-day return reversals to measure liquidity. Results are in Table 11.

INSERT TABLE 11 HERE

Table 11 shows a large and significantly positive coefficient for the changepoint term. Given that the Pastor-Stambaugh measure is a measure of liquidity (and not illiquidity, as with $ILLIQ$), this is in accordance with our earlier results. The location of the changepoint is July 2001 for LSEH/EMN funds².

There is evidence that hedge funds smooth returns, either on purpose or passively, through the illiquidity of some of their assets, like real estate investments, see Getmansky et al. (2004). Correcting for the possible smoothing of returns does not change our results.

Given the evidence for time-varying risk exposures of hedge funds, it could be that our results are influenced by changes in beta unrelated to liquidity. To test for this, we estimate a changepoint regression in the interaction term of beta and liquidity for a portfolio composed of only those hedge funds that have a changepoint in their beta. Table 12 has the results.

INSERT TABLE 12 HERE

The results in Table 12 show that the changepoint in the interaction term for beta and liquidity remains significant, with coefficients that are even slightly more negative than the baseline results in Table 3.

Another potential concern is that hedge fund trades may have an impact on market liquidity. This would create endogeneity, as our model takes liquidity as an exogenous variable. If that is so, the small hedge funds would be the least likely to be impacted. Table 13 has the results for a portfolio with hedge funds with average assets under management of less than \$50 million and \$150 million, respectively.

INSERT TABLE 13 HERE

The results on the interaction term of beta times liquidity are negative and significant, suggesting that the trading impact of large hedge funds on liquidity, if it is there, is not the main driver of our results. We have also used a definition of small funds as hedge funds for which the average assets under management are under \$50 million or \$150 million in any given month. The results are similar.

Finally, we test for robustness when estimating a changepoint model with two changepoints. We use the three hedge fund portfolios Primary Focus on Equities, Long-Short Equity Hedge/Equity Market Neutral and Fund-of-Funds and report the results in Table 14.

INSERT TABLE 14 HERE

² To mitigate a possible problem of outliers (small stocks that have extremely low volumes in one or more days), we also consider as an alternative measure of market illiquidity the Acharya and Pedersen (2005) version of $ILLIQ$, given by $ILLIQ_{i,t}^{AP} = \min(0.25 + 0.30 \cdot ILLIQ_{i,t}, 30)$. Our results remain qualitatively similar when we use this measure to proxy for aggregate market illiquidity.

For most portfolios, the two changepoints are very close together, e.g., Nov-99 and Jan-00, Feb-00 and Mar-00, etcetera. For such combinations of changepoints, we conclude that an extra changepoint does not so much pick up a real break in the data but rather increases the fit of the regression by fitting one month of data better. For changepoints further apart, the direction and significance of the changepoints is consistent with our estimates of one changepoint.

6 Conclusion

We show that the relation between hedge funds' US stock market exposure and market liquidity has undergone a significant change over the period 1994-2008. Using Amihud's (2002) ILLIQ measure as a proxy for market illiquidity, breakpoints in the beta-liquidity relation are found between February 2000 and July 2002, depending on the sample and specification. Before the breakpoint, hedge fund beta and liquidity are inversely related. After the break, the relationship turns to positive. Of the candidate dynamic strategies that we explore, and one liquidity strategy, only momentum jumps out as having the same change in the beta-liquidity relation.

Our results suggest that the liquidity timing strategies by investment funds, as found by Cao et al. (2013) and Huang (2012) are not necessarily a fundamental property of sophisticated investors, as the beta-liquidity relation is weaker or absent before 2000. Rather, liquidity timing is related to changes in market structure and technology. The logical conclusion is that it could change yet again, as markets, technology and regulations evolve over time. The timing model and time-series regressions suggest that liquidity timing depends on the strength of the relation between liquidity and expected volatility. The beta-liquidity relation of hedge funds is an evolving phenomenon that might change again in the future.

Of all the candidate strategies that could relate to the specific patterns that we find for market beta and liquidity, momentum is the most promising. Many hedge funds have significant exposure to momentum, and the beta-liquidity pattern of the returns to the momentum strategy is very similar to the one found for hedge funds. Pairs trading, liquidity trading and reversal do not display these dynamics and we find only few hedge funds that load significantly on the returns to these strategies. Given the popularity of momentum as an investment strategy employed by hedge funds, a similarity in time-varying betas between momentum returns and hedge fund returns is not implausible. This brings a new perspective on momentum profits and its dynamics.

Appendix A: Derivation of the optimal beta as a function of liquidity

We model a data generating process for the returns of hedge fund i . The return decomposition, given N risk factors is given by

$$r_{i,t+1} = \alpha_{i,t} + \beta_{m,i,t} \cdot r_{m,t+1} + \sum_{j=1}^2 \beta_{m,i}^{(j)} \cdot r_{m,t+1-j} + \sum_{k=1}^{N-1} \beta_{k,i,t} \cdot r_{k,t+1} + \varepsilon_{i,t+1}, \quad (\text{A1})$$

where $r_{i,t+1}$ is the excess return of fund i at time $t + 1$, $r_{m,t+1}$ is the excess return of the market at time $t + 1$, $r_{k,t+1}$ are the returns of $N - 1$ factors, $\beta_{m,i,t}$ is the sensitivity of fund i 's return to the contemporaneous market return, set at time t , $\beta_{k,i,t}$ is the sensitivity of fund i to factor k , determined at time t , $\alpha_{i,t}$ is the abnormal return of the fund, and $\varepsilon_{i,t+1}$ is the error term. The final two terms have lagged market returns to account for serial correlation in hedge fund returns, generally linked with illiquid holdings, see Getmansky et al. (2004).

Dropping the subscript i and assuming that $E_t[\varepsilon_{t+1}] = 0$, $E_t[r_m, \varepsilon_{t+1}] = 0$ and $E_t[r_{k,t+1}, \varepsilon_{i,t+1}] = 0$, we can express the expected return at $t + 1$, conditional on the information at time t as:

$$E_t[r_{t+1}] = \alpha_t + \beta_{m,t} E_t[r_{m,t+1}] + \sum_{j=1}^2 \beta_m^{(j)} \cdot r_{m,t+1-j} + \sum_{k=1}^{N-1} \beta_{k,t} E_t[r_{k,t+1}] \quad (\text{A2})$$

The fund manager optimizes the factor exposures $\beta_{m,t}$ and $\beta_{k,t}$, $k = 1, \dots, N - 1$ of his portfolio at time t , given expectations of the opportunity set the next period. He solves the following problem:

$$\max_{\beta_m, \beta_{1,t}, \dots, \beta_{N-1,t}} E_t[U(r_{t+1})], \quad (\text{A3})$$

where U is the utility function of the manager. Differentiating with respect to $\beta_{m,t}$ and setting the result equal to zero, we obtain:

$$\beta_{m,t}^* = \frac{1}{\gamma} \cdot \frac{E_t[r_{m,t+1}]}{\sigma_{m,t+1}^2}, \quad (\text{A4})$$

where

$$\gamma = -\frac{E_t[U''(r_{t+1})]}{E_t[U'(r_{t+1})]}, \quad (\text{A5})$$

which is the Rubinstein (1973) measure of risk aversion, assumed to be fixed. See also Admati et al. (1986), who derive the same relationship. Equation (A4) states that the optimal exposure to the market involves a risk-return trade-off, conditional on the information set at time t and scaled by the risk aversion parameter γ .

The sensitivity of the optimal hedge fund's market exposure with respect to market-wide liquidity $L_{m,t}$ follows from Equation (A4) as:

$$\frac{\partial \beta_{m,t}^*}{\partial L_{m,t}} = \frac{1}{\gamma \sigma_{m,t+1}^2} \left[\frac{\partial E_t[r_{m,t+1}]}{\partial L_{m,t}} - \frac{2E_t[r_{m,t+1}]}{\sigma_{m,t+1}} \cdot \frac{\partial \sigma_{m,t+1}}{\partial L_{m,t}} \right]. \quad (\text{A6})$$

The expression in (A6) is similar to that of Busse (1999), who analyzes the sensitivity of mutual fund beta to volatility. Our expression is different in having both a direct effect of liquidity (the first term) and an indirect effect of liquidity on beta through volatility (the second term).

The sign of our variable of interest, $\partial \beta_{m,t}^* / L_{m,t}$, is determined by the difference of the two terms that make up the right-hand side of Equation (A6). The optimal timing of the market beta due to liquidity depends on a trade-off between the direct effect of liquidity on expected returns, and the effect that runs via volatility. The net effect might be either positive or negative, inducing time-variations in the response of market beta to liquidity with potentially switching signs. The timing of market exposure that is related to liquidity is eventually determined by the risk-return trade-off of providing liquidity, as perceived by hedge fund managers. The risk-return trade-off could be seen as favorable or unfavorable, depending on market circumstances and the expectations of hedge fund managers.

Appendix B: Significance Testing of Changepoints

We start from partial structural change model for a single changepoint τ^* :

$$R_t = \alpha_i + \beta_0 r_{m,t} + (\delta_0^1 + \delta_1^1 \cdot 1_{\{t > \tau^*\}}) L_{m,t} r_{m,t} + \lambda \sigma_{m,t} r_{m,t} + \sum_{j=1}^2 \beta^{(j)} \cdot r_{m,t-j} + \sum_k \gamma_k \cdot F_{t,k} + \varepsilon_t, \quad (\text{B1})$$

The optimal changepoint τ^* is the one that maximizes the fit, i.e. the change date that renders the minimum sum of squared errors. To test for the significance of the changepoint, we compute the F -statistic of Andrews et al. (1996) for each candidate date τ_k and its corresponding least-square parameter estimates:

$$F(\tau_k) = \frac{[SSE^* - SSE(\tau_k)](T - 2\nu)}{SSE(\tau_k)\nu}, \quad (\text{B2})$$

where SSE^* is the sum of squared errors of an estimated constant parameter model (obtained by setting $\delta_1^1 = 0$), $SSE(\tau_k)$ corresponds to the changepoint regression for time τ_k , T denotes the sample size, and ν equals the number of factors in the changepoint regression plus one. We calculate the following two limiting cases of the exponential F -statistic of Andrews et al (1996) that direct power against alternatives of small and large parameter changes respectively:

$$\begin{aligned} Avg - F &= \sum_{\tau_k} F(\tau_k) J(\tau_k), \\ Exp - F_\infty &= \log \sum_{\tau_k} \exp\left(\frac{mv}{2} F(\tau_k)\right) J(\tau_k), \end{aligned} \quad (\text{B3})$$

where $J(\tau_k)$ is a weighting function. We equally weigh the F -statistics and obtain the critical values using a bootstrap procedure, see Bollen and Whaley (2009) and Patton and Ramadorai (2013). First, a constant parameter model is estimated under the null of no changepoint, i.e. with $\delta_1^1 = 0$ in (B1). Second, we bootstrap samples of hedge fund returns of length T by re-sampling the residuals and adding them to the fitted return estimates from the constant parameter model. To account for autocorrelation, we follow Politis and Romano (1994) and Patton and Ramadorai (2013) by drawing the residuals in blocks of random size and starting points. The block lengths are drawn from a geometric distribution, with an average block length of 3. For each bootstrapped sample we estimate the changepoint model (B1) and calculate the $Avg - F$ and the $Exp - F_\infty$ statistics in (B3). We simulate and estimate 1000 sets of hedge fund returns and set the 90th percentile of the distribution of a test statistic as the critical value at 10% . A changepoint parameter shift is significant if the test statistic exceeds that critical level.

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Panel A: LSEH/EMN

Panel B: Primary Focus on Equities

Figure 1: F-statistics of a changepoint in hedge fund portfolio returns

This figure shows the exp-F-statistics calculated following eq. (7) from the optimal changepoint model in (5). Plotted are the F-statistics for the whole permissible range of date changes τ for value-weighted portfolios of Long-Short Equity Hedge (LSEH) and Equity Market Neutral (EMN) hedge funds (Panel A), as well as all hedge funds with Primary Focus on Equities (Panel B), with the following specification for the dynamics of the market beta:

$$\beta_t = \beta_0 + (\delta_0 + \delta_1 \cdot 1_{\{t > \tau\}})ILLIQ_t + \lambda\sigma_{m,t},$$

where $ILLIQ_t$ is Amihud's (2002) measure of stock market illiquidity in month t based on constituents of the S&P 500, the S&P 400 or the S&P 600 index, $\sigma_{m,t}$ is the stock market return volatility as proxied by the CBOE VIX index and τ is the changepoint. R^m is the return of the S&P 500, the S&P 400 or the S&P 600 index respectively.

Table 1. Summary statistics of hedge fund portfolios

The table presents summary statistics of value-weighted returns of portfolios of hedge funds grouped by style classification. The sample period is from January 1994 to December 2008.

	N	Mean	Median	STD	Skewness	Kurtosis	Min	Max
Funds with primary focus on equities	3,162	0.32	0.41	2.39	0.15	5.62	-8.68	9.66
Long-short Equity Hedge and Equity Market Neutral	3,322	0.71	0.90	2.60	0.25	6.43	-8.56	12.43
Convertible Arbitrage	235	0.31	0.65	1.73	-3.90	25.91	-12.05	2.72
Dedicated Short Bias	42	0.08	-0.44	4.80	0.81	4.63	-8.66	22.25
Emerging Markets	470	0.52	1.05	4.41	-0.65	6.51	-21.36	15.77
Event-Driven	659	0.54	0.82	1.44	-1.89	9.50	-6.56	3.19
Fund-of-Funds	3,018	0.30	0.38	1.93	-1.15	8.17	-9.80	5.88
Global Macro	417	0.56	0.46	3.28	0.17	7.20	-14.51	12.93
Multi-Strategy	780	0.56	0.57	2.95	0.09	6.61	-10.43	12.78

Table 2. Market factors and liquidity measures

The table presents summary statistics of the risk factors and the liquidity measures. Panel A summarizes the returns of the market factors, S&P 500, S&P 400 and the S&P 600 index. Panel B reports the descriptives of the monthly Amihud illiquidity measure (ILLIQ), the Pástor-Stambaugh liquidity measure and their innovations from an AR(2) model based on S&P 500, S&P 400 or S&P 600 constituents. It also reports the descriptives of ILLIQ residuals from regressing the ILLIQ variable on two tick change dummies to capture the tick change from 1/8 to 1/16 on June 24, 1997 and the change from 1/16 to the decimal system on January 29, 2001, as well as two time trend variables equal to the difference between the current year and the year 1994 (1997) or the first year when the stock is included in the S&P 500 index, whichever is later, following Hameed et al. (2010). Panel C summarizes the Fung-Hsieh risk factors. Apart from the market return, they include a size factor (SMB), monthly change in the 10-year treasury constant maturity yield, monthly change in the Moody's Baa yield less 10-year treasury constant maturity yield, and three trend-following factors: PFTSBD (bond), PFTSFX (currency), and PFTSCOM (commodity). The sample period is from January 1994 to December 2008.

	Mean	Median	STD	Skewness	Kurtosis	Min	Max
<i>Panel A: Market factors</i>							
S&P 500	0.31	0.96	4.30	-0.80	4.36	-16.83	9.31
S&P 400	0.35	0.68	4.91	-0.93	5.56	-21.62	11.20
S&P 600	0.36	1.06	5.16	-0.81	4.58	-20.22	11.32
<i>Panel B: Liquidity measures</i>							
Amihud ILLIQ (S&P 500)	0.34	0.38	0.15	-0.03	1.55	0.11	0.64
Amihud ILLIQ (S&P 400)	0.38	0.40	0.19	0.10	1.66	0.11	0.75
Amihud ILLIQ (S&P 600)	0.46	0.50	0.23	0.06	1.71	0.13	1.01
Amihud ILLIQ innovations (S&P 500)	0.001	-0.003	0.04	0.76	5.23	-0.09	0.14
Amihud ILLIQ innovations (S&P 400)	0.001	-0.006	0.05	1.09	6.72	-0.13	0.24
Amihud ILLIQ innovations (S&P 600)	0.001	-0.007	0.07	0.61	5.79	-0.21	0.26
Amihud ILLIQ residuals (S&P 500)	0.48	0.45	0.07	0.81	2.77	0.38	0.67
Pástor-Stambaugh liquidity (S&P 500)	-0.002	-0.002	0.005	0.07	9.34	-0.02	0.02
Pástor-Stambaugh liquidity innovations (S&P 500)	-0.0001	0.0001	0.005	0.91	9.86	-0.02	0.02
<i>Panel C: Fung-Hsieh risk factors</i>							
Small minus big (SMB)	0.18	-0.18	3.75	0.85	10.64	-16.85	21.99
Yield change	-0.01	-0.04	0.24	-0.17	4.53	-1.11	0.65
Change in default spread	0.01	-0.01	0.20	1.41	19.34	-0.99	1.45
PTFSBD	-0.01	-0.04	0.15	1.42	5.89	-0.25	0.69
PTFSFX	0.01	-0.03	0.20	1.33	5.52	-0.30	0.90
PTFSCOM	0.00	-0.03	0.14	1.25	5.48	-0.23	0.65

Table 3. Changepoint Estimation for Hedge Fund Portfolios

This table reports the changepoint estimation results for value weighted portfolios of hedge funds, given by Equation (5), with the following specification for the dynamics of the market beta:

$$\beta_t = \beta_0 + (\delta_0 + \delta_1 \cdot 1_{\{t > \tau\}}) L_{m,t} + \lambda \sigma_{m,t},$$

where $L_{m,t}$ is Amihud's (2002) measure of stock market illiquidity *ILLIQ* in month t (Panel A), or its residual $\varepsilon(ILLIQ)$ obtained from regressing the *ILLIQ* variable on predicted changes in liquidity, following Hameed et al. (2010) (Panel B). R^m is the return of the S&P 500 index. $\sigma_{m,t}$ is the stock market return volatility as proxied by the CBOE VIX index and τ is the changepoint. Only hedge funds with more than 24 monthly observations are included. Newey-West corrected t-values are given between parentheses. *, ** and *** denote significance at the 90%, 95% and 99%-level, respectively. We test for significance of the changepoint for a given portfolio using a parametric bootstrap. Changepoint significance is given for the 90% level of the *exp-F* statistic. The sample period is from January 1994 to December 2008.

	R^m		$R^m ILLIQ$		$R^m 1_{\{t>\tau\}} ILLIQ$		$R^m VIX$		Changepoint date	R^2
Panel A: ILLIQ										
Funds with primary focus on equities	0.49***	(4.75)	0.08	(0.29)	-0.98***	(-5.54)	-0.0025	(-0.93)	Sep-00*	0.63
Long-short equity hedge and equity market neutral	0.45***	(4.22)	0.03	(0.10)	-0.79***	(-4.34)	0.0014	(0.57)	Sep-00*	0.74
Convertible arbitrage	0.24	(1.55)	-0.83*	(-1.90)	-0.76**	(-2.55)	0.0109***	(3.38)	Feb-01*	0.55
Dedicated short bias	-1.30***	(-10.52)	0.73***	(2.64)	1.52***	(6.51)	-0.0049*	(-1.66)	Jan-01*	0.86
Emerging markets	0.61***	(3.24)	0.10	(0.21)	-1.36***	(-3.77)	0.0028	(0.46)	Jan-02	0.50
Event-driven	0.29***	(3.45)	-0.35*	(-1.85)	-0.49***	(-3.70)	0.0028	(1.47)	Apr-00*	0.66
Fund-of-funds	0.33***	(2.84)	-0.32	(-1.10)	-0.86***	(-5.10)	0.0044*	(1.78)	Sep-00*	0.61
Global macro	0.69***	(3.28)	0.42	(1.02)	-1.04***	(-2.73)	-0.0167***	(-3.64)	Sep-98*	0.30
Multi-strategy	0.29**	(2.17)	0.55	(1.41)	-1.02***	(-4.91)	-0.0018	(-0.42)	Feb-00*	0.43
Panel B: Residual ILLIQ										
Funds with primary focus on equities	1.00***	(5.22)	-1.12**	(-2.31)	-0.77***	(-8.25)	0.0032	(0.94)	Sep-00*	0.64
Long-short equity hedge and equity market neutral	0.54***	(2.75)	-0.17	(-0.35)	-0.52***	(-5.87)	0.0021	(0.61)	Sep-00*	0.72
Convertible arbitrage	0.09	(0.52)	-0.30	(-0.71)	0.51**	(2.06)	0.0050	(1.64)	Jan-05*	0.55
Dedicated short bias	-1.26***	(-3.96)	0.49	(0.66)	0.61***	(3.67)	-0.0027	(-0.59)	Jan-01*	0.85
Emerging markets	0.76*	(1.71)	-0.21	(-0.19)	-0.92***	(-3.65)	0.0036	(0.49)	Nov-00*	0.51
Event-driven	0.26*	(1.69)	-0.22	(-0.56)	-0.21**	(-2.08)	0.0029	(1.28)	Sep-98*	0.65
Fund-of-funds	0.68***	(3.69)	-1.12**	(-2.39)	-0.52***	(-7.59)	0.0082***	(2.62)	Sep-00*	0.60
Global macro	1.11**	(2.34)	-0.64	(-0.59)	-0.81***	(-3.59)	-0.0125**	(-2.03)	Sep-98*	0.30
Multi-strategy	1.08***	(3.69)	-1.50*	(-1.95)	-1.02***	(-6.74)	0.0087	(1.62)	Sep-00*	0.44

Table 4. Small-, Mid- and Large-cap ILLIQ

This table reports the changepoint estimation results for hedge fund portfolios, using liquidity measures for small-, mid- and large-cap market indices. We estimate a changepoint model of the returns of value-weighted portfolios of hedge funds, given by Equation (5), with the following specification for the dynamics of the market beta:

$$\beta_t = \beta_0 + (\delta_0 + \delta_1 \cdot 1_{\{t > \tau\}}) \cdot L_t + \lambda \sigma_{m,t},$$

where $L_{m,t}$ is Amihud's (2002) measure of stock market illiquidity *ILLIQ* in month t based on the constituents of the S&P 500, the S&P 400 or the S&P 600 index in that month, $\sigma_{m,t}$ is the stock market return volatility as proxied by the CBOE VIX index and τ is the changepoint-month. R^m is the index-return of the S&P 500, the S&P 400 or the S&P 600 index respectively. Funds are further sorted into portfolios according to the most appropriate market index variable (S&P 500 Large cap, the S&P 400 Midcap or the S&P 600 Small cap-index) on the basis of the AIC criterion from a multivariate regression of individual hedge fund returns on the Fung and Hsieh (1997) 7-factor model, augmented with contemporaneous AR(2) residuals of the Amihud illiquidity measure. We consider only hedge funds with more than 24 monthly observations. Newey-West corrected t-values are given between parentheses. *,** and *** denote significance at the 90%, 95% and 99%-level, respectively. We test for significance of the changepoint for a given portfolio using a parametric bootstrap. Changepoint significance is given for the 90% level of the *exp-F* statistic. The sample period is from January 1994 to December 2008.

	R^m		$R^m \text{ILLIQ}$		$R^m 1_{\{t>\tau\}} \text{ILLIQ}$		$R^m \text{VIX}$		Changepoint date	R^2
Market index: S&P 500 (33 %)										
Primary Focus on Equity	0.50***	(4.67)	0.78***	(2.66)	-0.76***	(-4.39)	-0.0108***	(-3.15)	Jan-00*	0.63
Long-short equity hedge and market neutral	0.46***	(5.92)	0.36	(1.57)	-0.64***	(-4.36)	-0.0033	(-1.54)	Aug-01	0.78
Convertible arbitrage	0.26***	(2.63)	-0.18	(-0.67)	-0.92***	(-3.32)	0.0034	(1.26)	Jul-01*	0.52
Dedicated short bias	-1.40***	(-10.10)	0.32	(1.02)	1.74***	(6.65)	-0.0021	(-0.60)	Jan-01*	0.82
Emerging markets	0.70***	(3.33)	0.38	(0.76)	-1.30***	(-3.23)	-0.0019	(-0.28)	Nov-00	0.49
Event-driven	0.15**	(2.48)	0.05	(0.32)	-0.22**	(-2.25)	-0.0003	(-0.21)	Sep-98	0.63
Fund-of-funds	0.39***	(4.97)	-0.14	(-0.68)	-0.84***	(-5.53)	0.0014	(0.63)	Sep-00*	0.68
Global macro	0.53**	(2.28)	1.66***	(3.33)	-1.37***	(-3.37)	-0.0218***	(-3.56)	Sep-98*	0.31
Multi-strategy	0.38***	(3.13)	0.67	(1.61)	-1.14***	(-4.92)	-0.0033	(-0.66)	Feb-00*	0.46
Market index: S&P 400 Midcap (53 %)										
Primary Focus on Equity	0.40***	(4.56)	-0.33*	(-1.87)	-0.73***	(-4.79)	0.0023	(1.21)	Jan-01*	0.61
Long-short equity hedge and market neutral	0.54***	(5.10)	-0.33	(-1.48)	-1.08***	(-5.07)	0.0032	(1.39)	Jan-01*	0.64
Convertible arbitrage	-0.04	(-0.48)	0.11	(0.62)	1.38***	(3.89)	0.0022	(1.30)	Nov-04*	0.61
Dedicated short bias	-0.60***	(-3.04)	-0.22	(-0.59)	-0.73**	(-2.04)	0.0106*	(1.89)	Apr-01	0.47
Emerging markets	0.44***	(2.94)	-0.35	(-1.26)	-1.01***	(-4.03)	0.0066	(1.65)	Feb-01*	0.53
Event-driven	0.33***	(4.22)	-0.43***	(-2.84)	-0.37***	(-4.36)	0.0033*	(1.94)	Apr-00*	0.65
Fund-of-funds	0.26***	(2.81)	-0.32*	(-1.71)	-0.67***	(-4.37)	0.0050**	(2.59)	Feb-01*	0.58
Global macro	0.55***	(3.49)	-0.45	(-1.63)	-0.48	(-1.28)	-0.0059	(-1.25)	Sep-98	0.20
Multi-strategy	0.21**	(2.29)	-0.19	(-0.98)	-0.36***	(-3.12)	0.0031	(1.41)	Sep-98*	0.42
Market index: S&P 600 Smallcap (14 %)										
Primary Focus on Equity	0.23***	(6.81)	0.08	(1.32)	-0.32***	(-6.18)	-0.0011	(-1.10)	Mar-00*	0.68
Long-short equity hedge and market neutral	0.25***	(6.27)	0.19**	(2.31)	-0.45***	(-7.30)	-0.0006	(-0.47)	May-00*	0.71
Convertible arbitrage	0.05	(0.46)	0.07	(0.51)	-0.26***	(-3.04)	0.0002	(0.07)	Sep-98	0.19
Dedicated short bias	-0.49**	(-2.47)	-0.21	(-0.69)	-0.37	(-1.32)	0.0067	(0.99)	Jan-01	0.43
Emerging markets	0.29**	(2.31)	-0.34*	(-1.78)	-0.48***	(-2.64)	0.0067	(1.42)	Mar-01	0.35
Event-driven	0.13**	(2.10)	0.09	(0.95)	-0.25***	(-4.26)	0.0032*	(1.96)	Jul-99*	0.73
Fund-of-funds	0.10	(1.31)	-0.02	(-0.20)	-0.44***	(-5.65)	0.0016	(0.73)	May-01*	0.48
Global macro	0.05	(0.38)	0.61***	(3.15)	0.88***	(5.87)	-0.0157***	(-4.29)	Jun-01*	0.27
Multi-strategy	0.07*	(1.70)	0.09	(1.23)	-0.11**	(-2.00)	-0.0003	(-0.22)	Sep-98	0.29

Table 5. Changepoint Estimation for Individual Hedge Funds

This table reports the changepoint estimation results for individual hedge funds. We estimate the changepoint model given by Equation (5) on the returns of individual hedge funds. Time-varying market betas evolve according to the following specification:

$$\beta_t = \beta_0 + (\delta_0 + \delta_1 \cdot 1_{\{t > \tau\}}) L_{m,t} + \lambda \sigma_{m,t},$$

where $L_{m,t}$ is Amihud's (2002) measure of stock market illiquidity *ILLIQ* in month t (Panel A), or its residual $\varepsilon(ILLIQ)$ obtained from regressing the *ILLIQ* variable on predicted changes in liquidity, following Hameed et al. (2010) (Panel B). $\sigma_{m,t}$ is the stock market return volatility as proxied by the CBOE VIX index, and τ is the changepoint. R^m is the return of the S&P 500 index. Reported are parameter estimates of the dynamic beta specification of individual funds with a significant changepoint in years 1998 through 2007 according to the *exp-F* statistic at a 90% significance level with critical values obtained using a parametric bootstrap. The sample period is from January 1994 to December 2008.

Changepoint year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Panel A: ILLIQ										
% of funds with a changepoint	4%	5%	18%	16%	6%	9%	5%	4%	5%	22%
$R^m ILLIQ$	-0.38	0.28	-0.39	-0.45	0.14	1.00	-1.48	0.84	-0.63	0.11
Average t-statistic	(0.70)	(0.39)	(-0.59)	(-0.85)	(0.38)	(0.46)	(0.03)	(-0.20)	(-0.02)	(0.17)
Cross-sectional t-statistic	(-0.52)	(0.68)	(-2.58)	(-2.62)	(0.83)	(1.83)	(-1.05)	(0.73)	(-0.38)	(0.09)
$R^m 1_{\{t > \tau\}} ILLIQ$	-0.31	-0.24	-1.75	-1.45	0.22	1.84	0.82	-2.41	-1.87	-0.31
Average t-statistic	(-2.14)	(-1.58)	(-3.94)	(-3.37)	(0.59)	(1.54)	(1.41)	(-0.60)	(-0.63)	(-0.31)
Cross-sectional t-statistic	(-0.90)	(-0.71)	(-8.73)	(-9.31)	(0.65)	(2.92)	(1.59)	(-3.12)	(-1.43)	(-0.35)
Panel B: Residual ILLIQ										
% of funds with a changepoint	6%	5%	19%	14%	6%	9%	3%	4%	6%	19%
$R^m \varepsilon(ILLIQ)$	0.08	0.38	-1.01	-0.68	0.67	0.18	0.12	1.16	-0.28	-1.70
Average t-statistic	(0.09)	(-0.15)	(-0.99)	(-1.16)	(0.50)	(0.06)	(0.28)	(-0.11)	(-0.91)	(-0.54)
Cross-sectional t-statistic	(0.11)	(0.52)	(-2.38)	(-2.29)	(2.15)	(0.38)	(0.04)	(1.16)	(-0.16)	(-1.47)
$R^m 1_{\{t > \tau\}} \varepsilon(ILLIQ)$	-0.49	-0.15	-1.39	-0.76	0.09	0.92	0.40	-0.14	-0.22	0.91
Average t-statistic	(-1.92)	(-1.15)	(-3.77)	(-3.26)	(0.12)	(1.96)	(2.10)	(0.13)	(0.15)	(0.76)
Cross-sectional t-statistic	(-2.03)	(-0.53)	(-7.67)	(-6.11)	(0.37)	(3.71)	(0.99)	(-0.31)	(-0.53)	(2.11)
Panel C: Percentages per style										
Long-short equity hedge and equity market neutral	3%	4%	15%	12%	8%	8%	5%	7%	7%	30%
Convertible arbitrage	4%	6%	0%	2%	8%	6%	20%	8%	12%	33%
Dedicated short bias	0%	0%	43%	0%	29%	0%	0%	0%	0%	29%
Emerging markets	7%	7%	8%	8%	2%	9%	0%	1%	9%	41%
Event-driven	2%	7%	10%	4%	10%	4%	13%	10%	8%	28%
Fund-of-funds	3%	1%	10%	17%	2%	13%	5%	8%	7%	31%
Global macro	0%	0%	8%	13%	3%	1%	5%	12%	12%	41%
Multi-strategy	6%	1%	3%	9%	2%	8%	9%	8%	7%	45%

Table 6. Selecting on Hedge Fund Characteristics

This table reports the changepoint estimation results for hedge fund portfolios composed of hedge funds with characteristics that are most likely to influence the results. The results are the estimation of the model in Equation (5), with the following specification for the dynamics of the market beta:

$$\beta_t = \beta_0 + (\delta_0 + \delta_1 \cdot 1_{\{t > \tau\}}) ILLIQ_{m,t} + \lambda \sigma_{m,t},$$

where $ILLIQ_{m,t}$ is Amihud's (2002) measure of stock market illiquidity $ILLIQ$ in month t , $\sigma_{m,t}$ is the stock market return volatility as proxied by the CBOE VIX index and τ is the changepoint. R^m is the return of the S&P 500 index. Value-weighted portfolios are formed using hedge funds that (1) do not employ leverage, (2) have low redemption frequency, (3) have redemption notice periods of 60 days or more, (4) have lock-up periods of more than 3 months, or (5) have below-median fund-flow volatility, computed as in Sirri and Tufano (1998). Panel A has the results for value-weighted portfolios of funds with primary focus on equities (PFE). Panel B reports results on Long-Short Equity Hedge (LSEH) and Equity Market Neutral (EMN) hedge funds. Panel C reports results for portfolios of funds-of-funds. Newey-West corrected t-values are given between parentheses. *, ** and *** denote significance at the 90%, 95% and 99%-level, respectively. We test for significance of the changepoint for a given portfolio using a parametric bootstrap. Changepoint significance is given for the 90% level of the $exp-F$ statistic. The sample period is from January 1994 to December 2008.

	Not using leverage		Low redemption frequency (quarterly and above)		Long redemption notice period (60 days or more)		Long lock-up periods (more than 3 months)		Low (below median) fund flow volatility	
	(1)		(2)		(3)		(4)		(5)	
Panel A: PFE funds										
[% of funds]	[39%]		[39%]		[21%]		[21%]		[46%]	
R^m	0.43***	(4.13)	0.53***	(4.92)	0.43***	(4.33)	0.44***	(4.10)	0.36***	(5.49)
$R^m ILLIQ$	0.06	(0.23)	0.15	(0.57)	-0.01	(-0.04)	0.40	(1.28)	-0.23	(-1.38)
$R^m 1_{\{t>\tau\}} ILLIQ$	-0.94***	(-5.25)	-1.09***	(-5.68)	-1.09***	(-6.06)	-0.89***	(-4.99)	-0.63***	(-6.13)
$R^m VIX$	0.0004	(0.16)	-0.0031	(-1.11)	0.0012	(0.44)	-0.0051	(-1.46)	-0.0002	(-0.14)
Changepoint	Sep-00*		Sep-00*		Sep-00		Jan-00*		May-00*	
R ²	0.69		0.65		0.66		0.51		0.67	
Panel B: LSEH/EMN funds										
[% of funds]	[45%]		[36%]		[15%]		[25%]		[43%]	
R^m	0.38***	(3.72)	0.50***	(5.18)	0.48***	(4.00)	0.56***	(4.57)	0.37***	(5.54)
$R^m ILLIQ$	-0.04	(-0.13)	0.23	(0.86)	-0.25	(-0.77)	-0.24	(-0.74)	-0.27	(-1.53)
$R^m 1_{\{t>\tau\}} ILLIQ$	-0.86***	(-5.19)	-0.79***	(-4.69)	-0.71***	(-2.94)	-0.68***	(-3.97)	-0.63***	(-5.70)
$R^m VIX$	0.0033	(1.44)	-0.0002	(-0.09)	0.0021	(0.66)	0.0029	(1.02)	0.0008	(0.51)
Changepoint	Sep-00*		Sep-00*		Sep-00		Sep-00*		May-00*	
R ²	0.73		0.79		0.63		0.73		0.65	
Panel C: Fund-of-funds										
[% of funds]	[65%]		[30%]		[28%]		[11%]		[41%]	
R^m	0.28**	(2.41)	0.31***	(2.94)	0.33***	(3.35)	0.42***	(3.83)	0.36***	(4.24)
$R^m ILLIQ$	-0.42	(-1.45)	-0.43	(-1.61)	-0.22	(-0.88)	-0.52*	(-1.87)	-0.16	(-0.73)
$R^m 1_{\{t>\tau\}} ILLIQ$	-0.88***	(-5.43)	-0.86***	(-5.42)	-0.91***	(-5.82)	-0.98***	(-5.62)	-0.78***	(-5.84)
$R^m VIX$	0.0073***	(3.00)	0.0060***	(2.70)	0.0039*	(1.97)	0.0040*	(1.90)	-0.0001	(-0.05)
Changepoint	Sep-00*		Sep-00*		Sep-00*		Sep-00*		Sep-00*	
R ²	0.58		0.68		0.69		0.64		0.64	

Table 7: Characteristics of candidate dynamic strategies for hedge funds

This table reports the changepoint estimation results for four dynamic strategies. The pairs trading strategy is that of Gatev et al. (2006), Momentum and Short-term Reversal are obtained from Kenneth French' website, and the Liquidity strategy is that of Ben Rephael et al. (2010), based on large-cap stocks. We estimate a changepoint regression as given by Equation (5) with the following specification for the evolution of market beta:

$$\beta_t = \beta_0 + (\delta_0 + \delta_1 \cdot 1_{\{t > \tau\}})L_t + \lambda\sigma_{m,t}$$

where L_t is Amihud's (2002) measure of stock market illiquidity in month t , $\sigma_{m,t}$ is the stock market return volatility as proxied by the CBOE VIX index, and τ is the changepoint. R^m is the return of the S&P 500 index. Newey-West corrected t-values are given between parentheses. *, ** and *** denote significance at the 90%, 95% and 99%-level, respectively. We test for significance of the changepoint for a given portfolio using a parametric bootstrap. Changepoint significance is given for the 90% level of the *exp-F* statistic. The sample period is from January 1994 to December 2008.

	Liquidity	Pairs trading	Momentum	Reversal
R^m	-0.13 (-1.28)	-0.02 (-0.88)	0.17 (0.47)	-0.64** (-2.14)
R^mILLIQ	-0.07 (-0.28)	0.07 (0.74)	-0.03 (-0.02)	1.15 (1.43)
$R^m1_{\{t > \tau\}}ILLIQ$	-0.69*** (-3.66)	0.18** (2.40)	-3.42*** (-4.26)	1.50** (2.56)
R^mVIX	0.0099*** (3.72)	-0.0002 (-0.22)	-0.0012 (-0.12)	0.0054 (0.76)
Changepoint	Sep-02	Sep-02	Jan-01*	Feb-00
R^2	0.15	0.08	0.39	0.23

Table 8. Sorting hedge fund returns on the loading on the dynamic strategies

This table reports the changepoint estimation results for the returns of value-weighted portfolios of hedge funds that load or not on four dynamic strategies. The pairs trading strategy is that of Gatev et al. (2006), Momentum and Short-term Reversal are obtained from Kenneth French' website, and the Liquidity strategy is that of Ben Rephael et al. (2010), based on large-cap stocks. Whether funds belong to the loading or non-loading portfolio for a given strategy is determined from a multivariate regression of individual hedge fund returns on the S&P 500 market index return and the return of the dynamic strategy. We estimate a changepoint regression as given by Equation (5) with the following specification for the evolution of market beta:

$$\beta_t = \beta_0 + (\delta_0 + \delta_1 \cdot 1_{\{t > \tau\}}) L_{m,t} + \lambda \sigma_{m,t}$$

where $L_{m,t}$ is Amihud's (2002) ILLIQ measure of stock market illiquidity in month t , $\sigma_{m,t}$ is the stock market return volatility as proxied by the CBOE VIX index and τ is the changepoint. R^m is the return of the S&P 500 index. For each strategy, we report the percentage of loading funds, the coefficient δ_1 of the interaction term, and the changepoint date. The portfolio of PFE funds contains hedge funds with primary focus on equities, and LSEH/EMN denotes the portfolio with hedge funds from Long-Short Equity Hedge (LSEH) and Equity Market Neutral (EMN). Newey-West corrected t -values are given between parentheses. *, ** and *** denote significance at the 90%, 95% and 99%-level, respectively. We test for significance of the changepoint for a given portfolio using a parametric bootstrap. Changepoint significance is given for the 90% level of the $exp-F$ statistic. The sample period is from January 1994 to December 2008. If the number of loading funds is too small to make a full time series, the cell is left blank.

	Panel A: Liquidity							Panel B: Pairs trading						
	Loading funds			Non-loading funds				Loading funds			Non-loading funds			
	Perc.	$R^m 1_{\{t > \tau\}} ILLIQ$	Chgpt.	$R^m 1_{\{t > \tau\}} ILLIQ$	Chgpt.			Perc.	$R^m 1_{\{t > \tau\}} ILLIQ$	Chgpt.	$R^m 1_{\{t > \tau\}} ILLIQ$	Chgpt.		
PFE funds	7%	-2.23*** (-5.37)	Jul-02*	-1.00*** (-5.93)	Sep-00*			2%	-1.18*** (-4.22)	Nov-00*	-0.98*** (-5.49)	Sept-00*		
LSEH/EMN	8%	-2.23*** (-5.62)	Sep-01*	-0.79*** (-4.56)	Sep-00*			3%			-0.79*** (-4.25)	Sep-00*		
Convertible arbitrage	3%			1.63*** (3.04)	Jan-05*			3%			-0.76** (-2.54)	Feb-01*		
Dedicated short bias	2%			1.48*** (6.36)	Jan-01*			10%			1.55*** (6.60)	Jan-01*		
Emerging markets	7%	-2.01*** (-3.80)	Feb-01*	-1.36*** (-3.78)	Nov-00			0%			-1.36*** (-3.78)	Nov-00		
Event-driven	3%			-0.49*** (-3.81)	Apr-00*			3%	1.29*** (4.59)	Jun-03*	-0.48*** (-3.61)	Apr-00*		
Fund-of-funds	9%	-1.01*** (-6.64)	Apr-00*	-0.86*** (-4.99)	Sep-00*			1%	0.65** (2.51)	Jun-95	-0.86*** (-5.11)	Sep-00*		
Global macro	6%	-0.47 (-1.03)	Mar-97	-1.09*** (-2.73)	Sep-98*			6%	-3.60*** (-3.06)	May-04*	-1.37*** (-3.78)	Sep-98*		
Multi-strategy	7%	-6.94*** (-3.26)	May-07*	-1.02*** (-5.01)	Feb-00*			1%			-1.02*** (-4.90)	Feb-00*		
	Panel C: Momentum							Panel D: Reversal						
	Loading funds			Non-loading funds				Loading funds			Non-loading funds			
	Perc.	$R^m 1_{\{t > \tau\}} ILLIQ$	Chgpt.	$R^m 1_{\{t > \tau\}} ILLIQ$	Chgpt.			Perc.	$R^m 1_{\{t > \tau\}} ILLIQ$	Chgpt.	$R^m 1_{\{t > \tau\}} ILLIQ$	Chgpt.		
PFE funds	29%	-1.19*** (-5.00)	Feb-00*	-0.68*** (-5.09)	May-00*			4%	-0.66*** (-3.38)	Feb-01*	-1.00*** (-5.56)	Sept-00*		
LSEH/EMN	33%	-1.74*** (-6.49)	Jul-01*	-0.55*** (-4.20)	Sep-00			5%	1.17*** (3.99)	Feb-00*	-0.83*** (-4.44)	Sep-00*		
Convertible arbitrage	3%	-1.15*** (-4.87)	Feb-01*	-0.76** (-2.52)	Feb-01*			11%	-1.06*** (-2.66)	Feb-01*	-0.73** (-2.56)	Feb-01*		
Dedicated short bias	17%	3.01*** (3.20)	Mar-04*	1.40*** (6.16)	Jan-01*			0%			1.52*** (6.51)	Jan-01*		
Emerging markets	21%	-2.10*** (-4.23)	Nov-00*	-1.18*** (-3.31)	Apr-01			1%	1.68** (2.46)	Aug-97	-1.37*** (-3.77)	Nov-00		
Event-driven	13%	-0.70*** (-3.45)	Jun-00*	-0.36*** (-3.39)	Sep-98*			6%	-0.78*** (-2.82)	Feb-01*	-0.49*** (-3.67)	Apr-00*		
Fund-of-funds	37%	-1.07*** (-5.95)	Sep-00*	-0.57*** (-3.64)	Sep-00*			1%	-0.40** (-2.36)	Aug-96*	-0.87*** (-5.11)	Sep-00*		
Global macro	19%	-2.94*** (-5.46)	Nov-00*	-0.67* (-1.67)	Sep-98			4%			-1.04*** (-2.73)	Sep-98*		
Multi-strategy	26%	-1.61*** (-4.32)	Feb-00*	-0.71*** (-3.56)	Sep-00*			4%	-0.48*** (-3.14)	Feb-01	-1.03*** (-4.91)	Feb-00*		

Table 9. Controlling Momentum for value, size and market timing

This table reports the changepoint estimation results for value-weighted hedge fund portfolios composed of funds with significant loadings on Momentum, controlling for value, size and market timing. A significant loading on Momentum is determined from a regression of the hedge fund return on the market return, SMB and HML. Panel A has the parameter estimates for the following specification of time-varying market beta in the changepoint model given by Equation (5):

$$\beta_t = \beta_0 + (\delta_0 + \delta_1 \cdot 1_{\{t > \tau\}})ILLIQ_t + \lambda\sigma_{m,t}$$

where $ILLIQ_t$ is Amihud's (2002) measure of stock market illiquidity in month t , $\sigma_{m,t}$ is the stock market return volatility as proxied by the CBOE VIX index and τ is the changepoint. Panel B reports parameter estimates for the following specification of time-varying market beta with market timing effects:

$$\beta_t = b_0 + (b_1 + b_2 \cdot 1_{\{t > \tau\}}) \cdot ILLIQ + c \cdot I_B$$

where I_B is a bear market indicator equal to 1 if the cumulative market return in the 12 preceding months is negative. The portfolio of PFE funds contains hedge funds with primary focus on equities, and LSEH/EMN denotes the portfolio with hedge funds from Long-Short Equity Hedge (LSEH) and Equity Market Neutral (EMN). We further split funds in portfolios according to the most appropriate market index variable (S&P 500, the S&P 400 or the S&P 600 index) on the basis of the AIC criterion from a multivariate regression of individual hedge fund returns on the Fung and Hsieh (1997) 7-factor model, augmented with contemporaneous AR(2) residuals of Amihud's (2002) illiquidity measure. We require at least 24 monthly observations per fund. For each portfolio and for each market index, we report the coefficient δ_1 (Panel A) or b_2 (Panel B) of the interaction term, and the changepoint date. Newey-West corrected t-values are given between parentheses. *, ** and *** denote significance at the 90%, 95% and 99%-level, respectively. We test for significance of the changepoint for a given portfolio using a parametric bootstrap. Changepoint significance is given for the 90% level of the $exp-F$ statistic. The sample period is from January 1994 to December 2008.

Panel A: Controlling for Value and Size

	S&P 500			S&P 400			S&P 600		
	$R^m 1_{\{t > \tau\}}ILLIQ$		Chgpt.	$R^m 1_{\{t > \tau\}}ILLIQ$		Chgpt.	$R^m 1_{\{t > \tau\}}ILLIQ$		Chgpt.
PFE funds	-1.19***	(-5.34)	Feb-00*	-1.37***	(-5.13)	Apr-01*	-0.90***	(-4.77)	Apr-01*
LSEH/EMN	-1.61***	(-5.81)	Jul-01*	-1.63***	(-5.85)	Apr-01*	-1.10***	(-5.27)	Apr-01*
Convertible arbitrage	-1.32***	(-4.19)	Mar-01*	-1.53***	(-5.40)	Mar-01*	-0.98***	(-4.80)	Mar-01*
Dedicated short bias	3.01***	(3.20)	Mar-04*	2.63***	(4.29)	Apr-05*	1.37**	(2.60)	Mar-04*
Emerging markets	-2.22***	(-4.98)	Nov-00*	-1.43***	(-4.04)	Nov-00*	-0.95***	(-4.10)	Nov-00*
Event-driven	-0.81***	(-4.65)	Jun-00*	-0.72***	(-4.39)	Jan-01*	-0.44***	(-3.92)	Jan-01*
Fund-of-funds	-1.07***	(-6.05)	Sep-00*	-0.89***	(-5.13)	Feb-01*	-0.63***	(-5.53)	Apr-01*
Global macro	-2.71***	(-5.07)	Nov-00*	-2.55***	(-6.25)	Mar-01*	-1.58***	(-6.09)	Mar-01*
Multi-strategy	-1.60***	(-4.41)	Feb-00*	-1.75***	(-4.14)	Feb-01*	-0.81***	(-3.04)	May-00*

Panel B: Controlling for Market timing

	S&P 500			S&P 400			S&P 600		
	$R^m 1_{\{t > \tau\}}ILLIQ$		Chgpt.	$R^m 1_{\{t > \tau\}}ILLIQ$		Chgpt.	$R^m 1_{\{t > \tau\}}ILLIQ$		Chgpt.
PFE funds	-1.15***	(-5.19)	Feb-00*	-1.35***	(-5.27)	Apr-01*	-0.90***	(-5.04)	Apr-01*
LSEH/EMN	-1.35***	(-3.58)	Jul-01	-1.49***	(-5.12)	Apr-01*	-1.08***	(-6.50)	Apr-01*
Convertible arbitrage	0.51	(1.08)	Mar-00	-0.67***	(-3.80)	Dec-00*	-0.51***	(-4.34)	Mar-01*
Dedicated short bias	1.08***	(3.11)	Jan-01	0.74***	(3.81)	Jan-99*	0.81***	(4.64)	Dec-00*
Emerging markets	0.68*	(1.76)	Mar-99	0.97***	(3.43)	Mar-97	-1.46***	(-4.04)	Jul-06*
Event-driven	-0.44	(-1.47)	Jun-00	-0.72***	(-3.34)	Jan-01*	-0.38***	(-3.45)	Jan-01*
Fund-of-funds	-0.89***	(-3.77)	Sep-00*	-0.57***	(-4.60)	Jul-00*	-0.60***	(-5.91)	Apr-01*
Global macro	-3.24***	(-5.47)	May-97*	-1.68***	(-3.65)	Nov-00*	-1.75***	(-5.56)	Mar-01*
Multi-strategy	-1.79***	(-3.47)	May-98*	-1.16***	(-3.30)	May-00	-0.84***	(-2.98)	May-00

Table 10. Controlling for Backfill Bias

We estimate a changepoint regression on the returns of value-weighted portfolios of hedge funds with controls for backfill bias. To account for backfill bias, we exclude the observations for each fund before the month in which the fund was added to the TASS database. The changepoint model is in Equation (5), with the following specification for the dynamics of the market beta:

$$\beta_t = \beta_0 + (\delta_0 + \delta_1 \cdot 1_{\{t > \tau\}})L_{m,t} + \lambda\sigma_{m,t},$$

where $L_{m,t}$ is Amihud's (2002) measure of stock market illiquidity $ILLIQ$ in month t (Panel A), or its residual $\varepsilon(ILLIQ)$ obtained from regressing the $ILLIQ$ variable on predictable changes in liquidity (Panel B). $\sigma_{m,t}$ is the stock market return volatility as proxied by the CBOE VIX index, τ is the changepoint, and R^m is the return of the S&P 500 index. The portfolio of PFE funds consists of funds with primary focus on equities. LSEH/EMN denotes the portfolio with hedge funds from Long-Short Equity Hedge (LSEH) and Equity Market Neutral (EMN). We consider only hedge funds with more than 24 monthly observations. Newey-West corrected t-values are given between parentheses. *, ** and *** denote significance at the 90%, 95% and 99%-level, respectively. We test for significance of the changepoint for a given portfolio using a parametric bootstrap. Changepoint significance is given for the 90% level of the *exp-F* statistic. The sample period is from January 1994 to December 2008.

	R^m		$R^m ILLIQ$		$R^m 1_{\{t>\tau\}} ILLIQ$		$R^m VIX$		Chgpt	R^2
<i>Panel A: ILLIQ</i>										
PFE funds	0.52***	(4.32)	0.17	(0.54)	-1.11***	(-5.62)	-0.0032	(-0.79)	Jun-00*	0.46
LSEH/EMN	0.47***	(4.36)	-0.02	(-0.06)	-0.76***	(-4.10)	0.0009	(0.31)	Sep-00*	0.71
Convertible arbitrage	-0.07	(-0.73)	0.40*	(1.70)	1.94***	(4.23)	-0.0015	(-0.60)	Jan-05*	0.61
Dedicated short bias	-1.41***	(-9.12)	1.21***	(2.78)	1.29***	(3.49)	-0.0044	(-0.81)	Apr-00	0.65
Emerging markets	0.59***	(2.99)	0.26	(0.55)	-1.45***	(-3.70)	0.0030	(0.48)	Nov-00*	0.52
Event-driven	0.32***	(4.48)	-0.33**	(-2.08)	-0.44***	(-3.72)	0.0004	(0.26)	Apr-00*	0.66
Fund-of-funds	0.30***	(2.78)	-0.13	(-0.46)	-0.76***	(-4.75)	0.0021	(0.79)	Sep-00*	0.62
Global macro	0.34	(1.44)	4.15***	(6.79)	-3.10***	(-5.83)	-0.0226***	(-3.29)	May-97*	0.38
Multi-strategy	0.44***	(3.29)	0.60	(1.30)	-1.35***	(-4.97)	-0.0052	(-0.96)	Feb-00*	0.38
<i>Panel B: Residual ILLIQ</i>										
PFE funds	1.33***	(4.98)	-1.80***	(-2.64)	-0.99***	(-7.67)	0.0069	(1.40)	Sep-00*	0.48
LSEH/EMN	0.63***	(3.15)	-0.34	(-0.64)	-0.53***	(-5.93)	0.0019	(0.49)	Sep-00*	0.71
Convertible arbitrage	-0.06	(-0.38)	0.10	(0.25)	0.64***	(2.89)	0.0025	(0.85)	Jan-05*	0.60
Dedicated short bias	-1.96***	(-5.03)	2.41**	(2.47)	0.52**	(2.32)	-0.0102	(-1.38)	Apr-00	0.64
Emerging markets	0.90**	(2.07)	-0.44	(-0.43)	-1.07***	(-3.68)	0.0058	(0.74)	Nov-00*	0.51
Event-driven	0.27*	(1.83)	-0.12	(-0.32)	-0.19*	(-1.95)	-0.0001	(-0.07)	Sep-98	0.62
Fund-of-funds	0.53***	(2.90)	-0.65	(-1.43)	-0.49***	(-6.55)	0.0043	(1.41)	Sep-00*	0.57
Global macro	0.12	(0.20)	3.59**	(2.44)	-2.65***	(-5.66)	-0.0209**	(-2.55)	Apr-98*	0.37
Multi-strategy	1.40***	(3.78)	-1.82*	(-1.79)	-1.26***	(-5.59)	0.0063	(0.89)	May-00*	0.30

Table 11. Using the Pástor-Stambaugh liquidity measure

This table reports the changepoint estimation results for value-weighted portfolios when the Pástor-Stambaugh liquidity measure is used. We estimate Equation (5), with the following specification for the dynamics of the market beta:

$$\beta_t = \beta_0 + (\delta_0 + \delta_1 \cdot 1_{\{t > \tau\}})PS_{m,t} + \lambda\sigma_{m,t},$$

where $PS_{m,t}$ is the aggregate Pástor and Stambaugh (2003) measure of stock market illiquidity in month t (Panel A) or its residual obtained from regressing the $PS_{m,t}$ variable on predictable changes in liquidity (Panel B). $\sigma_{m,t}$ is the stock market return volatility as proxied by the CBOE VIX index and τ is the changepoint. R^m is the return of the S&P 500 index. The portfolio of PFE funds consists of funds with primary focus on equities. LSEH/EMN denotes the portfolio with hedge funds from Long-Short Equity Hedge (LSEH) and Equity Market Neutral (EMN). We consider only hedge funds with more than 24 monthly observations. Newey-West corrected t-values are given between parentheses. *, ** and *** denote significance at the 90%, 95% and 99%-level, respectively. We test for significance of the changepoint for a given portfolio using a parametric bootstrap. Changepoint significance is given for the 90% level of the *exp-F* statistic. The sample period is from January 1994 to December 2008.

	R^m		$R^m PS$		$R^m 1_{(t>\tau)} PS$		$R^m VIX$		Chgpt	R^2
<i>Panel A: PS</i>										
PFE funds	0.39***	(4.90)	-37.98***	(-3.03)	48.34***	(3.87)	-0.0032	(-1.08)	Jun-98*	0.60
LSEH/EMN	0.40***	(6.52)	2.53	(0.78)	36.64***	(2.94)	0.0007	(0.36)	Oct-01*	0.70
Convertible arbitrage	0.14*	(1.68)	12.13***	(3.99)	-147.47**	(-2.20)	-0.0010	(-0.33)	Mar-05*	0.59
Dedicated short bias	-1.00***	(-11.09)	-11.34	(-1.50)	-73.86***	(-3.95)	-0.0008	(-0.25)	Feb-02*	0.85
Emerging markets	0.59***	(4.21)	18.59*	(1.93)	96.33***	(3.08)	0.0022	(0.41)	Jan-02	0.50
Event-driven	0.15***	(3.52)	0.31	(0.04)	12.46*	(1.74)	0.0007	(0.38)	Jun-98	0.67
Fund-of-funds	0.15**	(2.55)	-21.29*	(-1.91)	32.55***	(2.89)	0.0019	(0.91)	Jun-98*	0.58
Global macro	0.63***	(4.31)	-95.12**	(-2.44)	117.70***	(3.03)	-0.0173***	(-3.04)	May-97	0.30
Multi-strategy	0.22*	(1.81)	-73.61***	(-2.91)	80.75***	(3.22)	0.0009	(0.21)	May-98*	0.39
<i>Panel B: Residual PS</i>										
PFE funds	0.53***	(6.97)	4.08	(0.95)	36.79***	(4.13)	-0.0046*	(-1.87)	Jul-01*	0.60
LSEH/EMN	0.46***	(7.33)	2.35	(0.68)	28.40***	(3.66)	-0.0003	(-0.16)	Aug-01*	0.71
Convertible arbitrage	0.12	(1.61)	11.10***	(3.42)	-90.72*	(-1.95)	0.0002	(0.08)	Jul-07*	0.59
Dedicated short bias	-1.07***	(-11.08)	-0.52	(-0.06)	-32.04***	(-3.68)	0.0016	(0.48)	Dec-00*	0.85
Emerging markets	0.74***	(4.82)	14.92	(1.56)	52.70***	(2.95)	-0.0012	(-0.23)	Aug-01	0.50
Event-driven	0.20***	(4.68)	11.06***	(3.62)	-20.61	(-1.19)	-0.0005	(-0.24)	Aug-04	0.67
Fund-of-funds	0.17***	(2.89)	-15.67*	(-1.91)	26.95***	(3.27)	0.0019	(0.91)	Jun-98*	0.58
Global macro	0.67***	(4.09)	-82.37**	(-2.54)	104.27***	(3.32)	-0.0171***	(-2.92)	May-97	0.30
Multi-strategy	0.33***	(2.67)	-30.19**	(-2.42)	49.45***	(3.82)	-0.0010	(-0.23)	Jun-00*	0.41

Table 12. Funds with a Time-varying Market Exposure

This table has the changepoint estimation results for portfolios of hedge funds that have a significant changepoint in their market exposure. Hedge funds are selected on the basis of changepoint regressions of their return on the Fung and Hsieh (1997) 7-factor model with a time-varying market beta specified as:

$$\beta_{i,t} = \beta_{i,0} + \beta_{i,1} \cdot 1_{\{t > \tau\}}.$$

Funds are selected when they have a significant changepoint in their individual market exposures based on the 90% level of the *exp-F* statistic with critical values obtained using a parametric bootstrap. We then form value-weighted portfolios of these funds and estimate the changepoint model given by Equation (5) with the following specification for the dynamics of the market beta:

$$\beta_t = \beta_0 + (\delta_0 + \delta_1 \cdot 1_{\{t > \tau\}}) L_{m,t} + \lambda \sigma_{m,t},$$

where $L_{m,t}$ is Amihud's (2002) measure of stock market illiquidity *ILLIQ* in month t (Panel A), or its residual $\varepsilon(ILLIQ)$ obtained from regressing the *ILLIQ* variable on predictable changes in liquidity (Panel B). $\sigma_{m,t}$ is the stock market return volatility as proxied by the CBOE VIX index and τ is the changepoint. R^m is the return of the S&P 500 index. The portfolio of PFE funds consists of funds with primary focus on equities. LSEH/EMN denotes the portfolio with hedge funds from Long-Short Equity Hedge (LSEH) and Equity Market Neutral (EMN). We consider only hedge funds with more than 24 monthly observations. Newey-West corrected t-values are given between parentheses. *, ** and *** denote significance at the 90%, 95% and 99%-level, respectively. Changepoint significance is given for the 90% level of the *exp-F* statistic. The sample period is from January 1994 to December 2008.

	PFE funds		LSEH/EMN funds		Fund-of-funds	
	(1)	(2)	(3)	(4)	(5)	(6)
<i>Panel A: ILLIQ</i>						
R^m	0.53*** (5.24)	0.56*** (5.60)	0.48*** (4.63)	0.47*** (4.79)	0.42*** (3.53)	0.40*** (3.40)
$R^m ILLIQ$	-0.05 (-0.21)	0.12 (0.46)	0.03 (0.12)	0.01 (0.04)	-0.16 (-0.62)	-0.30 (-1.02)
$R^m 1_{\{t > \tau\}} ILLIQ$	-1.15*** (-6.02)	-1.04*** (-5.63)	-0.90*** (-5.25)	-0.91*** (-4.86)	-0.93*** (-5.75)	-1.03*** (-5.78)
$R^m VIX$		-0.0045 (-1.58)		0.0004 (0.15)		0.0039 (1.55)
Changepoint	Sep-00*	Sep-00*	Aug-01*	Aug-01*	Sep-00*	Sep-00*
R^2	0.63	0.64	0.74	0.74	0.63	0.63
<i>Panel B: Residual ILLIQ</i>						
R^m	1.01*** (6.27)	1.03*** (5.31)	0.49*** (3.22)	0.46** (2.36)	0.59*** (3.95)	0.85*** (4.38)
$R^m \varepsilon(ILLIQ)$	-0.91*** (-3.07)	-0.99** (-1.97)	0.05 (0.20)	0.17 (0.35)	-0.44 (-1.59)	-1.34*** (-2.70)
$R^m 1_{\{t > \tau\}} \varepsilon(ILLIQ)$	-0.79*** (-6.90)	-0.80*** (-7.89)	-0.52*** (-5.41)	-0.50*** (-5.66)	-0.54*** (-5.89)	-0.66*** (-8.47)
$R^m VIX$		0.0007 (0.21)		-0.0011 (-0.35)		0.0088*** (2.68)
Changepoint	Sep-00*	Sep-00*	Sep-00*	Sep-00*	Sep-00*	Sep-00*
R^2	0.65	0.65	0.73	0.73	0.62	0.63

Table 13. Small funds

This table reports the changepoint estimation results for value-weighted portfolios of hedge funds with average assets under management (AUM) of less than \$50 million (Panel A) or less than \$150 million (Panel B). The changepoint model is in Equation (5) with the following specification for the dynamics of the market beta:

$$\beta_t = \beta_0 + (\delta_0 + \delta_1 \cdot 1_{\{t > \tau\}})L_{m,t} + \lambda\sigma_{m,t},$$

where $L_{m,t}$ is Amihud's (2002) measure of stock market illiquidity $ILLIQ$ in month t , $\sigma_{m,t}$ is the stock market return volatility as proxied by the CBOE VIX index and τ is the changepoint. R^m is the return of the S&P 500 index. The portfolio of PFE funds consists of funds with primary focus on equities. LSEH/EMN denotes the portfolio with hedge funds from Long-Short Equity Hedge (LSEH) and Equity Market Neutral (EMN). We consider only hedge funds with more than 24 monthly observations. Newey-West corrected t-values are given between parentheses. *, ** and *** denote significance at the 90%, 95% and 99%-level, respectively. We test for significance of the changepoint for a given portfolio using a parametric bootstrap. Changepoint significance is given for the 90% level of the $exp-F$ statistic. The sample period is from January 1994 to December 2008.

	PFE funds		LSEH/EMN funds		Fund-of-funds	
	(1)	(2)	(3)	(4)	(5)	(6)
<i>Panel A: AUM less than \$50 million</i>						
R^m	0.56*** (5.09)	0.55*** (5.15)	0.51*** (4.52)	0.51*** (4.72)	0.40*** (3.56)	0.39*** (3.58)
$R^m ILLIQ$	-0.40* (-1.79)	-0.51* (-1.79)	-0.11 (-0.42)	-0.12 (-0.37)	-0.02 (-0.07)	-0.13 (-0.40)
$R^m 1_{\{t > \tau\}} ILLIQ$	-0.74*** (-4.36)	-0.82*** (-4.44)	-0.77*** (-4.25)	-0.78*** (-3.94)	-0.65*** (-3.78)	-0.74*** (-4.02)
$R^m VIX$		0.0025 (1.00)		0.0003 (0.10)		0.0026 (0.96)
Changepoint	Jan-01*	Jan-01*	Jul-01*	Jul-01*	Jul-01*	Jul-01*
R^2	0.68	0.68	0.73	0.73	0.71	0.71
<i>Panel B: AUM less than \$150 million</i>						
R^m	0.49*** (5.04)	0.48*** (5.14)	0.49*** (4.46)	0.47*** (4.53)	0.39*** (3.33)	0.36*** (3.24)
$R^m ILLIQ$	-0.23 (-1.18)	-0.29 (-1.17)	-0.08 (-0.33)	-0.20 (-0.65)	0.00 (0.02)	-0.19 (-0.62)
$R^m 1_{\{t > \tau\}} ILLIQ$	-0.69*** (-4.69)	-0.73*** (-4.67)	-0.80*** (-4.75)	-0.90*** (-4.94)	-0.69*** (-4.03)	-0.86*** (-4.62)
$R^m VIX$		0.0015 (0.63)		0.0028 (1.08)		0.0047* (1.74)
Changepoint	Sep-00*	Sep-00*	Jul-01*	Jul-01*	Jul-01*	Jul-01*
R^2	0.69	0.69	0.73	0.74	0.7	0.71

Table 14. A model with two changepoints

This table reports the changepoint estimation results for value-weighted portfolios of hedge funds, given by Equation (5), with the following specification for the dynamics of the market beta:

$$\beta_t = \beta_0 + (\delta_0 + \delta_1 \cdot 1_{\{\tau_1 < t \leq \tau_2\}} + \delta_1 \cdot 1_{\{t > \tau_2\}}) L_{m,t} + \lambda \sigma_{m,t},$$

where $L_{m,t}$ is Amihud's (2002) measure of stock market illiquidity *ILLIQ* in month t (Panel A), or its residual $\varepsilon(ILLIQ)$ obtained from from regressing the *ILLIQ* variable on predictable changes in liquidity (Panel B). R^m is the return of the S&P 500 index. $\sigma_{m,t}$ is the stock market return volatility as proxied by the CBOE VIX index and τ_1 and τ_2 are two changepoints. The portfolio of PFE funds consists of funds with Primary Focus on Equities. LSEH/EMN denotes the portfolio with hedge funds from Long-Short Equity Hedge (LSEH) and Equity Market Neutral (EMN). We consider only hedge funds with more than 24 monthly observations. Newey-West corrected t-values are given between parentheses. *, ** and *** denote significance at the 90%, 95% and 99%-level, respectively. We test for significance of the changepoint for a given portfolio using a parametric bootstrap. Changepoint significance is given for the 90% level of the *exp-F* statistic for joint significance of the two changepoints. The sample period is from January 1994 to December 2008.

	PFE funds		LSEH/EMN funds		Fund-of-funds	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: <i>ILLIQ</i>						
R^m	0.39*** (3.80)	0.38*** (2.97)	0.36*** (3.30)	0.37*** (3.78)	0.25* (1.96)	0.43*** (4.38)
$R^m ILLIQ$	0.13 (0.59)	-0.48 (-1.49)	0.29 (1.26)	0.33 (1.22)	0.06 (0.23)	0.24 (0.97)
$R^m 1_{\{\tau_1 < t \leq \tau_2\}} ILLIQ$	2.14*** (8.89)	-0.67*** (-4.62)	-6.15*** (-7.54)	-6.21*** (-7.54)	-0.70*** (-4.52)	2.08*** (8.78)
$R^m 1_{\{t > \tau_2\}} ILLIQ$	-0.77*** (-4.88)	-1.10*** (-4.88)	-0.52*** (-3.21)	-0.49*** (-3.01)	-0.07 (-0.18)	-0.72*** (-4.68)
$R^m VIX$		0.0057** (2.24)		-0.0014 (-0.57)		-0.0036 (-1.34)
Changepoint τ_1	Nov-99*	Sep-00*	Feb-00*	Feb-00*	Sep-00*	Nov-99*
Changepoint τ_2	Jan-00*	Jul-01*	Mar-00*	Mar-00*	Nov-03*	Jan-00*
R^2	0.66	0.62	0.74	0.77	0.61	0.66
Panel B: Residual <i>ILLIQ</i>						
R^m	0.74*** (4.08)	0.73*** (3.34)	0.36** (2.25)	0.30 (1.50)	0.38** (2.39)	0.86*** (4.45)
$R^m \varepsilon(ILLIQ)$	-0.52 (-1.50)	-0.50 (-0.91)	0.27 (0.87)	0.50 (0.96)	-0.16 (-0.54)	-1.70*** (-3.26)
$R^m 1_{\{\tau_1 < t \leq \tau_2\}} \varepsilon(ILLIQ)$	1.86*** (9.12)	1.86*** (8.72)	-5.15*** (-7.73)	-5.22*** (-7.88)	-0.52*** (-6.43)	0.37*** (2.89)
$R^m 1_{\{t > \tau_2\}} \varepsilon(ILLIQ)$	-0.58*** (-5.94)	-0.58*** (-5.94)	-0.42*** (-4.25)	-0.41*** (-4.40)	-0.11 (-0.62)	-0.47*** (-6.66)
$R^m VIX$		-0.0002 (-0.05)		-0.0024 (-0.72)		0.0114*** (3.29)
Changepoint τ_1	Nov-99*	Nov-99*	Feb-00*	Feb-00*	Sep-00*	Feb-99*
Changepoint τ_2	Jan-00*	Jan-00*	Mar-00*	Mar-00*	Nov-03*	Sep-00*
R^2	0.66	0.66	0.74	0.74	0.61	0.62