Comparison on Asset Pricing Models: Application of CAPM, Fama-French 3 factors model and Fama-French 5 factors model

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Abstract. There are many mainstream models in the academic community, such as CAPM, Fama-French 3 factors model, Fama-French 5 factors model. Chinese stock exchange since its establishment in 1990, has had more than 30 years of development. Nowadays, Fama-French 3 factors model is commonly considered as a more suitable model. However, because of the difference between the Chinese and American markets. The practical application of the models mentioned above in the Chinese market remain to be verified. This paper gathers the monthly data of stocks traded in the Shanghai Stock Exchange from 2002 to 2022 and the annual report data of its corresponding companies, follows the construction method of the model, compares the application of each model. As a result, Fama-French 3 and 5 factors model both have good performance in the sample. MKT and HML factors have significant influence in the model. But the CMA factor may be less satisfied in this market, and further discussion is required.

Keywords: Asset pricing model; CAPM; Fama-French 3 factors model; Fama-French 5 factors model; Chinese stock market.

1. Introduction

Since the birth of the financial market, asset pricing has been an issue of great concern to the public. In recent decades of development, a variety of asset pricing models emerge in endlessly. Early in the 1960s, William Sharper (1964), Jack Treynor (1962), John Lintner (1965a,b), and Jan Mossin (1966) created the Capital Asset Pricing Model (CAPM) [1-4]. It is the foundation of contemporary theories of financial market prices and is extensively used in various areas like investment decision-making and corporate finance. It primarily examines the connection of expected return and assets in the securities market, as well as, the process of forming an equilibrium price. And it is well-known in the field of securities theory.

However, this model primarily focuses on connection between the sensitivity of market portfolio returns and securities returns, no other factors included. CAPM states that linear relationships exist between the systematic risk of the entire stock market and stock return. According to Banz (1981), a stock's return and market value are connected [5]. In a series of subsequent studies, it was pointed out that indicators like, the reciprocal price to earnings ratio (E/P) and book-to-market ratio (BE/ME), could be used to describe the movement of stock price, demonstrating the connection between risk factors and stock prices. In 1993, Fama and French noted that a model with three factors might be developed to account for the stock return rate. The study pointed out that capitalization and book-to-market ratio are vital when creating a model to account for a portfolio's excess return.[6]. This model was improved in 2015 by Fama and French, on the basis of the initial research. Two new factors RMW and CMA were added into the model, which expanded the three factors model into a five factors model. This paper discusses the application of these models in Chinese market and compare the feasibility between each model.

In Chinese market, a few numbers of paper have discussed models. Especially on Fama French 3 & 5 factors model. About five factors model, it has been demonstrated that the five factors model can increase the performance of the three factors model for A-share on the Chinese stock market. However, the best model for Chinese stock market is still under discussion. Many research have discussed the topic, including Zhao et al. (2016), Li et al. (2017), Yang Wenjian (2017) [7-9].

Currently most of the study have the conclusion that there are no obvious profitability or investment effect on Chinese stock market while others may disagree. For the given background, this paper mainly aimed at evaluating and comparing the CAPM, Fama-French 3 and 5 factors model in Shanghai Stock Exchange, A-share market especially, with the purpose of providing more analysis on the topic.

2. Data and method

2.1 Data

This paper analysis the Non-ST A share traded on Shanghai stock market in a quarterly level from March 2002 to June 2022. Most of the raw data used in this paper, is collected form the financial terminal such as CSMAR, Wind, EPSDATA. These parts of data contain the monthly individual stock returns, risk free interest rate for each month, Shanghai Composite Index. For related company, the data requires their monthly and yearly balance sheet and income statement, and their total market capitalization during the accounting period. These are mainly from their quarterly and yearly financial reports.

For such a long time period, there will be some data lost during the years. To make the resource more reliable, we should choose the company with complete information reported annually. The main tools to formalize the data is R and Python.

In Chinese market, the financial year normally has the same start and end date with natural year. But the company usually post their report quarterly and annually, this implies the lack of monthly information. Hence in this paper we set each period in 3 months to make sure that the demanded accounting information could be obtained before the next portfolio is constructed.

Figure 1 shows the coverage of our sample size compared with total number of normal traded stocks paid in RMB among Shanghai Stock Exchange. Frankly, our sample covers at least 90% of the market. This graph enhances the comparability of the mimicking portfolios in our following steps.

For the details to construct the factors, this paper mainly uses the approach provided in Fama and French(1993,2015a).

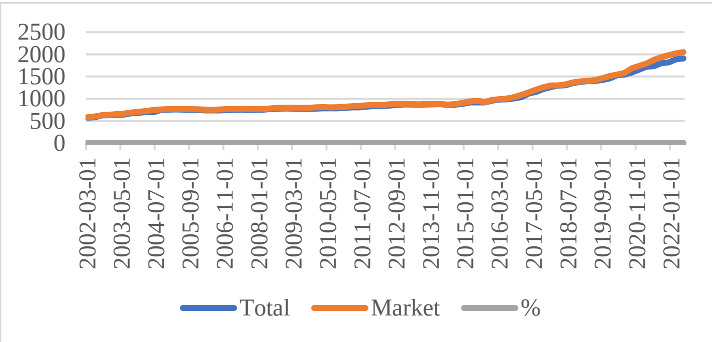

Figure 1. Coverage

2.2 Method

2.2.1 CAPM

Capital Asset Price Model (CAPM) is proposed by Treynor, Sharpe, Lintner, and Mossin. Using simple mathematical calculations, the methodology that is based on Markowitz's Modern Asset Allocation Theory (MPT) expands the connection between systemic risk, risk coefficient, and asset return. Although, the CAPM theory is frequently incompatible with experimental results and impractical., it has always been a crucial theory in financial economics, serving as a foundation for more complex models.

$$E[R_i] = R_f + \beta_i(E[R_m] - R_f) \tag{1}$$

Where, $E[R_i]$ is expected return of investment; R_f is risk-free interest rate; β_i is β coefficient; $E[R_m]$ denotes the expected market return for market m; $E[R_m] - R_f$ represents market risk premium.

2.2.2 Fama-French model

(a) Three factors

In 1992, Fama and French proposed some factors that could be the reason why different stocks perform on the US stock market differ from one another. The study mainly discussed the influence of size, bool-to-market ratio, and price-to-earnings ratio of listed companies. These factors can explain the variance in stock returns, as opposed to the beta value of the market.[10] According to Fama and French, the excess returns mentioned above serve as compensation for risk factors that the CAPM does not take into account.

$$R_{it} - R_{Ft} = a_i + b_i(R_{Mt} - R_{Ft}) + s_i SMB_t + h_i HML_t + e_{it} \tag{2}$$

Where, R_{it} is return on portfolio *i* for period t; R_{Ft} denotes risk-free return; R_{Mt} is return on the portfolio; e_{it} is zero mean residual; $R_{Mt} - R_{Ft}; SMB_t; HML_t$ here are the factors mentioned in the Fama and French(1993) [6]. $R_{Mt} - R_{Ft}$ here is known as MKT. It represents the expected return of generated portfolio. SMB_t is defined as the return on a diversified portfolio of large stocks less the income from a diversified portfolio of small stocks. HML_t measures the variance in income from the portfolios of high B/M and low B/M stocks.

(b) Five factors

After years of applying and proving on the model, Fama-French 3 factors model are proven as incomplete model for expected returns. Hence, the profitability and investment factors are introduced to the model from Fama and French (2015).[11] The equation given as:

$$R_{it} - R_{Ft} = a_i + b_i(R_{Mt} - R_{Ft}) + s_i SMB_t + h_i HML_t + r_i RMW_t + c_i CMA_t + e_{it} \tag{3}$$

In addition to the three factors model, The difference between returns on portfolios built by stocks with strong and weak profitability is displayed by RMW_t. Also according to Fama and French (2015), CMA_t is the difference between the returns on conservative and aggressive portfolios that are built using low or high investment company stocks. [11]

2.3 factor construction

To apply the Fama-French 3 factors and 5 factors model, we need to find the main variables which is 'Size', 'Book-to-market', 'Operating profitability' and 'Investment'. In this paper, we use total market capitalization to show the size for each company. And we take asset growth for each company to represent the changes in investment, following Chiah et al. (2016).[5] It is defined as:

$$AG_t = \frac{TA_t}{TA_{t-1}} - 1 \tag{4}$$

TA_t means the total assets in quarter t and TA_{t-1} is the total assets in the quarter $t-1$. And to find the changes in profitability, ROE for each quarter which is defined as:

$$ROE_t = \frac{Net\,profit_t}{SHEQ_t} \tag{5}$$

Where $SHEQ$ is total shareholder^' s equity in quarter t. And it is promoted by Hou et al.(2015a,2015b) [13].

(i) Size

It is known to us all that size is highly related to the profitability. In this paper we use market capitalization to represent company's size. Following Fama and French (1993), the size is calculated as price times shares.[6] In quarter t from 2002 to 2022, all stocks in our sample are sorted on size, then we use medium number to split codes into small and big groups (S and B). From the result, the small and big groups have small difference on stock quantities, the difference varies from 0.11% to 6.33%

Book-to-Market. The ratio of book common equity to market equity for the same financial period is known as book-to-market equity. The company with negative book common equity is disregarded when determining breakpoints for the Low (bottom 30 percent), Medium (middle 40 percent), and High (top 30 percent).

As a way to construct the mimicking portfolios, we find the company in the intersection of different groups. Company with small size and low book-to-market equity are allocated into SL portfolio. Company with small size and medium BE/ME are named as SM group. Follow the same logic, our stocks are divided into six portfolio which are SL, SM, SH, BL, BM, BH. the next step is to compute their quarterly value weighted return (from quarter T to T+1) and the portfolios are constructed into quarter T+1. To ensure the timeliness of the information, company without opening, closing price or equity information must be excluded in the portfolios.

Operating Profitability. To compute a company's ROE, we use the net-profit before the tax divided by total shareholder's equity. After that we use the same method to break the stocks into 3 groups, Robust, Neutral, Weak, and construct six portfolios from the intersection between these 3 groups and Small-Big groups. These portfolios are named as SW, SN, SR, BW, BN, BR.

Investment. Follow the same steps as above, stocks are separated into 3 groups, Conservative, Neutral and Aggressive. Therefore 6 portfolios could be built as SC, SN, SA, BC, BN, BA.

Follow these ways to construct the factors:

Table 1. factors

Name	Method
SMB_t	$SMB_{B/M} = \frac{(SH+SM+SL)}{3} - \frac{(BL+BM+BL)}{3}$ $SMB_{OP} = \frac{(SR+SN+SW)}{3} - \frac{(BR+BN+BW)}{3}$ $SMB_{INV} = \frac{(SC+SN+SA)}{3} - \frac{(BC+BN+BA)}{3}$ $SMB_t = \frac{(SMB_{B/M}+SMB_{OP}+SMB_{INV})}{3}$
HML_t	$HML_t = \frac{(SH+BH)}{2} - \frac{(SL+BL)}{2}$
RMW_t	$RMW_t = \frac{(SR+BR)}{2} - \frac{(SW+BW)}{2}$
CMA_t	$CMA_t = \frac{(SC+BC)}{2} - \frac{(SA+BA)}{2}$

By applying each equation to portfolios, getting SMB, HML, RMW, CMA factors for each quarter (as shown in table 1).

From table 2, among the factors we obtained, all MKT is smaller than 0, and others contains positive and negative numbers. Meanwhile, MKT shows the greatest standard deviation and data for CMA have the least difference. And the figure 2 here provides the correlations among each factor. The HML share the positive relationship with SMB and MKT. RMW and CMA also have the positive correlation. For the rest of them, negative correlation appears. From the graph 1, we can see that RMW has a medium correlation with SMB. Same situation appears on CMA-SMB and CMA-HML. But the correlations remain in an acceptable range.

Table 2. Mean and Sd

	MKT	SMB	HML	RMW	CMA
Mean	-0.1822	-0.0164	-0.0189	0.0079	0.0026
Sd	0.1065	0.0372	0.0461	0.0322	0.0215

Table 3. Average excess return (in percentage)

	Book-to-market			Operating Profitability			Investment		
Small	-1.00%	-1.78%	-2.06%	-1.34%	-1.83%	-1.54%	-1.36%	-1.83%	-1.64%
Big	-0.50%	-0.50%	-1.10%	-0.78%	-0.52%	1.01%	-0.12%	0.08%	0.67%

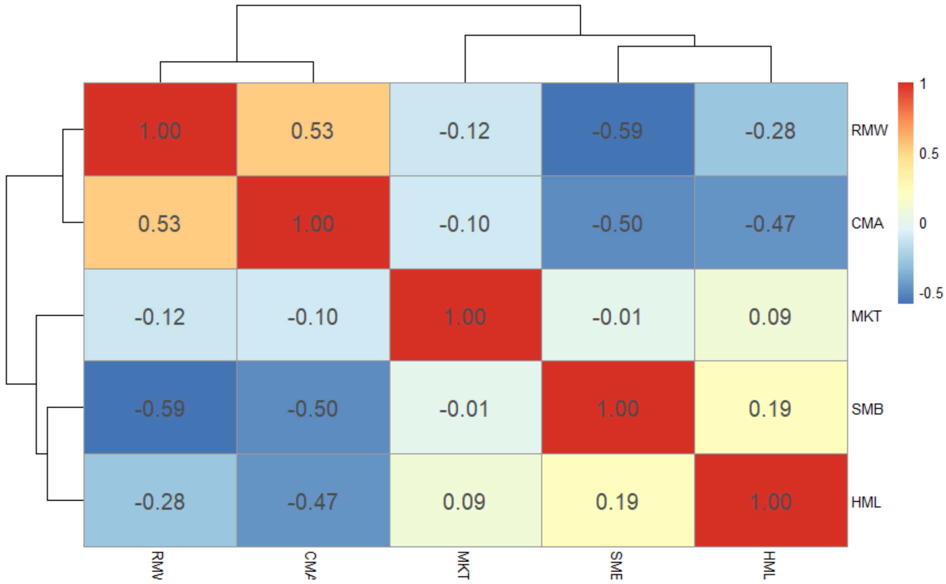

Figure 2. Correlation heat map

From Table 3, the lowest average return appears in the portfolio which is small-size and neutral-investment. The highest average return comes with features as large size and small BM. The larger the market cap stocks in the portfolio, the lower the average monthly return. This rule also appeared in the research from Fama – French (2015a). The average yield of stocks in the low BM group is higher than the average yield of stocks in the high BM group. In table above, the average return on stocks increases substantially from top to bottom as size increases.

3. Empirical Results

In this paper we mainly compare the efficiency of CAPM, Fama-French 3 factors model and Fama-French 5 factors model on our portfolios. By examining the size of the intercept term, it is possible to determine the interpretation of the five-factor model for excess returns. By comparing the beta for each factor, the degree and sign of the influence on the return of the stock portfolio are obtained. The sign of the regression coefficient ahead of the factor is used to indicate the relationship between the corresponding generated portfolios and the factor. It is also a way to examine the contribution of each factor on the portfolios.

Apart from all these, we observe the adjusted R^2 as a way to evaluate the success of the regression.

Here we take size/BM portfolios for instance. Results given in table 4. From all portfolios, F statistics given are all significant at 1% level, this implies that all models here basically explained the excess return for each portfolio. Among all the regressions, the greatest adjusted R^2 belongs to SL portfolio under five-factor model which is 0.9272. It shows that for SL portfolio, Fama-French Five Factors model is basically able to illustrate the return for each quarter in this portfolio. And the smallest adjusted R^2 shows in SL portfolio under CAPM which is 0.6814. Although it is not a much convincing grade compared with the largest adjusted R^2, 0.6814 is still acceptable for a number to reflect the fitting degree. In general, adjusted R^2 number from five-factor model is larger than other two models, and the range of it is from 0.8938 to 0.9272.

For 3 factors model, the adjusted R^2 varies from 0.8896 to 0.9245. And the smallest number for CAPM is 0.6814 while the largest is 0.8792. By these number, we can briefly conclude that Fama-French three factors model and Fama-French five factors model outperform the CAPM on the sample. But to decide which one is the best, this paper choose to use step regression along with AIC. The details will be given in the next part.

Table 4. Size/BM Portfolios

	SL	SL	SL	SM	SM	SM	SH	SH	SH
MKT	0.9570**	1.0022**	0.9935**	1.0011**	1.0172**	1.0121**	1.0039**	0.9986**	0.9928**
	(0.0725)	(0.0356)	(0.0352)	(0.0672)	(0.0405)	(0.0409)	(0.0610)	(0.0394)	(0.0397)
SMB		1.4463**	1.3473**		1.3990**	1.3251**		1.2116**	1.1321**
		(0.1027)	(0.1142)		(0.1167)	(0.1326)		(0.1136)	(0.1287)
HML		-	-		-	-		-0.0027	-0.0431
		(0.0836)	(0.0889)		(0.0950)	(0.1032)		(0.0924)	(0.1002)
RMW			-0.3040*			-0.1578			-0.1833
			(0.1456)			(0.1691)			(0.1641)
CMA			0.0373			-0.0888			-0.0726
			(0.2239)			(0.2600)			(0.2523)
Intercept	-0.0226	-0.0068	-0.0085	-0.0223	-0.0035	-0.0049	-0.0247	-0.0058	-0.0073
	(0.0153)	(0.0076)	(-0.0076)	(0.0141)	(0.0086)	(0.0088)	(0.0129)	(0.0084)	(0.0085)
Observation	82	82	82	82	82	82	82	82	82
Adjusted	0.6814	0.9245	0.9272	0.7315	0.9045	0.9039	0.7693	0.9055	0.9054

Note: Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Among these regressions, the beta value of the market factor (MKT) is basically around 1, which indicates that the MKT, also known as $R_{Mt} - R_{Ft}$ in equations [2-3], is the most significant factor for regression of the return, that is, the excess return changes closely with the movement of market factor.

The coefficient of the market capitalization factor (SMB) is decreasing among small size portfolios, and both of them are relatively large positive value, all exceeding 1. And the coefficient of the large size portfolio is a small negative value. Comparing the factor coefficients for small-cap stocks, only the coefficient of the market cap factor SMB is larger, indicating that the earnings of small-cap stocks are mainly explained by this factor.

Table 4. Size/BM Portfolios (continued)

	BL	BL	BL	BM	BM	BM	BH	BH	BH
MKT	0.9346***	0.9876***	0.9869***	1.0183***	1.0424***	1.0393***	1.0092***	0.9912***	0.9876***
	(0.0572)	(0.0397)	(0.0405)	(0.0477)	(0.0390)	(0.0395)	(0.0415)	(0.0347)	(0.0352)
SMB		0.2331*	0.2225'		0.5997***	0.5436***		0.4677***	0.437654***
		(0.1145)	(0.1313)		(0.1124)	(0.1281)		-0.1001	(0.1141)
HML		-0.8894***	-0.8952***		-0.4400***	-0.4751***		0.2628**	0.2560**
		(0.0931)	(0.1022)		(0.0914)	(0.0997)		(0.0815)	(0.0888)
RMW			-0.0214			-0.0730			-0.1420
			(0.1675)			(0.1634)			(0.1456)
CMA			-0.0147			-0.14633			0.0951
			(0.257456)			(0.2512)			(0.2238)
Intercept	-0.0004	-0.0037	-0.0039	-0.0065	-0.0006	-0.0018	-0.0141	-0.0047	-0.0051
	(0.0121)	(0.0085)	(0.0087)	(0.0100)	(0.0083)	(0.0085)	(0.0088)	(0.0074)	(0.0076)
Observations	82	82	82	82	82	82	82	82	82
Adjusted R^2	0.7665	0.8896	0.8868	0.8490	0.9010	0.8996	0.8792	0.9171	0.9160

When the capitalization of the portfolios is in the same degree, the coefficient of the valuation factor HML rises along with the increase of Book-to-Market ratio. All the HML factors have negative coefficient in small size groups. And the highest BM portfolio has the positive HML factor which implies the valuation factor the contribute the positive influence on the return. And follow this trend, HML may have a better performance in portfolios constructed by larger size stocks.

Profit factor RMW from the table has not performed an obvious linear relationship, but one thing to be noticed is that large-size portfolios tend to have larger coefficient of RMW compared with smaller size portfolios. But they all negative and both in small number compared with other factors. This indicate that RMW might be less forcefully interpreted in the model.

For the investment factor CMA, there is not much the regression coefficient is not significantly monotonicity. But both SL and BH portfolios has a positive coefficient on CMA factor.

On other portfolios, Size/OP and Size/INV groups follows quite similar logic among these factors.

4. Discussion

From the table 4 we can see that both 3 factors model and 5 factors model have a high R^2 number which implies they can simulate the trend and explain the excess return in a decent way. And the residual standard error for each model in each regression just have a slightly difference. Follow the logic in Fama and French (2015), 5 factors model with more details in the function and more diverse aspects to explain the excess return presumably have a better performance than 3 factors model. However, from the table 4 we may find that 3 factors model is slightly outperform 5 factors, just in adjusted R^2 number.

By using the step regression function in R, we have factors that makes the significant contribution in the regression for each portfolio in size/BM group.

Table 5. Most related factors for portfolios

	SL	SM	SH	BL	BM	BH
MKT	o	o	o	o	o	o
SMB	o	o	o	o	o	o
HML	o	o		o	o	o
RMW	o					
CMA						

Table 5 shows the most related factors among 5 factors for each portfolio, it is obvious that CMA is the least related. In another way of speaking, CMA might not be a good choice in the model to analyze the sample.

In previous analyses, we knew that there may be multicollinearity problems between factors, so we performed a multicollinearity test.

Table 6. Multicollinearity

		Intercept	MKT	SMB	HML	RMW	CMA	R^2
MKT	coefficient	-0.18		-0.17	0.27	-0.44	0.07	-0.02
	t-value	-12.74		-0.47	0.93	-0.93	0.09	
SMB	coefficient	-0.02	-0.02		-0.02	-0.36	-0.45	0.20
	t-value	-2.14	-0.47		-0.20	-2.59	-2.06	
HML	coefficient	-0.01	0.04	-0.03		-0.15	-0.77	0.15
	t-value	-0.89	0.93	-0.20		-0.81	-2.80	
RMW	coefficient	0.00	-0.03	-0.22	-0.06		0.62	0.35
	t-value	-0.51	-0.93	-2.59	-0.81		3.86	
CMA	coefficient	0.00	0.01	-0.12	-0.12	0.26		0.38
	t-value	-0.88	0.09	-2.06	-2.80	3.86		

From the table 6 and correlation obtained from figure 1, it implies that there is a clear collinearity relationship between CMA factor and other factors. This implies that CMA might not be that suitable for Shanghai Stock Exchange market. If no extra factors added into our model, 3 factors will be a better solution for our sample.

For further analyze, figure 3 below gives the Residuals vs Fitted graph, Normal Q-Q plot, Scale-Location plot and Residuals vs Leverage graph.

The red line in Residuals vs Fitted graph represents an approximation of relationship for variable. From the graph we could be able to draw a conclusion that there is a linear relationship between our residuals and fitted values. And from the Normal Q-Q plot we can see that the most of points located on the line, though it is not a 45-degree line, it can be concluded that there is linear relationship. The Scale-Location graph is to check if the residuals are spread equally along the range of predictors. The table below is still acceptable since there is only a slightly curve appears on the red line. From the Residuals vs Leverage, only one point is out of Cook's distance, and this should be excluded.

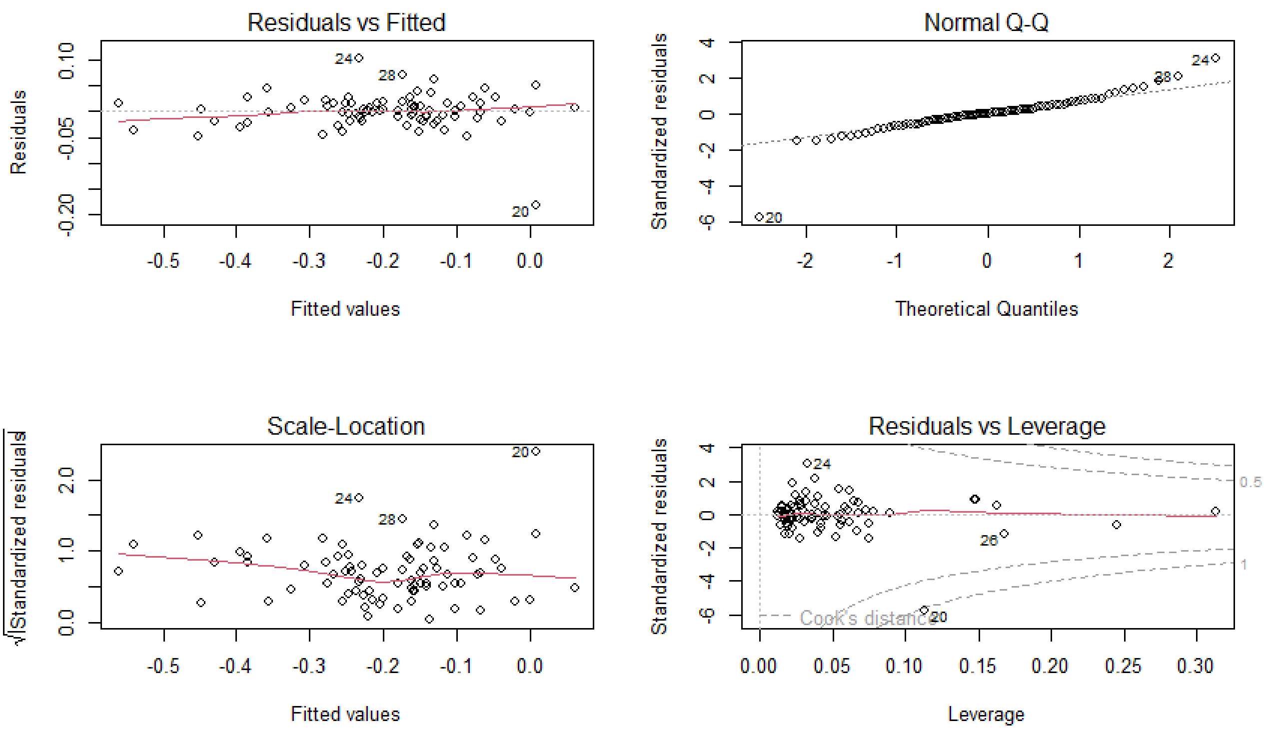

Figure 3. Combination of 4 graphs

5. Conclusion

The Fama-French three factors model outperforms the other two in the Shanghai Stock Exchange market, but the five factors model is also effective. Compared with these two models, CAPM seems less persuasive. Among the factors, CMA factor has collinearity with others, which weakens the fit of the five factors model, but the performance of RMW in the regression is acceptable. All portfolios' return changes with the market factor MKT, which is the most significant factor to stock returns. Apart from MKT, SMB is the second significant factors. The effect of SMB, the market value factor of A-share market, is obvious, and the return of portfolio generated by small cap stocks is significantly higher than that of portfolios generated by large cap stocks. And HML might play a more significant role in large cap stocks.

In summary, for the sample this paper analyze, 3 factors model is a better way to explain the excess return. The five factors model is a great progress, but it is still not perfect for this market. RMW and CMA need to be adjusted for Chinese market.

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