HEDGE FUNDS: RISK AND PERFORMANCE

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This paper models hedge fund exposure to risk factors and examines time-varying performance of hedge funds. From existing models such as asset-based style (ABS)-factor model, standard asset class (SAC)-factor model, and four-factor model, we extract the best six factors for each hedge fund portfolio by investment strategy. Then, we find combinations of risk factors that explain most of the variance in performance of each hedge fund portfolio based on investment strategy. The results show instability of coefficients in the performance attribution regression. Incorporating a time-varying factor exposure feature would be the best way to measure hedge fund performance. Furthermore, the optimal models with fewer factors exhibit greater explanatory power than existing models. Using rolling regressions, our customized investment strategy model shows how hedge funds are sensitive to risk factors according to market conditions.

Keywords: Hedge funds; risk factor; performance; capital asset pricing model; instant history bias; survivorship bias.

JEL Codes: G11, G24

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1. Introduction

It is well known that hedge funds are less regulated relative to traditional mutual funds enabling fund managers to take long/short positions in almost any financial instruments and use extremely high levels of leverage. Hedge fund managers are given almost full discretion in determining investment strategies, portfolio composition, and level of leverage. Highly skilled managers can actively respond to changes in market conditions and quickly adjust their portfolios and exposures to changes in various risk factors. Therefore, it is natural that such exposure is dynamic and time-varying.

Hedge funds adopt diverse investment strategies and provide investors with options to select hedge funds that best fit to their risk preference. Since hedge funds can go both long and short and/or can invest in most types of financial instruments, risk levels can vary from neutral to extremely high. Hedge fund managers usually announce risk characteristics or investment strategies of their funds to investors. Hedge funds likely exhibit different exposures to the changes in risk factors based on their investment strategies. For instance, fixed-income funds primarily invest in fixed-income securities, which are usually issued by corporations, banks, and governments. As the name implies, the interest payments are often fixed with respect to frequency and amount. As such, they are less exposed to equity market volatility and their performance tends to be stable and less sensitive to the equity market movements. However, equity hedge funds are highly exposed to changes in micro- and macro-economic conditions, as well as firm earnings and cash flow. [Fung & Hsieh \(1997a\)](#) note that depending on investment strategies, hedge funds possibly achieve different levels of returns given the same or similar market environments. Therefore, it seems somewhat contradictory that a set of risk factors is used to estimate performance of hedge funds pursuing many different investment strategies, or that an aggregate hedge fund portfolio is used to represent those hedge funds by offsetting unique features of funds in each category.

Hedge fund investors are considered to be relatively well educated and knowledgeable in various aspects of investing suggesting that a significant part of any investment decision is based on analytics and underlying information. However, a sophisticated investor would still make a biased decision if the analysis is based on biased information or benchmarks. To be able to make unbiased performance analysis of hedge funds that use a variety of investment strategies, we need to develop a customized set of risk factor for each investment strategy. Our assertion is also related to a well-known fact that hedge funds actively respond to changes in market condition by adjusting their portfolio accordingly. This means that hedge funds can be very flexible as needed in adjusting their exposure to risk factors. However, traditional asset pricing models assume constant beta over the sample period. We therefore argue that constant-beta models do not work well since hedge funds actively and continuously respond to market conditions. Instead, asset pricing models need to be flexible so that they can catch and reflect responses to the changes in the market conditions.

The purpose of this study is therefore to develop the best customized models to optimally estimate hedge funds' dynamic performance and exposure with respect to

investment strategies and sets of the corresponding risk factors. We make several attempts.

We first conduct clustering analysis based on the Pearson correlation-coefficients to group risk factors based on the standard asset class (SAC) factor model, asset-based style (ABS) model, and the four-factor model, neither of which consider any dynamic features of hedge funds. These models do select a few standard risk factors to explain hedge fund performance across the entire hedge fund universe rather than investment strategy specific factors. We do not expect that a risk factor can make equal contribution in explaining the performance of all hedge funds, which pursue different investment strategies. We also focus on the shortcomings that make the models less practical, on one hand, for investors looking for a certain type of fund that fits their risk preference or portfolio, and on the other hand, for fund managers determining risk preference of target investors. Our proposal leads necessarily to a narrow and focused model. In classifying hedge funds based on investment strategies, we can find a series of risk factors and models that may well capture hedge fund performance for each investment strategy. Among the four hedge fund investment strategies suggested by Agarwal *et al.* (2009), Relative Value (RV) relies on spread relationships to minimize exposure to risk factors. We expect that risk factors such as credit spread and the 10-year treasury yield as a proxy for bond-oriented risk factors can make a significant contribution compared to other investment strategies. Security Selection (SS) focuses on reducing systematic risk by taking long and short position in undervalued and overvalued assets. We expect that the Fama-French three-factor model can significantly contribute to explaining the performance of hedge funds following a SS strategy.

We then estimate single-factor rolling regression parameters using risk factors employed in existing models and find the top six factors for each hedge fund portfolio based on investment strategy. Analyzing recursive residuals from constant-beta models, we examine the stability of coefficients over time to show that constant-beta models do not properly measure dynamic exposure to risk factors, and that a rolling regression model is a better option to find the combinations of risk factors that explain most of the performance. Finally, we select an optimal model based on hedge fund investment strategy, which appropriately estimates dynamic performance and exposure to dynamic risk factors.

We find that there are two types of biases that bias hedge fund returns upwardly, and that these can be mitigated by handling the data appropriately. Our findings also reveal that the SAC-factor model is more likely to suffer from multicollinearity because risk factors are highly correlated with each other. We select one factor from each group of factors to eliminate this potential problem. By applying rolling regression analysis to the single-factor model, we show that risk factor coefficients are unstable across time. This can be attributed to the active and dynamic management of risk exposure responding to the changes in market conditions. We also statistically show that existing constant-beta models, which implicitly assume static or buy-and-hold investment strategies, cannot appropriately estimate hedge fund performance and

exposure to risk factors. The proposed multi-factor rolling regression models based on investment strategy provide more explanatory power than the existing constant-beta models. Our models are also more parsimonious than the constant-beta models.

We contribute to the existing hedge fund literature in the following ways. First, we show that coefficients from our rolling regression analysis over time-varying windows are unstable. Thus, it is inappropriate to estimate hedge fund performance and exposure to risk factors with constant-beta models. Hedge fund managers can respond quickly to changes in market conditions. Therefore, employing rolling regression analysis would so far be the best way to reflect the dynamic features of hedge funds when measuring performance and exposures. Second, we find that the optimal models based on investment strategy best explain hedge fund performance and exposure to risk factors. The optimal models with fewer factors exhibit greater explanatory power than existing models, and rolling regression analysis makes the models more credible in estimating the active and dynamic management of hedge funds. In addition, by combining different factors tailored to investment strategies, we can make the models more elaborate and provide better insight into hedge fund management practices. The paired *t*-tests of *R*-squared statistics support our models showing significant improvements in explanatory power compared to ABS-, SAC- and Four-factor models.

The results for the Directional Trader (DT) strategy, which is based on predicting market price movements, show that 80% of the explanatory power lies within a model of two factors: emerging market return and volatility index (VIX). We conjecture that investment decisions of DT are highly based on equity market conditions. The results of RV and SS are within our expectations. As shown by the coefficient value and as expected, RV has a unique risk factor, credit spread. This appears to be the key risk factor in RV's investment decisions and can be attributed to investment style of RV, which is to maintain a certain level of return while minimizing risk. The return of SS is primarily explained by risk factors related with the equity market such as market risk premium, VIX and spread between returns of small and large companies. It is attributed to the feature of SS, which is to focus on reducing systematic risk. Using rolling regression analysis, we customize the investment strategy-specific model to clearly show how sensitive hedge fund risk factors are according to market conditions. The stability tests already show that rolling regression beta provides better fits to measure risk exposure of hedge funds actively responding to market conditions. A set of unique risk factors based on investment strategies surely helps to improve the models' explanatory power. With the optimal models developed in this study, we argue that investors are able to make better informed investment decisions based on their risk preferences.

2. Data and Descriptive Statistics

We use monthly time series returns for hedge funds, funds of hedge funds (FOFs), Fung & Hsieh's ABS factor and SAC factor, Carhart (1997)'s four factors, a factor for DeBondt & Thaler (1985)'s contrarian strategy, and a VIX. Returns for hedge

funds and FoFs are collected from Global Hedge Fund Database provided by BarclayHedge. It provides data on 2689 (2072) active and 4200 (1845) inactive hedge funds. We exclude funds with observations for less than 12 months of observations; funds that report returns not in net-of-all fees; and funds that are not involved in the four broad investment strategies suggested by Agarwal *et al.* (2009). As a result, we have 2556 (1970) active and 3786 (1705) inactive hedge funds.

Existing research has repeatedly shown that because hedge fund data are voluntarily reported, data potentially suffer from survivorship and instant history (backfilled) biases. Fortunately, our database provides “graveyard” data, which include funds that have ceased reporting. By combining information for active and inactive funds, we can minimize the survivorship bias caused by liquidated or delisted hedge funds. Instant history bias (or backfilled bias) is caused by backfilled-period information. We follow the general method of handling instant history bias by dropping returns of the first year.

Column (C) in Table 1 exhibits positive figures from about 0.24% to 2.3% on an annual basis across all investment strategies (significant at the 5% level). This indicates that hedge fund returns tend to be inflated by backfilled information, which can be at least partially eliminated by removing reported returns for the initial 12-month reporting. Column (D) shows positive figures for all investment strategies, but only three of six portfolios — AG, DT, and FoF — exhibit significant difference at 5% the level. In column (E), the difference between hedge fund portfolio returns that control for both and none of the biases all appear to be positive and significant, except in one case.

To control for biases, we remove returns of the first year since inception, and combine returns of active and inactive funds. The comparisons of these returns not only confirm the existence of instant history bias and survivorship bias, but also show that the ways we control for the biases appear to be quite effective.

We categorize hedge funds into four broad investment strategies following Agarwal *et al.* (2009) — DT, RV, SS, and multi-process (MP) — involving strategies provided by different vendors. We create six equally-weighted portfolios for aggregate hedge funds and FoFs, as well as for the four broad investment strategies. The data cover period from January 1994 to December 2008 (180 months). We select the sample period because since we have at least 40 hedge funds every month to make up each investment strategy portfolio. In addition, the majority of recent studies also choose sample period from 1994 to 2010 because (1) major database began providing information about funds that stop reporting, which controls for survivorship bias and (2) the time period in question includes several major events such as the dot.com bust and the mortgage financial crises. Recent studies (Aiken *et al.* 2015, Bali *et al.* 2014, Busiere *et al.* 2015, Qin & Bai 2014); all of which use data sets ending in 2007 and 2009 and also focus on specific periods to study specific hedge fund phenomena. Following Fung & Hsieh (2004a)’s ABS factor, we use the monthly total return of the S&P 500 index as an “Equity market factor”; the monthly total return of Russell 2000 index less the S&P 500 index as a “Size spread factor”; the monthly change in

Table 1. Control for biases: Instant history and survivorship biases.

	(A) Instant history bias			(B) No instant history bias			(C) Controlling for instant history bias only		(D) Controlling for survivorship bias only		(E) Controlling for both biases	
	(1) Alive	(2) Dead	(3) All	(4) Alive	(5) Dead	(6) All	(1)–(4)		(1)–(3)		(1)–(6)	
AG	1.0472	0.8212	0.9639	0.9397	0.7379	0.8706	0.1075* (9.1483)		0.0832* (3.8543)		0.1766* (8.5297)	
DT	1.2247	0.8574	1.0713	1.0323	0.7347	0.9189	0.1924* (5.2066)		0.1533* (3.6557)		0.3058* (6.6755)	
RV	0.6906	0.5963	0.6802	0.6225	0.5304	0.6128	0.0681* (5.7452)		0.0104 (0.4531)		0.0778* (3.2007)	
SS	1.1337	0.9725	1.0975	1.0370	0.8794	0.9975	0.0968* (5.9609)		0.0362 (1.0865)		0.1362* (3.8048)	
MP	0.9119	0.8102	0.9062	0.8598	0.7513	0.8401	0.0522* (3.1714)		0.0058 (0.1169)		0.0719 (1.4318)	
FoF	0.6044	0.5028	0.5709	0.5837	0.4800	0.5506	0.0207* (2.4922)		0.0335* (3.2378)		0.0539* (3.9553)	

Notes: Table 1 reports mean returns on hedge fund portfolios for the various investment strategies and compare the results before and after controlling for either or both instant history bias or/and survivorship bias. The three columns under (B) control for instant history bias, columns under “Alive (or Dead)” denote mean returns of active (or inactive) hedge fund portfolios, and columns under “All” (both 3 and 6) denote hedge fund returns that control for survivorship bias. Therefore, the column under (B) and “Alive” denotes hedge fund returns that control for instant history bias only; the column under (A) and “All” denotes hedge fund returns controlling for survivorship bias only; the column under (B) and “All” denotes hedge fund returns controlling for both instant history and survivorship bias; and the column under (A) and “Alive” denotes hedge fund returns excluding any control for biases. Columns (C), (D), and (E) include differences in mean returns between portfolios controlling and not controlling for instant history bias, for survivorship bias, and for both biases. The figures in the parentheses are *t*-statistics, and “*” denotes significance at the 5% level.

the 10-year constant maturity treasury yield as a “Bond market factor”; and the monthly change in Moody’s Baa yield less 10-year treasury constant maturity yield as a “Credit spread factor.” We also utilize SAC factor from Fung & Hsieh (1997a): the MSCI North American equities as “US equities”; the MSCI non-US equities as “non-US equities”; the JPMorgan US Government bonds as “US Government bonds”; the JPMorgan non-US Government bonds as “Non-US Government bonds”; the one-month Eurodollar deposit rate of the previous month as the “Eurodollar deposit return”; the gold bullion in London bullion market as the “Spot Gold”; and the Federal Reserve Traded-Weighted Index of the US dollar against major currencies as the “US dollar index.” The 10-year treasury constant maturity yield, Moody’s Baa yield, and traded-weight index of the US dollar against major currencies are obtained from the Board of Governors of the Federal Reserve System.^a The remaining data were collected from DataStream. Carhart’s four-factor model (the excess return on the market, the performance of small stocks relative to large stocks, the performance of value stocks relative to growth stocks, and momentum) and DeBondt and Thaler’s Contrarian strategy are provided at the Professor French’s home page.^b In addition, we employ the Chicago Board Options Exchange Market VIX as a proxy for investor sentiment. The VIX is obtained from DataStream, and we use the value measured at the beginning of every month.

Panel A in Table 2 shows that the mean monthly returns on hedge fund portfolios ranged from 0.55% to 1.00% with standard deviations from 1.15% to 3.01%. Among the four broad investment strategies, portfolios of DT and SS exhibit the highest mean monthly returns compared to two other portfolios of RV and MP while they also show the highest standard deviation. This is consistent with the idea that the higher the risk, the greater the return. In fact, the investments of DT and SS hedge funds are conducted based on market movement predictions or based on estimated asset values, leading to relatively greater risk. In contrast, RV hedge funds take positions by maintaining a certain level of spread to minimize risk or market exposure, leading to lower risk. FoFs show the lowest mean return and shape ratio. This can be partially attributed to the fact that investors pay fees to FoFs as well as hedge funds included in the portfolio of the FoFs.

Panel B in Table 2 reports that all risk factors, excluding Non-US Government Bonds and US Dollar Index, are non-normally distributed. Scott & Horvath (1980) claim that investors with positive marginal utility are risk averse for all wealth levels and prefer higher first and third moments (mean and skewness) and lower second and fourth moments (standard deviation and kurtosis). By comparing descriptive statistics of hedge fund portfolios with those of equity market indexes (S&P 500, US equity, non-US equity, emerging market, and market risk premium), hedge funds seem to be outperforming equity market indexes based only on mean and standard deviation. If we take skewness and kurtosis into account due to the non-normal

^a<http://www.federalreserve.gov/econresdata/releases/statisticsdata.htm>.

^bhttp://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html.

Table 2. Descriptive statistics for the returns on hedge fund portfolios and risk factors.

Panel A: Returns on hedge fund portfolios.									
Fund type	Active (%)	Inactive (%)	Return			Sharpe ratio	Skewness	Kurtosis	Jarque-Bera
			Mean	Std. Dev	Median	Max	Min		
AG		2556/3786	0.87*	2.19	1.05	7.80	-8.58	-0.90	6.75
DT		868(34)/771(20)	0.92*	3.01	1.32	9.90	-13.44	-0.96	6.57
RV		341(13)/713(19)	0.61*	1.15	0.76	2.18	-7.91	-3.24	21.81
SS		1030(40)/1275(34)	1.00*	2.72	1.18	10.63	-9.42	-0.21	4.81
MP		317(12)/1027(27)	0.84*	1.70	0.99	6.41	-6.90	-0.97	7.96
FoF		1970/1705	0.55*	1.74	0.66	6.19	-7.03	-0.96	7.35
									169.14*

Panel B: Returns on risk factors.									
Asset class			Return			Sharpe ratio	Skewness	Kurtosis	Jarque-Bera
			Mean	Std. Dev	Median	Max	Min		
PTFSBD			-0.80	14.89	-3.70	68.86	-25.36	1.42	5.87
*PTFSCOM			0.20	14.03	-2.51	64.75	-23.04	1.26	5.48
PTFSFX			0.85*	19.91	-2.82	90.27	-30.13	1.34	5.62
S.P			0.52	4.46	1.18	12.05	-18.20	-0.90	5.16
SC.LC			-0.04*	3.65	0.04	17.61	-21.88	-0.57	11.65
D-10Y			-0.02*	0.28	-0.02	0.95	-1.08	-0.04	4.23
D-CREDSRPR			0.02*	0.20	0.01	1.53	-0.44	2.72	19.95
USEQ			0.53*	4.58	1.20	10.68	-18.53	-1.02	5.25
NONUSEQ			0.34	4.74	0.92	10.26	-22.93	-1.19	6.11
EMF			0.23*	7.19	0.93	12.63	-34.13	-1.28	6.37
USGB			0.54*	1.38	0.65	6.26	-4.59	-0.04	4.86
NONUSGB			0.54	2.44	0.55	7.99	-5.62	0.20	3.46
EURODOLLAR			0.35*	0.15	0.42	0.59	0.08	-0.56	1.92
GOLD			0.44	4.39	-0.17	18.84	-18.76	0.05	5.94
USDOLLAR			-0.07*	1.69	0.13	6.49	-4.79	-0.04	3.85

Table 2. (Continued)

Panel B: Returns on risk factors.									
Asset class	Return				Sharpe ratio	Skewness	Kurtosis	Jarque-Bera	
	Mean	Std. Dev	Median	Max					
MKT_RF	0.31*	4.48	1.01	8.18	-18.54	0.07	-0.99	4.77	52.97*
SMB	-0.08*	3.79	-0.19	13.81	-22.19	-0.10	-1.16	10.75	490.70*
HML	0.47	3.42	0.34	13.84	-9.95	0.05	0.56	5.69	63.64*
MOM	0.87	5.06	0.77	18.39	-25.03	0.11	-0.56	7.73	176.96*
CONTRARIAN	0.37	4.13	0.19	16.27	-14.51	0.01	0.17	7.12	128.38*
VIX	0.98*	17.39	-0.29	64.58	-39.55	0.04	0.60	3.82	15.68*

Notes: Table 2 reports summary statistics including mean, standard deviation, skewness, kurtosis, and Jarque-Bera statistics, as well as the Sharpe ratios for the monthly hedge fund portfolio returns and risk factors. The Sharpe ratio is a change in an average excess return against a unit change in risk (standard deviation). Jarque-Bera normality test is asymptotically distributed as a central χ^2 with two degrees of freedom under the null hypothesis with 5% critical value 5.99. “*” denotes significance at the 5% level.

For Panel A, each portfolio return is an equally-weighted average of individual hedge fund returns with corresponding investment strategy with the exceptions of the aggregate hedge fund return consisting of all hedge fund returns and the fund of hedge funds return. The four hedge fund investment strategies follow Agarwal *et al.* (2009). DTs mostly predict the direction of market price movements of currencies, commodities, equities, and bonds in the future and cash market, and based on their analyses, undertake investments. Emerging markets, Macro, Market timing, Foreign exchange, Sector, and Short Bias/Selling are included in Directional Trading. RV focuses on spread relationships between prices of assets to minimize exposure to risk factors. It does include Arbitrages (Convertible/Merger Arbitrages), Market neutral, Fixed income, and Long-short credit. SS mainly focuses on reducing the systematic risk in the process by taking long and short positions in undervalued and overvalued securities, respectively. It does include Equity hedge/non-hedge, Long/short equity hedge, Global, No bias, and Variable bias. MP involves multiple strategies performed by the hedge funds. Those hedge funds usually invest in the opportunities created by significant transaction events, such as mergers & acquisitions, spin-offs, bankruptcy reorganizations, recapitalizations, and share buybacks. MP does include Event-driven, Distressed securities, and Multi-strategy.

Panel B includes seven ABS factors suggested by Fung & Hsieh (2004a), and eight SAC factors suggested by Fung & Hsieh (1997a). In addition, we include Fama & French (1993)’s three factors along with Carhart (1997)’s momentum, DeBondt & Thaler (1985)’s contrarian strategy, and VIX for investor sentiment.

distribution of returns on hedge fund portfolios and risk factors, we may not reach the same conclusion. Higher mean returns and lower standard deviation, or higher Sharpe ratios are likely to be achieved at some costs.

3. Econometric Methodology

Static models with common risk factors may not be adequate in examining performance and risk exposure of all types of hedge funds. We modify and combine Jensen (1967)'s and Sharpe (1992)'s models using rolling regression analysis to estimate hedge fund performance and exposure to risk factors. To estimate performance and exposure to risk factors associated with different investment strategies, we first create four equally-weighted hedge funds portfolios based on investment strategies (DT, RV, SS, and MP), one for aggregate hedge funds (AG) and one for FoFs. These six portfolios include all monthly time series returns corresponding to investment strategy after controlling for instant history and survivorship biases. As a second step, we estimate hedge fund exposure to each of the following known risk factors: Fung and Hsieh's ABS factor and SAC factor, Carhart's four factor, contrarian strategy, and VIX. We employ the single-factor model by Jensen (1967) and Black *et al.* (1972):

$$R_{it} - R_{ft} = \alpha_i + (R_{mt} - R_{ft})\beta_i + \varepsilon_{it}, \quad (3.1)$$

where $i = \text{AG, DT, RV, SS, MP, and FoF}$. R_{it} , R_{mt} , and R_{ft} denote returns on hedge fund index i , risk factors, and risk-free asset at time t , respectively. β_i indicates the factor loading or exposures of returns to hedge fund indexes and to changes in risk factors. We conduct rolling regression analyses with fixed windows of 24(36)-month observations and use the adjusted R -squared values to examine the relation between hedge fund indexes and risk factors. The top six factors providing the highest adjusted R -squared values are selected for the multi-factor model to estimate hedge fund exposure to risk factors. In this way, we obtain information of unique relationships between each of the risk factors and specific investment strategies based on the adjusted R -squared values. Among the variables, we consider some proxy for the same or similar risk factors. For example, equity market factor (S&P 500) among ABS factors, the US equities (MSCI North America equities) and emerging market equities among SAC factors and market are all used as proxies for the US stock market. Thus, we select one among the variables that works as a proxy for the same or similar factors.

Table 3 reports the Pearson correlation-coefficients between risk factors and groups of these risk factors from clustering based on the Pearson correlation-coefficients. The 21 risk factors are clustered into 15 groups. Risk factors clustered in the same group, especially those that proxy for equity markets are highly correlated with each other with correlation-coefficients ranging from 0.69 to 0.98. Employing highly correlated variables as independent variables in the same model results in an increased possibility of multi-collinearity, which may lead to biased standard errors.

Table 3. Clustering and correlation-coefficients between monthly returns on risk factors.

Group	Risk factors	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
1	MKT.RF																				
1	S.P	0.91**																			
1	USEQ	0.93**	0.98**																		
1	NONUSEQ	0.83**	0.82**	0.81**																	
1	EMF	0.78**	0.69**		0.79**																
2	SMB	0.18*	0.09	0.10	0.18*	0.28**															
2	SC.LC	0.18*	0.05	0.06	0.21**	0.27**															
3	HML	-0.41**	-0.33**	-0.36**	-0.26**	-0.31**	-0.45**	0.00													
4	MOM	-0.23**	-0.32**	-0.29**	-0.19*	-0.20**	-0.08	0.08	0.04												
5	CONTRARIAN	0.29**	0.36**	0.34**	0.23*	0.25**	0.25**	-0.02	-0.16*	-0.35**											
6	PTFSBD	-0.17*	-0.11	-0.13	-0.15*	-0.20**	0.00	-0.08	-0.05	0.05											
7	PTFSOM	-0.15*	-0.15*	-0.14*	-0.10	-0.14	-0.03	-0.02	-0.01	0.19*	-0.09	0.18*									
8	PTSEFX	-0.19*	-0.14	-0.17*	-0.18*	-0.21**	0.00	0.02	0.05	0.10	-0.11	0.10*	0.36**								
9	D.JOY	0.14	0.10	0.09	0.15*	0.19**	0.23**	0.18*	-0.12	-0.18*	0.03	-0.15*	-0.09	-0.13							
10	D.CREDSPR	-0.50**	-0.49**	-0.48**	-0.56**	-0.53**	-0.32**	-0.25**	0.15*	0.28**	-0.24**	0.16*	0.22**	0.30**	-0.49**						
11	USGB	-0.16*	-0.13	-0.12	-0.18*	-0.20**	-0.20**	-0.21**	0.08	0.10	0.01	0.13	0.03	0.11	-0.94**	0.47**					
11	NONUSGB	-0.01	0.00	0.00	0.20**	0.00	0.00	-0.01	-0.05	0.01	0.06	0.14	0.07	0.20**	-0.48**	0.18*	0.48**				
12	EURODOLLAR	0.07	0.11	0.11	0.00	-0.09	-0.17*	-0.13	0.00	0.08	-0.08	-0.04	-0.03	-0.03	-0.03	0.11	0.07	-0.09			
13	GOLD	0.08	0.02	0.03	0.23**	0.25**	0.13	0.21**	0.00	0.13	-0.01	0.00	0.22**	0.02	-0.16*	-0.08	0.12	0.36**	-0.13		
14	USDOLLAR	-0.22**	-0.20**	-0.22**	-0.33**	-0.28**	-0.15*	-0.08	0.13	0.08	-0.18*	0.01	0.08	-0.06	0.10	0.17*	-0.08	0.53**	0.16*	-0.23**	
15	VIX	-0.05**	-0.56**	-0.57**	-0.52**	-0.54**	-0.11	-0.14	0.22**	0.12	-0.21**	0.26**	0.09	0.22**	-0.12	0.34**	0.14	0.15*	0.04	-0.02	0.04

Notes: This table reports the Pearson correlation-coefficients between risk factors and groups of risk factors using clustering based on the Pearson correlation-coefficients. The 21 risk factors are clustered into 15 groups. Risk factors clustered in the same group, especially, those that proxy for equity markets, are highly correlated with each other; the correlation coefficients range from 0.69 to 0.98. Using variables that are highly correlated with each other as independent variables in the same model tends to increase the possibility of multicollinearity, and lead to biased conclusions. Therefore, we choose only one risk factor from those factors clustered into the same group based on correlation-coefficients. Other than equity markets proxies, [Fama & French \(1993\)](#)'s size premium and [Fung & Hsieh \(2004a\)](#)'s size spread factor, as well as returns on the US Government Bonds and non-US Government Bonds are clustered in the same group, respectively. "***" and "**" denote significance at the 1% and 5% level, respectively.

Therefore, based on their correlation-coefficients, we choose only one risk factor from the factors clustered in the same group. Other than equity market proxies, the only other two clusters are (1) Fama & French (1993)'s size premium and Fung & Hsieh (2004a)'s size spread factor, as well as returns on (2) US Government Bonds and non-US Government Bonds.

As a last step, in order to simultaneously estimate hedge fund performance and exposure to specific risk factors, we extend the single-factor model into Sharpe (1992)'s multi-factor model, which considers all factors in one regression analysis:

$$R_{it} - R_{ft} = \alpha_i + \sum_{t=1}^n (X_t - R_{ft}) B_i + \varepsilon_{it}, \quad (3.2)$$

where X_t denotes vector of risk factors at time t ; α_i denotes the abnormal returns of hedge fund index i and fund managers' investment skill; and B_i denotes a vector of exposure to hedge fund index i to the risk factors. α_i and B_i are estimated by rolling regression analysis with a fixed window of 24(36)-month's observations. From the rolling B_i based on varying windows, we can see how different hedge funds exposure to risk factors change with market conditions.

4. Empirical Results

4.1. Correlation analysis between returns on hedge fund portfolios and risk factors

Prior to estimating hedge fund performance and exposure to risk factors, we conduct correlation analysis and report the results in Table 4. Equity market-related risk factors generally exhibit high correlations with returns of hedge fund portfolios with coefficients ranging from 0.56 to 0.88. Especially, the market risk premium and the emerging market returns appear highly correlated with returns of the six hedge fund portfolios. The VIX also has relatively high correlation with the performance of the six hedge fund portfolios. High correlation-coefficients associated with equity market-related returns and VIX indicate that investment decisions are largely based on equity market conditions or movements. As a bond-oriented risk factor, the credit spread factor exhibits a negative correlation-coefficient around -0.5 over the six hedge fund portfolios, and -0.65 for returns on RV. The highly correlated relationship between the credit spread factor and returns on RV can be attributed to investment style of RV, which maintains a certain level of return and minimizes exposure to risk. Size premium factors show a somewhat high correlation with the portfolios, especially for SS returns. Based on the results of the correlation analysis, we have a rough idea of what sort of risk factors hedge funds are exposed to.

4.2. Rolling regression analysis of a single-factor model

In this section, we estimate single-factor regression analyses for all available factors to select risk factors. Furthermore, we apply rolling regression analysis to a

Table 4. Correlation-coefficients between monthly returns on hedge fund portfolios and risk factors.

Group		Agg. Hedge funds	DTs	RV	SS	MP	FoFs
1	MKT_RF	0.84**	0.80**	0.66**	0.86**	0.76**	0.69**
1	S_P	0.71**	0.68**	0.60**	0.72**	0.63**	0.56**
1	USEQ	0.73**	0.70**	0.61**	0.74**	0.65**	0.58**
1	NONUSEQ	0.76**	0.74**	0.63**	0.75**	0.69**	0.65**
1	EMF	0.81**	0.88**	0.60**	0.76**	0.72**	0.72**
2	SMB	0.24**	0.23**	0.14	0.28**	0.22**	0.19*
2	SC_LC	0.34**	0.29**	0.20**	0.39**	0.33**	0.28**
3	HML	-0.30**	-0.31**	-0.08	-0.36**	-0.23**	-0.19*
4	MOM	-0.02	-0.04	-0.06	-0.01	0.02	0.11
5	CONTRARIAN	0.16*	0.16*	0.23**	0.14	0.16*	0.08
6	PTFSBD	-0.20**	-0.22**	-0.24**	-0.16*	-0.23**	-0.24**
7	PTFSCOM	-0.13	-0.13	-0.20**	-0.10	-0.13	-0.08
8	PTFSFX	-0.16*	-0.16*	-0.24**	-0.11	-0.14	-0.12
9	D_10Y	0.14	0.14	0.08	0.14	0.13	0.11
10	D_CREDSPR	-0.52**	-0.50**	-0.65**	-0.45**	-0.51**	-0.50**
11	USGB	-0.14	-0.13	-0.08	-0.15*	-0.13	-0.11
11	NONUSGB	-0.03	-0.06	-0.04	-0.03	-0.02	-0.09
12	EURODOLLAR	0.15*	0.08	0.22**	0.16*	0.17*	0.18*
13	GOLD	0.18*	0.21**	0.16*	0.14	0.14	0.19*
14	USDOLLAR	-0.18*	-0.17*	-0.21**	-0.15*	-0.19	-0.14
15	VIX	-0.51**	-0.51**	-0.40**	-0.52**	-0.44**	-0.42**

Notes: This table reports correlation-coefficients between monthly returns of hedge fund portfolios by investment strategies and risk factors for the period January 1994 to December 2008. Groups are determined by clustering using Pearson correlation-coefficients. Risk factors in the same groups are likely to be highly correlated each other so that only one among those in the same groups is to be included into the model. Investment strategies for hedge fund portfolios are categorized by the four broad investment strategies (DT, RV, SS, and MP) as suggested by Aggarwal & Jorion (2009). Similarly, we use two general categories, hedge funds and fund of hedge funds. “**” and “*” denote significance at the 1% and 5% level, respectively.

single-factor model to capture the dynamic properties of hedge funds in the model. Since determination of window size in rolling regression analysis has been under debate, we utilize two different window sizes: 24 and 36 months.

Table 5 reports results from rolling regression analysis of the single-factor model by investment strategies and window size. Comparing the results from the models using the 24- and 36-month windows, the selection of appropriate risk factors should not differ significantly, so we focus the interpretation of Table 5 on the results from the 24-month window. Most of all, equity market-related factors, which account for the majority of hedge fund exposure, exhibit almost identical results in the average coefficients, adjusted *R*-squared statistics, and number of significant time frames for both window sizes. AG, DT, and FoF portfolios are the most exposed to emerging market movements. The emerging market index significantly explains the variance in the performance of these hedge funds across all time frames and shows substantially high adjusted *R*-squared statistics. Similarly, RV, SS, and MP portfolios are most exposed to Fama and French’s market risk premium factor compared to the other

Table 5. Results from rolling regression analysis of single-factor model by investment strategies and size of window.

	(A) 24M						(B) 36M					
	AG	DT	RV	SS	MP	FoF	AG	DT	RV	SS	MP	FoF
USEQ	(1) 0.3552	0.4791	0.1092	0.4747	0.2282	0.2176	0.3525	0.4812	0.1064	0.4696	0.2269	0.2159
	(2) 0.5014	0.4653	0.2860	0.5205	0.3722	0.3140	0.5138	0.4832	0.2879	0.5338	0.3807	0.3215
	(3) 157	155	142	157	154	145	145	145	145	145	145	145
NonUSEQ	(1) 0.3599	0.4846	0.1085	0.4730	0.2418	0.2430	0.3630	0.4919	0.1097	0.4761	0.2451	0.2394
	(2) 0.5945	0.5494	0.3323	0.6056	0.4812	0.4543	0.6093	0.5669	0.3462	0.6187	0.4956	0.4569
	(3) 157	152	144	157	156	148	145	144	142	145	145	144
EMF	(1) 0.2459	0.3683	0.0712	0.3048	0.1590	0.1740	0.2455	0.3674	0.0721	0.3047	0.1591	0.1674
	(2) 0.7037	0.7943	0.3733	0.6403	0.5340	0.5955	0.7160	0.8041	0.3887	0.6544	0.5443	0.5839
	(3) 157	157	155	157	157	157	145	145	145	145	145	145
sp	(1) 0.3540	0.4766	0.1105	0.4728	0.2265	0.2165	0.3530	0.4827	0.1073	0.4700	0.2264	0.2149
	(2) 0.4723	0.4399	0.2751	0.4912	0.3456	0.2940	0.4877	0.4607	0.2752	0.5062	0.3566	0.3007
	(3) 157	150	142	157	153	144	145	145	145	145	145	145
MKTF	(1) 0.4046	0.5319	0.1248	0.5430	0.2682	0.2603	0.3987	0.5305	0.1216	0.5335	0.2649	0.2547
	(2) 0.6973	0.6113	0.3956	0.7363	0.5549	0.4626	0.7014	0.6266	0.3950	0.7399	0.5542	0.4671
	(3) 157	157	156	157	157	154	145	145	145	145	145	145
SCLC	(1) 0.2691	0.3059	0.0734	0.3896	0.1829	0.1649	0.2644	0.3006	0.0739	0.3787	0.1805	0.1673
	(2) 0.2273	0.1533	0.1005	0.2734	0.1916	0.1713	0.2166	0.1469	0.1015	0.2611	0.1804	0.1660
	(3) 125	93	71	138	134	114	138	102	110	141	139	117
SMB	(1) 0.2641	0.2990	0.0768	0.3782	0.1856	0.1639	0.2514	0.2887	0.0755	0.3555	0.1736	0.1580
	(2) 0.2213	0.1452	0.1012	0.2631	0.2023	0.1537	0.2010	0.1335	0.1008	0.2408	0.1797	0.1386
	(3) 111	91	69	121	115	88	103	91	81	108	103	85
USGB	(1) -0.2443	-0.3186	-0.0883	-0.3114	-0.1513	-0.1535	-0.2627	-0.3539	-0.0876	-0.3347	-0.1633	-0.1554
	(2) 0.0341	0.0265	0.0500	0.0465	0.0203	0.0177	0.0246	0.0155	0.0319	0.0382	0.0103	0.0063
	(3) 38	30	41	45	32	30	32	30	28	52	22	21
NonUSEGB	(1) -0.0482	-0.1064	-0.0347	-0.0360	-0.0171	-0.0727	-0.0512	-0.1143	-0.0354	-0.0357	-0.0206	-0.0742
	(2) -0.0033	0.0156	0.0245	-0.0107	0.0180	0.0367	-0.0049	0.0127	0.0351	-0.0143	0.0213	0.0362
	(3) 7	23	43	8	25	44	6	34	57	7	39	43

Table 5. (Continued)

	(A) 24M						(B) 36M					
	AG	DT	RV	SS	MP	FoF	AG	DT	RV	SS	MP	FoF
Eurodollar	(1) 10.3657	10.8810	1.4608	16.8335	5.9389	6.5588	9.3804	9.5663	0.6940	15.7770	5.4535	6.2145
	(2) 0.0174	0.0154	0.0102	0.0224	0.0175	0.0270	0.0313	0.0241	0.0200	0.0377	0.0332	0.0400
	(3) 26	27	16	31	24	39	39	36	27	47	42	49
Gold	(1) 0.0943	0.1275	0.0279	0.1161	0.0703	0.0852	0.0903	0.1203	0.0252	0.1146	0.0659	0.0728
	(2) 0.0501	0.0755	0.0160	0.0370	0.0361	0.0574	0.0507	0.0747	0.0155	0.0376	0.0365	0.0555
	(3) 37	46	30	37	36	47	47	50	34	36	49	52
Usdollar	(1) -0.1344	-0.1255	-0.0481	-0.1961	-0.1256	-0.0548	-0.1487	-0.1413	-0.0512	-0.2205	-0.1351	-0.0588
	(2) 0.0128	0.0043	0.0460	0.0099	0.0472	0.0264	0.0086	-0.0014	0.0453	0.0082	0.0460	0.0226
	(3) 27	26	31	33	36	31	16	14	40	26	43	29
10y	(1) 1.3513	1.9808	0.5277	1.5739	0.8486	0.8611	1.4143	2.0923	0.5164	1.6687	0.8880	0.8464
	(2) 0.0525	0.0504	0.0696	0.0601	0.0336	0.0326	0.0350	0.0322	0.0453	0.0451	0.0161	0.0114
	(3) 46	40	63	41	38	36	39	49	42	53	20	21
credspr	(1) -3.8081	-5.3474	-1.7007	-4.2895	-2.9915	-3.0709	-4.2905	-6.0481	-1.9484	-4.8566	-3.3332	-3.3337
	(2) 0.1650	0.1395	0.2103	0.1574	0.1699	0.1378	0.1690	0.1480	0.2174	0.1578	0.1701	0.1359
	(3) 88	80	106	70	99	93	111	106	130	87	118	111
ptbtd	(1) -0.0169	-0.0220	-0.0122	-0.0163	-0.0145	-0.0134	-0.0207	-0.0275	-0.0135	-0.0205	-0.0179	-0.0164
	(2) 0.0390	0.0360	0.0604	0.0260	0.0441	0.0351	0.0386	0.0415	0.0741	0.0204	0.0493	0.0353
	(3) 31	31	41	32	31	36	47	44	48	40	47	43
ptcom	(1) -0.0106	-0.0144	-0.0054	-0.0147	-0.0066	0.0011	-0.0096	-0.0139	-0.0046	-0.0134	-0.0055	0.0017
	(2) 0.0251	0.0350	0.0073	0.0209	0.0153	0.0253	0.0119	0.0226	0.0007	0.0072	0.0031	0.0125
	(3) 33	39	19	31	31	33	19	31	13	16	13	16
ptfx	(1) -0.0067	-0.0098	-0.0041	-0.0069	-0.0044	-0.0009	-0.0070	-0.0106	-0.0036	-0.0075	-0.0043	-0.0008
	(2) 0.0083	0.0155	0.0164	0.0033	0.0080	0.0173	0.0031	0.0069	0.0095	-0.0015	0.0063	0.0097
	(3) 23	29	27	18	23	25	14	15	17	8	21	18
HML	(1) -0.1844	-0.2489	-0.0103	-0.2861	-0.0968	-0.0781	-0.1750	-0.2345	-0.0105	-0.2742	-0.0931	-0.0740
	(2) 0.1223	0.1019	0.0481	0.1425	0.1079	0.0565	0.1215	0.1032	0.0435	0.1463	0.1007	0.0576
	(3) 75	74	46	79	71	48	87	88	63	87	81	66

Table 5. (*Continued*)

	(A) 24M						(B) 36M					
	AG	DT	RV	SS	MP	FoF	AG	DT	RV	SS	MP	FoF
MOM	(1) 0.0530	0.0773	0.0276	0.0613	0.0194	0.0761	0.0321	0.0433	0.0161	0.0380	0.0127	0.0633
	(2) 0.1312	0.1299	0.0472	0.1428	0.0649	0.0932	0.1005	0.0981	0.0348	0.1109	0.0534	0.0738
	(3) 76	66	48	80	54	74	66	61	45	66	50	80
cont	(1) 0.1106	0.1148	0.0362	0.1683	0.0907	0.0445	0.1050	0.1194	0.0365	0.1537	0.0827	0.0423
	(2) 0.0403	0.0300	0.0338	0.0451	0.0447	0.0288	0.0286	0.0208	0.0272	0.0327	0.0326	0.0158
	(3) 38	33	28	43	39	35	46	39	32	49	56	26
VIX	(1) -0.0608	-0.0846	-0.0166	-0.0818	-0.0374	-0.0349	-0.0632	-0.0883	-0.0172	-0.0850	-0.0390	-0.0352
	(2) 0.2600	0.2536	0.1139	0.2779	0.1691	0.1575	0.2714	0.2640	0.1226	0.2907	0.1743	0.1533
	(3) 139	129	97	143	112	117	142	136	117	143	129	130

Notes: Table 5 reports (1) average coefficients, (2) average adjusted R -squared statistics, and (3) number of time frames during which the coefficient of each variable is significant at 5% significance level based on rolling regression analysis of the single-factor model. Full sample periods range from January 1994 to December 2008. The rolling regression analyses are performed with 24 months and 36 months of window sizes. We select variables that are to be applied in the rolling regression analysis of the multi-factor model based on the number of time frames during which the variable is significant and average adjusted R -squared values. Risk factors clustered in the same group cannot be selected into the model as independent variables to avoid multicollinearity problem and redundancy. The number of time frames with significant coefficients at 5% significance level is given more weight than the adjusted R -squared statistics. **Figures in bold** indicate the selected risk factors based on (2) and (3).

risk factors. Compared to other investment strategies, RV is more likely to pursue a stable income strategy, which accounts for its low sensitivity to changes in the market risk premium factor along with its relatively low adjusted R -squared statistics. As the first factor to which hedge funds are primarily exposed, we therefore select the emerging market index for AG, DT, and FoF portfolios, and Fama and French's market risk premium for RV, SS, and MP portfolios among equity market-related risk factors.

The VIX is the second most powerful risk factor in explaining hedge fund portfolio performance and exposure. Since the VIX increases as market uncertainty increases and investors turn to a pessimistic view about the market, it is inversely related to hedge fund performance. While all hedge fund portfolios are significantly exposed to the VIX over the majority of time frames, RV is relatively less sensitive to changes in the VIX. Instead, RV is most significantly exposed to the credit spread factor. We need to be cautious about the property of VIX measuring investor sentiment in equity markets and its relatively high correlation (from -0.52 to -0.65) with equity market-related factors. Therefore, using the VIX and equity market-related factor simultaneously in the same model may lead to a biased result and multicollinearity. Based on the average adjusted R -squared statistics and the number of time frames when hedge funds are significantly exposed to each risk factor, we select six risk factors. All hedge fund portfolios are exposed to a very similar set of risk factors, but the degree of the factors to which each portfolio is exposed may differ by investment strategy.

4.3. Selection of optimal multi-factor rolling regression model

In this section, we need to find the best combination of risk factors for different investment strategies that best explains hedge fund portfolio performance. Thus, we conduct multi-factor rolling regression analysis combining the selected risk factors from Sec. 4.2.

In Table 6, summarizing the results of the rolling regression analysis of the aggregate (AG) hedge fund portfolio, we first observe the VIX coefficients and size spread factor (SCLC), which range from positive to negative, indicating that exposure to these risk factors varies by market condition. Approximately, 75% of the variation in performance of the aggregate hedge fund portfolio is explained by a two-factor model and approximately 80% of the variation is explained by a six-factor model. As the number of factors increases, the average adjusted R -squared statistics and number of time frames with adjusted R -squared statistics greater than 70% also increase. Adding three more risk factors to the two-factor model increases the explanatory power of the model to almost 80% with 135 time frames out of 157 having R -squared statistics greater than 70%. Although the six-factor model has slightly greater R -squared statistics, it does not appear large enough to warrant adding additional risk factors. For the AG portfolio, therefore, we have an optimal

Table 6. Results from the multi-factor rolling regression analysis with 24-month window using selected risk factors.^c

	AG	EMF	VIX	SCLC	CRED	MOM	HML	C	Rsq
(1)	Mean	0.2402	−0.0056					0.6512	0.7088
	Median	0.2386	−0.0030					0.4732	0.7357
	Min	0.1469	−0.0432					−0.2981	0.3340
	Max	0.3433	0.0366					1.5030	0.9048
	#Sig.	157	34					107	91
* (2)	Mean	0.2279		0.1217				0.7085	0.7499
	Median	0.2172		0.1126				0.4639	0.7646
	Min	0.1399		−0.1207				−0.2925	0.4380
	Max	0.3340		0.2785				1.6371	0.9109
	#Sig.	157		115				111	113
(3)	Mean	0.2387			−0.5588			0.6892	0.7145
	Median	0.2302			−0.8433			0.4527	0.7566
	Min	0.1408			−4.4496			−0.0232	0.3400
	Max	0.3913			6.9998			1.4383	0.9017
	#Sig.	157			44			112	106
(4)	Mean	0.2444				0.0274		0.6198	0.7198
	Median	0.2368				0.0166		0.4722	0.7766
	Min	0.1533				−0.0928		−0.4366	0.3544
	Max	0.3556				0.2065		1.4838	0.8871
	#Sig.	157				29		113	109
(5)	Mean	0.2399					−0.0498	0.6579	0.7272
	Median	0.2376					−0.0150	0.5097	0.7394
	Min	0.1485					−0.3100	−0.3607	0.3503
	Max	0.3934					0.1561	1.5356	0.8895
	#Sig.	157					35	110	94
* (6)	Mean	0.2199	−0.0058	0.1280				0.6913	0.7571
	Median	0.2185	−0.0029	0.1236				0.4666	0.7564
	Min	0.0978	−0.0508	−0.1042				−0.3043	0.4240
	Max	0.3334	0.0335	0.2786				1.6426	0.9474
	#Sig.	157	36	115				105	114
(7)	Mean	0.2367	−0.0032		−0.6525			0.6763	0.7216
	Median	0.2297	−0.0011		−0.8586			0.4497	0.7648
	Min	0.1401	−0.0432		−4.9936			−0.0623	0.3487
	Max	0.4050	0.0412		6.6586			1.5033	0.9102
	#Sig.	157	42		43			106	100
(8)	Mean	0.2406	−0.0046			0.0271		0.6073	0.7256
	Median	0.2364	−0.0032			0.0148		0.4654	0.7685
	Min	0.1515	−0.0419			−0.0913		−0.3408	0.3221
	Max	0.3449	0.0407			0.2070		1.5334	0.9053
	#Sig.	157	31			29		107	108
(9)	Mean	0.2371	−0.0040				−0.0509	0.6451	0.7306
	Median	0.2319	−0.0033				−0.0209	0.4718	0.7411
	Min	0.1270	−0.0469				−0.3229	−0.3555	0.3200
	Max	0.3886	0.0369				0.1829	1.5659	0.9012
	#Sig.	157	33				32	106	92
* (10)	Mean	0.2187	−0.0022	0.1318	0.1406			0.7220	0.7815
	Median	0.2106	−0.0009	0.1258	−0.5374			0.4382	0.7901

Table 6. (Continued)

	AG	EMF	VIX	SCLC	CRED	MOM	HML	C	Rsqr
(11)	Min	0.1037	−0.0510	−0.2471	−5.2206			−0.0735	0.5266
	Max	0.4105	0.0482	0.2882	8.1095			1.6872	0.9448
	#Sig.	157	42	126	64			99	125
	Mean	0.2196	−0.0050	0.1277		0.0379		0.6481	0.7687
	Median	0.2164	−0.0023	0.1248		0.0322		0.4581	0.7946
	Min	0.1045	−0.0497	−0.0632		−0.0612		−0.3075	0.4007
	Max	0.3434	0.0390	0.3208		0.1629		1.6076	0.9486
	#Sig.	157	36	102		36		106	116
	Mean	0.2167	−0.0044	0.1199			−0.0360	0.6791	0.7658
	Median	0.2105	−0.0010	0.1161			−0.0081	0.4586	0.7566
(12)	Min	0.0706	−0.0495	−0.1023			−0.2701	−0.3618	0.3950
	Max	0.3715	0.0337	0.2985			0.1825	1.6856	0.9463
	#Sig.	157	37	94			34	101	126
	Mean	0.2140	−0.0018	0.1326	0.0702	0.0465		0.6818	0.7928
	Median	0.2059	−0.0012	0.1258	−0.2248	0.0441		0.4517	0.8183
(13)	Min	0.1022	−0.0506	−0.2095	−5.4772	−0.0677		−0.0568	0.5026
	Max	0.3836	0.0625	0.3348	8.0161	0.1761		1.6445	0.9461
	#Sig.	157	42	106	58	41		101	124
	Mean	0.2102	0.0002	0.1241	0.0792		−0.0576	0.7197	0.7916
	Median	0.2081	0.0032	0.1274	−0.5674		−0.0274	0.4211	0.7911
*(14)	Min	0.0805	−0.0491	−0.1839	−5.3774		−0.2694	−0.1193	0.5003
	Max	0.4027	0.0604	0.3261	6.8525		0.1059	1.6894	0.9473
	#Sig.	157	41	116	68		41	94	135
	Mean	0.2061	−0.0010	0.1207	−0.1959	0.0369	−0.0269	0.6762	0.8035
	Median	0.1929	−0.0012	0.1267	−0.4126	0.0421	0.0076	0.4300	0.8181
*(15)	Min	0.0869	−0.0495	−0.1817	−5.2795	−0.0835	−0.2434	−0.1089	0.4800
	Max	0.3991	0.0605	0.3381	7.0702	0.1735	0.1872	1.6541	0.9442
	#Sig.	157	39	103	59	39	37	97	134

Notes: This table reports results from two-factor, three-factor, four-factor, five-factor, and six-factor rolling regression analyses using as dependent variable the monthly returns on aggregate hedge fund portfolio. The sample periods are ranged from January 1994 to December 2008, and the rolling regression analyses are performed using the 24-month window. Risk factors are selected from the rolling regression analyses of the single-factor model based on the number of time frames during which coefficients are significant at 5% level and using mean *R*-squared value. The results include mean, median, minimum, and maximum regression coefficients of each variable; number of time frames during which coefficients of each variable is significant at 5% level; and mean, median, minimum, and maximum adjusted *R*-squared value, as well as number of time frames during which adjusted *R*-squared value (#Sig.) is greater than 70%. **Figures in bold** and “*” indicate the best models in each level that display the most stable and highest *R*-squared value based on the mean adjusted *R*-squared value and #Sig.

*Tables A.2–A.6 are available upon request.

combination of five risk factors: emerging market equities, VIX, SCLC, credit spread factor, and HML. Brief variable descriptions are provided in Table 7.

Table A.2 summarizes the results of the rolling regression analysis of the DT portfolio and the *R*-squared statistics appear to be higher than those of the aggregate hedge fund portfolio. Even the two-factor model explains 80% of the variation in the

Table 7. Variable description.

Variable	Description
EMF	MSCI emerging market index
VIX	Volatility index
SCLC	Size spread factor; monthly total return of Russell 2000 index less S&P 500 index
CRED	Credit spread; monthly change in Moody's Baa yield less 10-year constant maturity yield
MOM	Momentum
HML	Return on value firm less return on growth firm

performance of the DT portfolio. Adding additional factors increases the explanatory power to approximately 84%. Similarly, results of the regression analysis of the SS portfolio in Table A.4 show that approximately 83% of the variation in the portfolio's performance is explained by a two-factor model and 87% of the variation by six-factor model. The five-factor model of the SS portfolio explains at least 70% of variation over all of 157 time frames showing that the model has a great stability in its explanatory power. It can be attributed to the investment strategies of DT and SS portfolios, which mostly rely on the equity market movements. On the contrary, results in Table A.3 displays relatively low *R*-squared statistics ranging from about 47% for the two-factor model to about 54% for the six-factor model. The number of time frames with *R*-squared statistics greater than 70% also very low. Because an RV portfolio maintains a certain level of spread to minimize risk or market exposure, it puts relatively greater weight on credit-related financial assets. The RV portfolio exhibits lower coefficients for the equity market variable, indicating less exposure to equity market movements compared to hedge fund portfolios using the other investment strategies. The RV portfolio exhibits substantially higher sensitivity to the credit spread factor relying on the movements of credit-related financial assets. For MP and FoF portfolios, the multi-factor models in Tables A.5 and A.6 account for approximately 70% of the variation. The optimal combinations of risk factors for each investment are summarized in Table 8.

AG, DT, and SS portfolios show similar compositions of risk factors. It can be attributed to, first, the characteristics of the two investment strategies, which are

Table 8. Optimal combinations of risk factors for measuring performance of hedge funds by investment strategy.

	Combination of risk factors
AG	EMF, VIX, SCLC, CRED, HML
DT	EMF, VIX, SCLC, MOM
RV	MKT, CRED, VIX, SCLC, 10Y, MOM
SS	MKT, VIX, SCLC, MOM, CRED
MP	MKT, SCLC, VIX, CRED, HML
FoF	EMF, VIX, SCLC, CRED, HML

Table 9. Paired *t*-test of *R*-squared statistics between the selected model and the ABS-, SAC- and the four-factor models.

		Opt-ABS	Opt-SAC	Opt-factor
AG	Mean	0.0909*	0.0020	-0.0176
	<i>t</i> -statistics	6.3353	0.3458	-1.9443
DT	Mean	0.2429*	-0.0033	0.1492*
	<i>t</i> -statistics	14.4324	-1.0386	14.5148
RV	Mean	0.0643*	0.0479*	0.0446*
	<i>t</i> -statistics	7.2488	3.0134	4.5406
SS	Mean	0.1129*	0.0980*	-0.0012
	<i>t</i> -statistics	12.1288	8.7566	-0.2937
MP	Mean	0.0940*	0.0447*	0.0254*
	<i>t</i> -statistics	9.7943	3.6611	5.1601
FoF	Mean	0.1772*	-0.0154	0.0882*
	<i>t</i> -statistics	10.4143	-1.2545	7.1976

Notes: This table reports the results for testing mean differences in explanatory power (adjusted *R*-squared statistics) between our optimal model categorized by investment strategy and existing models. “*” denotes significance at the 5% level.

basically executed by predicting equity market movements. Second, AG portfolio is an average of all investment strategies and DT and SS portfolios make up 74% and 54% of active and inactive hedge funds in AG combined.

Table 9 reports paired *t*-test results and compares the explanatory power of the selected model with the ABS-factor model, SAC-factor model and Four-factor model. The mean differences of most pairs are significant indicating that the explanatory power of the selected model is greater than that of the existing models. Considering a smaller number of factors in the selected model compared to ABS- and SAC-factor models, it appears that the model customized by investment strategy is effective in improving the explanatory power and stability of the model. The mean difference between the optimal model and the SAC-factor model appears to be relatively small, so it can be considered to be almost as good as the selected model, or better than other two models. However, we must point out that the fact that the SAC-factor model simultaneously includes US equity, Non-US equity, and emerging market equity may lead to an increased multicollinearity problem. The selected optimal model provides much more reliable measure of dynamic hedge fund performance and stable, improved explanatory power.

The empirical results strongly support our research idea that hedge fund performance is better explained by a unique set of risk factors for each investment strategy. In addition, rolling regression betas are adjusted for hedge funds’ dynamic and active responses to changes in market conditions by narrowing down the time-varying window. The four investment strategies exhibit the highest explanatory power with a unique set of risk factors that we find from the rolling regression

analyses. We note that their explanatory powers are superior to those of ABS-, SAC- and Four-factor models.

5. Conclusion

In this study, we make several attempts to find the best customized models to optimally estimate hedge funds' dynamic performance and exposures by categorizing their investment strategies. We handle two types of biases: survivorship bias and instant history bias. We then select six factors that explain most of the variance in hedge fund performance conducting multi-factor rolling regression analyses using combinations of the risk factors. The optimal models consisting of the best combination of risk factors exhibit greater and more stable explanatory power compared to existing models. We observe that DT and SS portfolios are mostly exposed to equity market risk factors because their strategies are commonly based on the prediction of equity market movements. However, RV portfolios show a relatively large exposure to spread risk factors due to their investment strategy of pursuing returns while minimizing exposure to risk.

We make the following contribution to the existing literature. First, we show that hedge funds are managed in an active and dynamic manner correspondingly making it inappropriate to estimate hedge fund performance and exposure to risk factors assuming static or buy-and-hold investment strategies. Using rolling regression analysis appears to be the best way to reflect dynamic features of hedge funds when measuring hedge fund performance and risk exposures. Second, we find the optimal models that explain most of the hedge fund performance and their exposure to risk factors using investment strategy classifications. The optimal models with fewer factors exhibit greater explanatory power compared to existing models, and rolling regression analysis show that the models are more stable and credible in estimating active and dynamic management of hedge funds. We believe that our model, which is customized to a specific investment strategy, is very useful for both academic and practical purposes.

Appendix A. Stability Test for Hedge Fund Exposure to the Selected Risk Factors

We utilize rolling regression analysis to point out the weakness of existing models measuring hedge fund performance with their implicit assumption of a static investment strategy. We expect that the coefficients estimated by our rolling regression analysis will be unstable because of the active management style of hedge funds.^d Therefore, the coefficients estimated from existing models should be biased.

To formally test the variation of coefficients over varying windows, we employ two different methods. First, we run a regression of the coefficients against their corresponding time periods. We have 157(145) of β_i from the rolling regression

^dPlease refer to appendix for stability test of rolling regression betas.

analysis with 24(36)-month window of Eq. (3.1). Then, we can define the first 24-month as $T = 1$, the second 24-month as $T = 2$, and so on. The regression model to test stability of coefficients would be

$$\beta_{iT} = C + T + T^2 + \varphi,$$

where T is the sequence of windows from 1 to 157 for the 24-month window and from 1 to 145 for the 36-month window. β_{iT} is the coefficient at each sequence. If β_{iT} is

(a) Coefficients of emerging market index for aggregate HF portfolio over varying windows

(b) Coefficients of emerging market index for DT portfolio over varying windows

Notes: These graphs intend to exhibit how actively changing exposures of hedge funds following different investment strategies are to the same risk factor. With 24-month window for rolling regression analysis, the first coefficient recorded on December 1995 is for the sample period from January 1994 to December 1995, and then, the coefficients and fixed size of windows move to right by a month. We use other risk factors for rolling regression analysis, and therefore, we need to provide with graphs for those other factors. Since equity market-related risk factor, however, takes account for significant part of hedge fund exposure to risk factors, showing instability of equity market-related factor would be sufficient to support rolling regression analysis for estimating actively managed portfolio such as hedge funds.

Fig. A.1. Coefficients of equity market-related risk factor over varying windows from rolling regression analysis of single-factor model with 24-month window.

(c) Coefficients of market risk premium for RV portfolio over varying windows

(d) Coefficients of market risk premium for SS portfolio over varying windows

(e) Coefficients of market risk premium for MP portfolio over varying windows

Fig. A.1. (Continued)

(f) Coefficients of emerging market index for FoF portfolio over varying windows

Fig. A.1. (Continued)

stable over time, T and T^2 must be insignificant and zero. However, if T and/or T^2 are significant, β_{iT} will be regarded as changing over time. In this case, we reach the conclusion that coefficients of the corresponding risk factors are unstable showing that existing single factor models are inappropriate to estimate dynamic hedge fund performance.

(a) Coefficients of emerging market index for aggregate HF portfolio over varying windows

Notes: These graphs intend to exhibit how actively changing exposures of hedge funds following different investment strategies are to the same risk factor. With 36-month window for rolling regression analysis, the first coefficient recorded on December 1996 is for the sample period from January 1994 to December 1996, and then, the coefficients and fixed size of windows move to right by a month. We use other risk factors for rolling regression analysis, and therefore, we need to provide with graphs for those other factors. Since equity market-related risk factor, however, takes account for significant part of hedge fund exposure to risk factors, showing instability of equity market-related factor would be sufficient to support rolling regression analysis for estimating actively managed portfolio such as hedge funds.

Fig. A.2. Coefficients of equity market-related risk factor over varying windows from rolling regression analysis of single-factor model with 36-month window.

(b) Coefficients of emerging market index for DT portfolio over varying windows

(c) Coefficients of market risk premium for RV portfolio over varying windows

(d) Coefficients of market risk premium for SS portfolio over varying windows

Fig. A.2. (Continued)

(e) Coefficients of market risk premium for MP portfolio over varying windows

(f) Coefficients of emerging market index for FoF portfolio over varying windows

Fig. A.2. (Continued)

Table A.1 reports the results of the regression analysis of the coefficients of equity market-related risk factor against time, T . With a single exception of coefficients for DT, all the coefficients of both 24- and 36-month windows for hedge fund portfolios exhibit linear and quadratic relationships across time, T . Even DT, the only exception, displays a linear relationship. Although coefficients of T and T^2 are very low, they are significantly different from zero so that the β_{iT} s in every sequence are also significantly different from each other. It indicates that the coefficients have a significant pattern over time, and therefore, we may consider the coefficients to be unstable over time. As a second approach to showing the instability of coefficients for a single-factor rolling regression analysis, we utilize a method of recursive residuals. Recall our single-factor regression model of Eq. (3.1): $R_{it} - R_{ft} = \alpha_i + (R_{mt} - R_{ft})\beta_i + \varepsilon_{it}$, and substitute $R_{it} - R_{ft}$ with y_t and $R_{mt} - R_{ft}$ with x_t . Then,

Table A.1. Stability tests for coefficients of equity market-related risk factors from rolling regression analysis of single-factor model.

	24M			36M		
	<i>C</i>	<i>T</i>	<i>T</i> ²	<i>C</i>	<i>T</i>	<i>T</i> ²
AG	0.2297*	2.05E-04*		0.2274*	2.49E-04*	
	0.2024*	1.24E-03*	−6.53E-06*	0.2066*	1.10E-03*	−5.81E-06*
DT	0.3910*	−2.87E-04*		0.3901*	−3.11E-04*	
	0.3909*	−2.84E-04*	−2.02E-08	0.3966*	−5.78E-04*	1.83E-06
RV	0.1064*	2.33E-04*		0.1022*	2.66E-04*	
	0.1916*	−2.98E-03*	2.04E-05*	0.1826*	−3.02E-03*	2.25E-05*
SS	0.6206*	−9.83E-04*		0.6022*	−9.41E-04*	
	0.7000*	−3.98E-03*	1.90E-05*	0.6810*	−4.16E-03*	2.20E-05*
MP	0.3002*	−4.05E-04*		0.2992*	−4.70E-04*	
	0.3626*	−2.76E-03*	1.49E-05*	0.3680*	−3.28E-03*	1.92E-05*
FoF	0.1593*	1.85E-04*		0.1473*	2.75E-04*	
	0.2189*	−2.06E-03*	1.42E-05*	0.2063*	−2.13E-03*	1.65E-05*

Notes: This table reports the results from stability tests for coefficients of equity market-related risk factors from rolling regression analysis of the single-factor model. The testing models are $\beta_{iT} = C + T + \varphi$ and $\beta_{iT} = C + T + T^2 + \varphi$, where T denotes the sequence of window from 1 to 157 for 24-month window and 1 to 145 for 36-month window, as well as the β_{iT} is the coefficient at each sequence. “*” indicates significance at the 5% level.

we have a standard simple linear regression model: $y_t = \beta \cdot x_t + \varepsilon_t$, where $\varepsilon_t \sim iid\ N(0, \sigma^2)$ and $t = 1, \dots, T$. Instead of using the entire sample period, we estimate with the first k observations, $k + 1$ observations, and $k + n$. This procedure provides us with recursive coefficients, $\hat{\beta}_t$. At each time period t , $t = k, \dots, T - 1$, we can forecast the next time period $t + 1$, and express as $\hat{y}_{t+1,t} = \hat{\beta}_t \cdot x_{t+1}$. The forecasting errors or recursive residuals are expressed as $\hat{e}_{t+1,t} = y_{t+1} - \hat{y}_{t+1,t}$. The variance of the recursive residuals changes as the number of observations increases from k through T , because the model is estimated more precisely as the sample size increases. The recursive residuals are reported in the form of graph with two standard error bands. The recursive residuals outside the bands indicate instability of coefficients.

Other than the recursive residuals, we consider the standardized recursive residuals as $w_{t+1,t} \equiv \frac{\hat{e}_{t+1,t}}{\sigma \sqrt{r_t}}$, where $t = k, \dots, T - 1$. The cumulative sum (CUSUM) of the standardized recursive residuals is one of the methods to test parameter stability. Because $w_{t+1,t} \sim iid\ N(0, 1)$, CUSUM is just a sum of $iid\ N(0, 1)$ random variables, and express as $CUSUM_t \equiv \sum_{\tau=k}^t w_{\tau+1,\tau}$, $t = k, \dots, T - 1$. CUSUM is reported with its 95% probability bounds in the graph. CUSUM outside the bounds indicates parameter instability.

Figure A.3 displays the results of stability tests on the coefficients for the equity market-related risk factors using recursive residuals. Each row of figures includes

Notes: These graphs are drawn for stability tests of the coefficients for the equity market-related risk factors using recursive residuals. Each row includes plots displays the recursive residuals, the CUSUM of the standardized residuals, and CUSUM of squares from a single-factor regression analysis. The red (dotted) lines in the graphs of recursive residuals indicate two standard error bands, and those in the graphs of CUSUM and CUSUM of squares indicate 5% critical lines. The blue (solid) lines in the graphs indicate the recursive residuals, CUSUM of standardized residuals, and CUSUM of squares, respectively.

Fig. A.3. (Color online) Stability tests on the coefficients for equity market-related risk factors using recursive residuals.

Fig. A.3. (*Continued*)

Fig. A.3. (Continued)

Table A.2. Results from the multi-factor rolling regression analysis with 24-month window using selected risk factors.

	DT	EMF	VIX	SCLC	CRED	HML	MOM	C	Rsqr
*(1)	Mean	0.3697	−0.0018					0.6930	0.8084
	Median	0.3821	0.0043					0.5401	0.8088
	Min	0.2181	−0.0644					−0.2504	0.5573
	Max	0.4881	0.0393					1.7220	0.9363
	#Sig.	157	63					107	140
(2)	Mean	0.3574		0.0748				0.7501	0.8032
	Median	0.3534		0.0802				0.5456	0.8253
	Min	0.2811		−0.2666				−0.1995	0.5071
	Max	0.4908		0.2673				1.7032	0.9185
	#Sig.	157		31				109	139
(3)	Mean	0.3652			−0.5948			0.7578	0.7965
	Median	0.3560			−0.5226			0.5938	0.8159
	Min	0.2588			−6.6748			−0.0427	0.4940
	Max	0.5180			5.0950			1.6246	0.9212
	#Sig.	157			27			113	135
(4)	Mean	0.3654				−0.0308		0.7236	0.7987
	Median	0.3606				−0.0248		0.5505	0.8084
	Min	0.2667				−0.2736		−0.3343	0.5605
	Max	0.5386				0.1946		1.6909	0.9177
	#Sig.	157				20		105	142
(5)	Mean	0.3661					0.0380	0.6703	0.8043
	Median	0.3623					0.0267	0.5738	0.8347
	Min	0.2738					−0.0831	−0.4691	0.4930
	Max	0.4752					0.2218	1.6259	0.9152
	#Sig.	157					37	104	136
*(6)	Mean	0.3534	−0.0028	0.0888				0.7158	0.8187
	Median	0.3687	0.0034	0.0874				0.5459	0.8287
	Min	0.1668	−0.0715	−0.2585				−0.2981	0.5459
	Max	0.4752	0.0338	0.2706				1.7473	0.9434
	#Sig.	157	61	47				99	142
(7)	Mean	0.3675	−0.0008		−0.8382			0.7267	0.8130
	Median	0.3696	0.0037		−0.8342			0.5660	0.8241
	Min	0.2187	−0.0644		−6.7767			−0.1119	0.5394
	Max	0.5111	0.0408		4.7347			1.7203	0.9349
	#Sig.	157	68		32			108	139
(8)	Mean	0.3698	−0.0009			−0.0347		0.6920	0.8119
	Median	0.3753	0.0064			−0.0257		0.5517	0.8098
	Min	0.1941	−0.0630			−0.2884		−0.3024	0.5844
	Max	0.5154	0.0427			0.1868		1.7513	0.9332
	#Sig.	157	61			18		104	144
(9)	Mean	0.3695	−0.0010				0.0394	0.6382	0.8186
	Median	0.3767	0.0054				0.0258	0.5351	0.8443
	Min	0.2386	−0.0620				−0.0739	−0.4114	0.5380
	Max	0.4835	0.0390				0.2229	1.7201	0.9334
	#Sig.	157	60				36	100	140
(10)	Mean	0.3525	−0.0012	0.0868	−0.4027			0.7545	0.8259
	Median	0.3541	0.0039	0.0938	−0.2925			0.5627	0.8378

Table A.2. (Continued)

	DT	EMF	VIX	SCLC	CRED	HML	MOM	C	Rsqr
	Min	0.1678	-0.0715	-0.3649	-6.7892			-0.1582	0.5221
	Max	0.5250	0.0400	0.2909	7.3906			1.7529	0.9405
	#Sig.	157	64	58	37			100	140
(11)	Mean	0.3524	-0.0020	0.0844		-0.0223		0.7108	0.8196
	Median	0.3629	0.0061	0.0786		-0.0203		0.5398	0.8252
	Min	0.1068	-0.0667	-0.2579		-0.2515		-0.3480	0.5626
	Max	0.5024	0.0374	0.2648		0.1871		1.7608	0.9628
	#Sig.	157	63	41		18		102	143
* (12)	Mean	0.3532	-0.0021	0.0870			0.0466	0.6644	0.8261
	Median	0.3670	0.0048	0.0781			0.0504	0.5334	0.8458
	Min	0.1703	-0.0709	-0.1866			-0.0867	-0.3132	0.5253
	Max	0.4822	0.0376	0.3061			0.1715	1.7172	0.9410
	#Sig.	157	59	43			32	95	141
(13)	Mean	0.3464	0.0000	0.0828	-0.5762	-0.0429		0.7582	0.8260
	Median	0.3441	0.0051	0.0871	-0.1453	-0.0297		0.5723	0.8351
	Min	0.1232	-0.0663	-0.3402	-8.0715	-0.2469		-0.2243	0.5384
	Max	0.5309	0.0399	0.2776	5.9050	0.1392		1.7785	0.9621
	#Sig.	157	63	47	37	16		107	141
* (14)	Mean	0.3465	-0.0008	0.0861	-0.5189	0.0508		0.7107	0.8326
	Median	0.3544	0.0062	0.0807	-0.3497	0.0610		0.5945	0.8566
	Min	0.1676	-0.0709	-0.2937	-6.8778	-0.0870		-0.1306	0.4994
	Max	0.5250	0.0513	0.3341	7.2632	0.1667		1.7221	0.9377
	#Sig.	157	63	48	37	35		99	139
* (15)	Mean	0.3434	-0.0017	0.0742	-1.0075	-0.0061	0.0532	0.6975	0.8372
	Median	0.3457	0.0037	0.0786	-0.9442	0.0046	0.0658	0.5952	0.8598
	Min	0.1316	-0.0659	-0.3090	-7.9971	-0.2589	-0.1075	-0.2075	0.5116
	Max	0.5527	0.0391	0.3180	5.8432	0.2869	0.2151	1.7327	0.9631
	#Sig.	157	64	44	34	28	40	108	141

Notes: This table reports the results from the two-factor, three-factor, four-factor, five-factor, and six-factor rolling regression analyses using as dependent variable the monthly returns on the DT portfolio. The sample period ranges from January 1994 to December 2008, and the rolling regression analyses are performed using the 24-month window. Risk factors in this table are selected from the rolling regression analyses of the single-factor model based on the number of time frames during which coefficients are significant at 5% significance level based on the mean *R*-squared value. The results include mean, median, minimum, and maximum regression coefficients of each variable; number of time frames during which coefficients of each variable is significant at the 5% significance level; and mean, median, minimum, and maximum adjusted *R*-squared value, as well as number of time frames during which adjusted *R*-squared value (#Sig.) is greater than 70%. **Figures in bold** and “*” indicate the best models in each level that show the most stable and highest *R*-squared value based on the mean adjusted *R*-squared value and #Sig.

figures of the recursive residuals, the CUSUM of the standardized residuals and CUSUM of squares from a single-factor regression analysis, respectively. Analyzing the figures in the first row for the aggregate hedge fund portfolio, recursive residual, CUSUM and CUSUM of squares mostly stay within the 95% critical bounds. However, we can observe out of bound values for some periods. Those periods include Asian Financial Crisis in 1997–1998, the Dot.com bubble around 2000, and

Table A.3. Results from the multi-factor rolling regression analysis with 24-month window using selected risk factors.

	RV	MKT	CRED	VIX	SCLC	10y	MOM	C	Rsqr
*(1)	Mean	0.0966	-1.5351					0.3876	0.4672
	Median	0.1059	-1.0057					0.3646	0.4517
	Min	-0.0045	-5.0119					0.0623	0.0719
	Max	0.1985	1.1970					0.9079	0.8890
	#Sig.	128	70					128	11
(2)	Mean	0.1407		0.0051				0.3346	0.3904
	Median	0.1376		0.0030				0.3173	0.3851
	Min	0.0461		-0.0081				-0.1826	0.0518
	Max	0.3997		0.0371				0.9532	0.7831
	#Sig.	137		9				94	5
(3)	Mean	0.1163			0.0295			0.3534	0.4205
	Median	0.1079			0.0362			0.3399	0.4241
	Min	0.0382			-0.1172			-0.1549	0.0512
	Max	0.3590			0.1080			0.9108	0.8110
	#Sig.	143			46			107	5
(4)	Mean	0.1212				0.2989		0.3564	0.4238
	Median	0.1164				0.0995		0.3401	0.4162
	Min	0.0522				-0.9867		-0.2355	0.0344
	Max	0.3633				1.8672		0.9125	0.8029
	#Sig.	155				55		98	4
(5)	Mean	0.1215					0.0268	0.3313	0.3962
	Median	0.1153					0.0159	0.3281	0.3927
	Min	0.0222					-0.0352	-0.2756	0.0487
	Max	0.3680					0.1242	0.8121	0.7826
	#Sig.	139					18	96	4
(6)	Mean	0.1100	-1.5459	0.0045				0.3706	0.4629
	Median	0.1201	-1.0263	0.0034				0.3268	0.4474
	Min	-0.0170	-5.1692	-0.0167				0.0711	0.0373
	Max	0.2281	1.1095	0.0363				0.9486	0.8846
	#Sig.	111	72	23				110	19
(7)	Mean	0.0900	-1.4567		0.0251			0.3909	0.4872
	Median	0.0887	-0.8152		0.0336			0.4070	0.4896
	Min	0.0062	-5.2615		-0.1573			0.0863	0.0296
	Max	0.1955	1.1865		0.1170			0.9100	0.9016
	#Sig.	106	64		49			123	23
*(8)	Mean	0.0952	-2.3293			-0.5306		0.3745	0.5099
	Median	0.0990	-2.1415			-0.4988		0.3411	0.5016
	Min	0.0102	-7.1218			-2.1573		0.0237	0.1078
	Max	0.1889	1.2984			0.7579		0.9049	0.8935
	#Sig.	131	94			46		128	15
(9)	Mean	0.0929	-1.5728				0.0323	0.3690	0.4764
	Median	0.1040	-1.0701				0.0223	0.3365	0.4830
	Min	-0.0054	-4.6807				-0.0228	-0.0201	0.0257
	Max	0.1818	2.0994				0.1427	0.8159	0.8874
	#Sig.	113	70				25	119	13

Table A.3. (Continued)

	RV	MKT	CRED	VIX	SCLC	10y	MOM	C	Rsqr
(10)	Mean	0.1017	-1.4813	0.0044	0.0246			0.3723	0.4846
	Median	0.1087	-0.8483	0.0041	0.0353			0.3527	0.4731
	Min	-0.0351	-5.6298	-0.0179	-0.1638			0.0780	-0.0073
	Max	0.2237	1.1072	0.0384	0.1088			0.9423	0.9010
	#Sig.	98	64	24	49			113	25
* (11)	Mean	0.1048	-2.2750	0.0028		-0.4828		0.3516	0.5077
	Median	0.1153	-2.1504	0.0036		-0.5153		0.3021	0.4859
	Min	-0.0095	-6.7118	-0.0219		-1.7058		0.0122	0.0609
	Max	0.2057	1.2949	0.0314		0.7968		0.9468	0.8937
	#Sig.	113	86	21		41		109	19
(12)	Mean	0.1078	-1.5830	0.0050			0.0332	0.3520	0.4744
	Median	0.1132	-1.1352	0.0055			0.0255	0.3208	0.4795
	Min	-0.0194	-4.9418	-0.0125			-0.0208	0.0470	-0.0121
	Max	0.2057	1.9277	0.0356			0.1377	0.8561	0.8819
	#Sig.	107	71	29			23	112	16
* (13)	Mean	0.0968	-2.2018	0.0030	0.0279	-0.4614		0.3604	0.5316
	Median	0.1064	-1.9301	0.0038	0.0382	-0.4829		0.3370	0.5019
	Min	-0.0375	-6.9707	-0.0260	-0.1466	-2.1563		0.0057	0.0164
	Max	0.2004	1.3272	0.0349	0.1222	0.9637		0.9438	0.9067
	#Sig.	98	83	20	49	47		110	27
(14)	Mean	0.1014	-1.4341	0.0048	0.0264		0.0282	0.3622	0.4964
	Median	0.1100	-0.8313	0.0051	0.0335		0.0163	0.3293	0.4978
	Min	-0.0497	-5.7070	-0.0221	-0.1664		-0.0332	0.0686	-0.0631
	Max	0.1991	1.9812	0.0390	0.1343		0.1455	0.8695	0.8957
	#Sig.	98	69	26	50		29	111	26
* (15)	Mean	0.1006	-2.1809	0.0037	0.0284	-0.5028	0.0276	0.3515	0.5417
	Median	0.1061	-2.1547	0.0054	0.0341	-0.4396	0.0196	0.3298	0.5064
	Min	-0.0249	-6.7947	-0.0244	-0.1367	-1.9883	-0.0292	0.0056	0.1141
	Max	0.1798	1.7230	0.0344	0.1433	0.6013	0.1329	0.8710	0.9016
	#Sig.	102	88	21	40	48	16	107	26

Notes: This table reports results from two-factor, three-factor, four-factor, five-factor, and six-factor rolling regression analyses using as dependent variable the monthly returns on RV portfolio. The sample period ranges from January 1994 to December 2008, and the rolling regression analyses are performed using the 24-month window. Risk factors in this table are selected from the rolling regression analyses of the single-factor model based on the number of time frame during which coefficients are significant at 5% significance level using the mean *R*-squared value. The results include mean, median, minimum, and maximum regression coefficients of each variable; number of time frames during which coefficients of each variable is significant at 5% significance level; and mean, median, minimum, and maximum adjusted *R*-squared value, as well as number of time frames during which adjusted *R*-squared value (#Sig.) is greater than 70%. **Figures in bold** and “*” indicate the best models in each level that show the most stable and highest *R*-squared value based on the mean adjusted *R*-squared value and #Sig.

US Financial Crisis in 2008. In the figure for CUSUM, we can also observe that CUSUM starts declining sharply after 2000 and that it finally goes out of the lower bound in 2008. This may be sufficient partial evidence to say that regression coefficients are unstable over the time periods.

Table A.4. Results from the multi-factor rolling regression analysis with 24-month window using selected risk factors.

	SS	MKT	VIX	SCLC	MOM	HML	CRED	C	Rsqr
(1)	Mean	0.5854	0.0160					0.4825	0.7397
	Median	0.6067	0.0145					0.3833	0.7362
	Min	0.3413	−0.0283					−0.0898	0.5223
	Max	0.8056	0.0883					1.8449	0.8945
	#Sig.	157	26					81	106
*(2)	Mean	0.4877		0.2239				0.5850	0.8323
	Median	0.5018		0.2398				0.4249	0.8525
	Min	0.3030		−0.2244				−0.0582	0.5359
	Max	0.6733		0.4177				1.6121	0.9527
	#Sig.	157		141				119	142
(3)	Mean	0.5289			0.0651			0.4792	0.7713
	Median	0.5444			0.0583			0.4170	0.7840
	Min	0.3113			−0.2034			−0.1249	0.5648
	Max	0.7512			0.3444			1.6340	0.8807
	#Sig.	157			72			82	138
(4)	Mean	0.5380				0.0183		0.4897	0.7478
	Median	0.5372				0.0192		0.3896	0.7580
	Min	0.3881				−0.3043		−0.0720	0.4984
	Max	0.7239				0.2903		1.8069	0.8857
	#Sig.	157				46		73	114
(5)	Mean	0.5310					−2.9243	0.5172	0.7518
	Median	0.5636					−2.2382	0.3707	0.7632
	Min	0.2279					−13.5164	0.0647	0.5014
	Max	0.8094					2.1844	1.8730	0.8792
	#Sig.	157					41	76	122
*(6)	Mean	0.5330	0.0177	0.2260				0.5470	0.8394
	Median	0.5391	0.0100	0.2391				0.4128	0.8667
	Min	0.2759	−0.0252	−0.2259				−0.0946	0.5449
	Max	0.8288	0.0931	0.3919				1.6555	0.9565
	#Sig.	157	49	138				107	141
(7)	Mean	0.5851	0.0190		0.0691			0.4394	0.7772
	Median	0.6009	0.0178		0.0578			0.3924	0.7830
	Min	0.2821	−0.0264		−0.2048			−0.1891	0.5447
	Max	0.7857	0.0849		0.3591			1.6869	0.9017
	#Sig.	157	36		73			71	139
(8)	Mean	0.5818	0.0169			0.0187		0.4625	0.7515
	Median	0.5962	0.0120			0.0190		0.3718	0.7530
	Min	0.3634	−0.0298			−0.3161		−0.1197	0.5019
	Max	0.8247	0.0885			0.2916		1.8944	0.8905
	#Sig.	157	25			45		65	112
(9)	Mean	0.5740	0.0153				−2.8988	0.4781	0.7554
	Median	0.6301	0.0148				−2.2403	0.3452	0.7555
	Min	0.1983	−0.0277				−13.5325	−0.0720	0.5048
	Max	0.7972	0.0808				2.2359	1.8967	0.9002
	#Sig.	157	22				45	67	124

Table A.4. (Continued)

	SS	MKT	VIX	SCLC	MOM	HML	CRED	C	Rsqr
*(10)	Mean	0.5448	0.0196	0.2065	0.0750			0.5025	0.8588
	Median	0.5591	0.0162	0.2295	0.0310			0.3886	0.8629
	Min	0.2409	-0.0250	-0.1259	-0.0407			-0.1722	0.6676
	Max	0.8168	0.0897	0.3980	0.3306			1.6355	0.9542
	#Sig.	157	51	119	44			100	154
(11)	Mean	0.5426	0.0186	0.2286		0.0478		0.4974	0.8456
	Median	0.5417	0.0134	0.2389		0.0350		0.3251	0.8650
	Min	0.2851	-0.0269	-0.0799		-0.2856		-0.0868	0.5261
	Max	0.8359	0.0952	0.4235		0.2622		1.6930	0.9567
	#Sig.	157	48	133		46		84	141
(12)	Mean	0.5213	0.0176	0.2186			-1.4839	0.5506	0.8452
	Median	0.5485	0.0127	0.2352			-1.4591	0.4175	0.8680
	Min	0.2027	-0.0257	-0.3134			-6.9734	-0.0769	0.5273
	Max	0.8235	0.0969	0.3771			3.9028	1.6532	0.9587
	#Sig.	156	51	140			39	113	143
(13)	Mean	0.5437	0.0199	0.2104	0.0632	0.0490		0.4737	0.8608
	Median	0.5599	0.0158	0.2269	0.0245	0.0435		0.3271	0.8622
	Min	0.2492	-0.0267	-0.0919	-0.0547	-0.2591		-0.1836	0.6534
	Max	0.8218	0.0918	0.4268	0.3136	0.2833		1.6743	0.9543
	#Sig.	157	52	120	36	31		81	154
*(14)	Mean	0.5314	0.0196	0.1996	0.0732		-1.6080	0.5123	0.8648
	Median	0.5289	0.0171	0.2232	0.0289		-1.7341	0.3838	0.8643
	Min	0.2309	-0.0257	-0.2129	-0.0497		-7.4954	-0.0764	0.7095
	Max	0.8163	0.0909	0.3773	0.3965		3.7343	1.6437	0.9587
	#Sig.	157	50	122	39		47	103	157
*(15)	Mean	0.5352	0.0211	0.2069	0.0627	0.0463	-1.8173	0.4788	0.8685
	Median	0.5275	0.0172	0.2208	0.0200	0.0348	-2.1035	0.3215	0.8734
	Min	0.2368	-0.0269	-0.1743	-0.0639	-0.2634	-9.7522	-0.0527	0.6924
	Max	0.8426	0.0996	0.4280	0.4024	0.2388	3.1757	1.6847	0.9587
	#Sig.	157	61	123	32	37	43	73	155

Notes: This table reports results from two-factor, three-factor, four-factor, five-factor, and six-factor rolling regression analyses using as dependent variable the monthly returns on SS portfolio. The sample period ranges from January 1994 to December 2008, and the rolling regression analyses are performed using the 24-month window. Risk factors in this table are selected from the rolling regression analyses of the single-factor model based on the number of time frame during which coefficients are significant at 5% significance level using the mean *R*-squared value. The results include mean, median, minimum, and maximum regression coefficients of each variable; number of time frames during which coefficients of each variable is significant at 5% significance level; and mean, median, minimum, and maximum adjusted *R*-squared value, as well as number of time frames during which adjusted *R*-squared value (#Sig.) is greater than 70%. **Figures in bold** and “*” indicate the best models in each level that show the most stable and highest *R*-squared value based on the mean adjusted *R*-squared value and #Sig.

Specifically, figures for the DT portfolio are very similar to those of the aggregate hedge fund portfolio in terms of the movements of the recursive residuals, CUSUM and CUSUM of squares. However, the rest of the figures displays different movements. Recursive residuals in the RV portfolio maintain relatively narrow 95%

Table A.5. Results from the multi-factor rolling regression analysis with 24-month window using selected risk factors.

	MP	MKT	SCLC	VIX	CRED	HML	MOM	C	Rsqr
*(1)	Mean	0.2476	0.0971					0.5458	0.6265
	Median	0.2694	0.1191					0.5048	0.6458
	Min	0.0619	-0.1755					-0.2047	0.1443
	Max	0.3858	0.2614					1.1744	0.8975
	#Sig.	154	94					134	57
(2)	Mean	0.3039		0.0118				0.4870	0.5611
	Median	0.3262		0.0123				0.4468	0.5803
	Min	0.0729		-0.0207				-0.2439	0.1026
	Max	0.4591		0.0633				1.3151	0.8403
	#Sig.	152		24				115	20
(3)	Mean	0.2464			-2.4677			0.5430	0.6062
	Median	0.2790			-2.9058			0.4776	0.6246
	Min	0.0095			-6.5783			-0.1497	0.0807
	Max	0.3812			2.9567			1.3227	0.8941
	#Sig.	148			84			143	48
(4)	Mean	0.2776				0.0619		0.4789	0.5866
	Median	0.2858				0.0650		0.4744	0.6042
	Min	0.1259				-0.2090		-0.3162	0.2888
	Max	0.4215				0.2460		1.2523	0.8352
	#Sig.	157				48		104	34
(5)	Mean	0.2635					0.0141	0.5038	0.5654
	Median	0.2782					0.0111	0.4759	0.5978
	Min	0.0703					-0.1269	-0.3751	0.0753
	Max	0.3804					0.1444	1.1989	0.8628
	#Sig.	154					35	119	27
(6)	Mean	0.2820	0.1017	0.0123				0.5138	0.6374
	Median	0.2984	0.1176	0.0121				0.4679	0.6487
	Min	0.0338	-0.1764	-0.0254				-0.2092	0.1441
	Max	0.4698	0.2547	0.0641				1.2043	0.8962
	#Sig.	145	93	36				118	59
*(7)	Mean	0.2270	0.0906		-1.8715			0.5723	0.6660
	Median	0.2554	0.1031		-1.8262			0.5458	0.6817
	Min	0.0202	-0.2320		-5.6762			-0.0358	0.1071
	Max	0.3860	0.2691		3.1410			1.1781	0.9192
	#Sig.	143	100		76			145	72
(8)	Mean	0.2637	0.0938			0.0742		0.4960	0.6531
	Median	0.2827	0.1182			0.0485		0.4792	0.6717
	Min	0.0979	-0.1502			-0.1503		-0.2559	0.2658
	Max	0.4048	0.2697			0.2481		1.1277	0.8962
	#Sig.	157	92			46		114	61
(9)	Mean	0.2479	0.0909				0.0158	0.5338	0.6207
	Median	0.2719	0.1081				0.0113	0.5350	0.6451
	Min	0.0525	-0.1318				-0.0590	-0.3175	0.1040
	Max	0.3923	0.2661				0.1270	1.1586	0.8959
	#Sig.	150	90				12	133	63

Table A.5. (Continued)

	MP	MKT	SCLC	VIX	CRED	HML	MOM	C	Rsqr
*(10)	Mean	0.2613	0.0950	0.0123	-1.8627			0.5342	0.6784
	Median	0.2797	0.0999	0.0116	-2.0149			0.4746	0.6933
	Min	-0.0450	-0.2631	-0.0258	-5.9446			-0.0241	0.1127
	Max	0.4690	0.2682	0.0653	3.1607			1.1889	0.9272
	#Sig.	137	99	41	71			128	74
(11)	Mean	0.2988	0.1001	0.0130		0.0779		0.4660	0.6667
	Median	0.3220	0.1178	0.0126		0.0613		0.4428	0.6767
	Min	0.0432	-0.0997	-0.0278		-0.1545		-0.2633	0.2485
	Max	0.5042	0.2659	0.0639		0.2605		1.1845	0.8949
	#Sig.	139	92	35		46		93	64
(12)	Mean	0.2857	0.0930	0.0125			0.0193	0.4995	0.6341
	Median	0.3096	0.1062	0.0134			0.0127	0.4726	0.6645
	Min	0.0013	-0.1253	-0.0254			-0.0663	-0.3338	0.0998
	Max	0.4735	0.2592	0.0629			0.1435	1.1986	0.8946
	#Sig.	140	83	40			15	117	64
*(13)	Mean	0.2804	0.0947	0.0138	-1.9683	0.0697		0.4907	0.7069
	Median	0.3007	0.0995	0.0133	-2.0492	0.0733		0.4488	0.7267
	Min	-0.0264	-0.1966	-0.0292	-6.5212	-0.1344		-0.0696	0.2227
	Max	0.5360	0.2635	0.0630	2.9746	0.2313		1.1913	0.9237
	#Sig.	136	100	45	71	52		104	83
(14)	Mean	0.2650	0.0862	0.0128	-1.9735		0.0205	0.5245	0.6786
	Median	0.2879	0.0938	0.0151	-2.0089		0.0146	0.4955	0.7029
	Min	-0.0107	-0.2441	-0.0265	-5.9395		-0.0630	-0.1424	0.0691
	Max	0.4730	0.2591	0.0642	2.6357		0.1893	1.1881	0.9279
	#Sig.	135	83	42	71		20	129	80
*(15)	Mean	0.2760	0.0905	0.0132	-2.0545	0.0752	0.0098	0.4808	0.7063
	Median	0.3001	0.0941	0.0138	-1.8638	0.0751	-0.0013	0.4575	0.7244
	Min	-0.0075	-0.1976	-0.0290	-6.9683	-0.1370	-0.0718	-0.1486	0.1775
	Max	0.5224	0.2511	0.0603	2.3480	0.3440	0.1729	1.1888	0.9244
	#Sig.	127	88	49	72	45	11	103	85

Notes: This table reports results from two-factor, three-factor, four-factor, five-factor, and six-factor rolling regression analyses using as dependent variable the monthly returns on MP portfolio. The sample period ranges from January 1994 to December 2008, and the rolling regression analyses are performed using the 24-month window. Risk factors in this table are selected from the rolling regression analyses of the single-factor model based on the number of time frame during which coefficients are significant at 5% significance level using mean *R*-squared value. The results include mean, median, minimum, and maximum regression coefficients of each variable; number of time frames during which coefficients of each variable is significant at 5% significance level; and mean, median, minimum, and maximum adjusted *R*-squared value, as well as number of time frames during which adjusted *R*-squared value (#Sig.) is greater than 70%. **Figures in bold** and “*” indicate the best models in each level that show the most stable and highest *R*-squared value based on the mean adjusted *R*-squared value and #Sig.

critical bounds and show greater out of bound jumps around 1998 and 2008. CUSUM of squares stays out of bound all the way from 1997 to 2008. This indicates that regression coefficients for the RV portfolio are unstable over the majority of the sample periods. Figures for the SS portfolio commonly exhibit violations of bounds

Table A.6. Results from the multi-factor rolling regression analysis with 24-month window using selected risk factors.

	FoF	EMF	VIX	SCLC	CRED	MOM	HML	C	Rsqr
(1)	Mean	0.1836	0.0056					0.3540	0.5983
	Median	0.1848	0.0069					0.2683	0.5880
	Min	0.0679	−0.0246					−0.4463	0.3195
	Max	0.2922	0.0501					1.1234	0.8692
	#Sig.	157	25					81	29
(2)	Mean	0.1652		0.0602				0.3764	0.6242
	Median	0.1714		0.0696				0.2612	0.6172
	Min	0.0675		−0.2044				−0.4730	0.3140
	Max	0.2640		0.2016				1.2267	0.8566
	#Sig.	157		52				85	42
(3)	Mean	0.1675			−0.9888			0.3945	0.6112
	Median	0.1657			−1.2752			0.2668	0.5990
	Min	0.0637			−5.2728			−0.2767	0.3279
	Max	0.2723			3.9899			1.0993	0.8591
	#Sig.	157			45			83	35
*(4)	Mean	0.1784				0.0410		0.3058	0.6386
	Median	0.1819				0.0278		0.2459	0.6287
	Min	0.0951				−0.0773		−0.7178	0.3170
	Max	0.2705				0.1926		1.0933	0.8736
	#Sig.	157				43		68	58
(5)	Mean	0.1755					0.0245	0.3453	0.6017
	Median	0.1717					0.0329	0.2531	0.5897
	Min	0.0787					−0.1884	−0.5797	0.2649
	Max	0.2670					0.1838	1.1376	0.8582
	#Sig.	157					24	76	35
(6)	Mean	0.1727	0.0050	0.0646				0.3680	0.6284
	Median	0.1747	0.0068	0.0741				0.2583	0.6122
	Min	0.0272	−0.0245	−0.1909				−0.4636	0.2927
	Max	0.2910	0.0468	0.2016				1.2278	0.8754
	#Sig.	155	28	49				85	41
(7)	Mean	0.1788	0.0065		−1.0648			0.3846	0.6181
	Median	0.1718	0.0092		−1.1561			0.2608	0.6066
	Min	0.0652	−0.0242		−5.5255			−0.2901	0.3232
	Max	0.2951	0.0485		3.9192			1.1247	0.8684
	#Sig.	157	34		42			80	40
*(8)	Mean	0.1886	0.0061			0.0407		0.2983	0.6441
	Median	0.1838	0.0064			0.0247		0.2380	0.6431
	Min	0.0961	−0.0248			−0.0748		−0.6354	0.2937
	Max	0.2940	0.0557			0.1974		1.1170	0.8755
	#Sig.	157	33			41		70	59
(9)	Mean	0.1844	0.0055				0.0226	0.3398	0.6032
	Median	0.1799	0.0061				0.0218	0.2517	0.5892
	Min	0.0588	−0.0237				−0.1964	−0.5098	0.2997
	Max	0.3308	0.0501				0.2086	1.1586	0.8653
	#Sig.	157	20				20	78	32

Table A.6. (Continued)

	FoF	EMF	VIX	SCLC	CRED	MOM	HML	<i>C</i>	Rsq
(10)	Mean	0.1696	0.0066	0.0626	-0.7193			0.4034	0.6570
	Median	0.1641	0.0080	0.0709	-1.0509			0.2559	0.6674
	Min	0.0420	-0.0248	-0.3336	-5.5528			-0.3084	0.3139
	Max	0.3013	0.0550	0.2327	5.2599			1.2301	0.8777
	#Sig.	154	40	65	56			80	59
* (11)	Mean	0.1783	0.0055	0.0628		0.0458		0.3244	0.6579
	Median	0.1790	0.0065	0.0563		0.0284		0.2609	0.6580
	Min	0.0590	-0.0233	-0.1196		-0.0713		-0.5724	0.2616
	Max	0.2941	0.0536	0.2308		0.2134		1.1830	0.8751
	#Sig.	157	34	38		47		77	67
(12)	Mean	0.1729	0.0051	0.0673			0.0309	0.3580	0.6320
	Median	0.1699	0.0069	0.0681			0.0288	0.2504	0.6269
	Min	0.0124	-0.0233	-0.2012			-0.1587	-0.5252	0.3151
	Max	0.3293	0.0467	0.2386			0.2076	1.2320	0.8730
	#Sig.	152	24	52			19	81	50
* (13)	Mean	0.1692	0.0068	0.0609	-0.9452	0.0517		0.3661	0.6845
	Median	0.1674	0.0090	0.0566	-1.1636	0.0526		0.2555	0.7142
	Min	0.0619	-0.0237	-0.2663	-6.3679	-0.0837		-0.2929	0.2852
	Max	0.2731	0.0694	0.2502	5.2699	0.2256		1.1852	0.8732
	#Sig.	157	42	52	55	47		75	84
(14)	Mean	0.1670	0.0079	0.0669	-0.7791		0.0168	0.3997	0.6626
	Median	0.1611	0.0078	0.0739	-0.9747		0.0178	0.2320	0.6726
	Min	0.0257	-0.0243	-0.2815	-5.5069		-0.1568	-0.3967	0.3368
	Max	0.2945	0.0688	0.2588	5.1267		0.2062	1.2330	0.8711
	#Sig.	155	38	59	58		22	77	67
* (15)	Mean	0.1681	0.0064	0.0635	-1.0944	0.0518	0.0490	0.3537	0.6913
	Median	0.1638	0.0085	0.0624	-1.1048	0.0565	0.0380	0.2283	0.7133
	Min	0.0493	-0.0244	-0.2489	-6.0409	-0.0795	-0.0968	-0.3852	0.3455
	Max	0.2831	0.0688	0.2532	5.1555	0.2207	0.2917	1.1880	0.8658
	#Sig.	153	35	44	49	45	19	72	83

Notes: This table reports results from two-factor, three-factor, four-factor, five-factor, and six-factor rolling regression analyses using as dependent variable the monthly returns on FoF portfolio. The sample period ranges from January 1994 to December 2008, and the rolling regression analyses are performed using the 24-month window. Risk factors in this table are selected from the rolling regression analyses of the single-factor model based on the number of time frame during which coefficients are significant at 5% significance level using mean *R*-squared value. The results include mean, median, minimum, and maximum regression coefficients of each variable; number of time frames during which coefficients of each variable is significant at 5% significance level; and mean, median, minimum, and maximum adjusted *R*-squared value, as well as number of time frames during which adjusted *R*-squared value (#Sig.) is greater than 70%. **Figures in bold** and “*” indicate the best models in each level that show the most stable and highest *R*-squared value based on the mean adjusted *R*-squared value and #Sig.

around periods of the Dot.com bubble burst between 2000 and 2003. It shows that during that period, the SS portfolio has substantially changed its exposure to equity market-related risk factors. In the figures of the MP and FoF portfolios, we can observe bound violations during critical financial events that substantially affected

the global economy. All these figures commonly indicate that hedge fund portfolios with different strategies respond more actively and change their risk exposure to events, which affect global economies severely. Since the world economy is more global than in the past, these events will occur more frequently in the future. Thus, the tendency is that hedge funds actively respond to such events more frequently, and so does the instability of regression coefficients.

With the results of the two methods examining the stability of regression coefficients from single index model, we conclude that the coefficients are unstable, especially when an event affects the global economy. In addition, with a recent pattern of globalization, highly developed investment techniques and active hedge fund management of exposure to risk factors, the stability of the regression coefficients from the model is more likely to deteriorate in the future. Therefore, the rolling regression model is more efficient in capturing the dynamic management style of hedge funds and in measuring hedge fund exposure to a variety of risk factors.

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