Effectiveness test and improvement of CAPM model in Chinese stock market

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Abstract. With the increasing openness of capital market and supervision of stock market, plenty of scholars have made new explorations on the effectiveness of CAPM in Chinese stock market. On this basis, the way to improve the model according to the characteristics of the market is necessary to be further evaluated. Based on the analysis, this paper finds that CAPM and its related three-factor and five-factor models are not very suitable for Chinese stock market. However, CAPM series models are more suitable for the development of more mature Hong Kong stock market. The CAPM model can be improved by replacing redundant factors and adding new effective factors according to market characteristics to make it more suitable for selecting market. These results shed light on guiding further investigations to make appropriate improvements to CAPM series models.

Keywords: CAPM model; stock market; Fama-French three factor model; Fama-French five-factor model.

1. Introduction

Capital Asset Pricing Model (CAPM) uses a linear expression to connect the expected return and expected risk of assets, which is widely used in security valuation, which is proposed by Sharp and Lintner on the basis of portfolio selection theory and put forward by Markowitz [1-3]. Since Markowitz's theory does not work well in practice, scholars make effort to dig more suitable pricing scenarios and put forward CAPM. Treynor proposed CAPM based on the famous MM theorem [4, 5]. In 1972, Fischer Black proposed the zero-beta CAPM based on original model [6]. Afterwards, Fama and French proposed the three-factor and five-factor models to explain the return ratios of underling assets on account of the effective factors [7, 8]. Based on the original asset pricing model, lots of new forms of CAPM have been developed based on the original asset pricing model such as Arbitrage Pricing Theory (based on Factor Model), Intemporal Capital Asset Pricing Model (extend the traditional CAPM model to a dynamic environment) Consumption Capital Asset Pricing Model etc. [9-11].

Contemporarily, there are still many researches on CAPM model, including model improvements combined with machine learning, e.g., improved model based on machine learning. Considering the downside risk, the six-factor model is proposed [12]. Scholars have also explored the applicable industries of CAPM, indicating that CAPM is not applicable in some areas in China, e.g., cryptocurrency market, science and technology innovation board market and semiconductor industry. Scholars have also investigated the effectiveness of CAPM in the context of COVID-19, the impact of investor sentiment on CAPM model and the comparison with three factor model and five factor model. There are many differences between China's stock market and the developed western stock market, hence the effectiveness of CAPM in China's stock market are evaluated. At the same time, the shortcomings of CAPM are found and the improvements suggestions are put forward according to the current market situation. Since the practical results of CAPM were not ideal, Fama-French Three-factor Models and Fama-French five-factor Models were proposed to improve it.

Therefore, this paper will review the research on the effectiveness test and some improvement of CAPM in Chinese stock market since 2018. The rest part of the paper is organized as follows. The Sec. II will provide a brief introduction to CAPM including formula interpretation. The Sec. III will summary the state-of-art researches about CAPM validity test. The Sec. IV will discuss the empirical analysis in terms of Fama-French three factor model. The Sec. V will introduce an improvement

method of the Fama-French five-factor model of replacement redundancy factor. The Sec. VI will demonstrate the comparison between Fama-French three-factors models, Fama-French three-factors models and CAPM. Eventually, the Sec. VII gives the conclusion.

2. CAPM Models

Generally, the CAPM model can be mathematically described as follows:

$$E(R_a) - R_f = \beta\left[E(R_m) - R_f\right] \tag{1}$$

Here, $E(R_a)$ represents the expected return on asset a. $R_f$means risk-free rate of return and it is usually approximated by the interest rate on the rate of short-term Treasury bills. The $E(R_m)$ is the expected return on market portfolio m and $E(R_m) - R_f$ refers to market risk premium. Market risk premium means the difference between the expected rate of return and the risk-free rate of return of a market portfolio. β is the systemic risk coefficient for asset a. The formular for β is

$$\beta = \frac{Cov(R_a, R_m)}{Var(R_m)} \tag{2}$$

In practice, one can obtain R_a, R_f, and R_m. Nevertheless, the value of β can only be estimated by some quantitative method.

Table I. Partial stock regression data.

Code	β	R^2	P-value	Code	β	R^2	P-value	Code	β	R^2	P-value	Code	β	R^2	P-value
600000	1.682	0.859	0	600149	1.304	0.309	0.061	600077	1.598	0.668	0.001	600208	1.426	0.612	0.003
600004	0.814	0.853	0	600155	9.13	0.246	0.101	600082	1.43	0.708	0.001	600213	1.721	0.569	0.005
600006	1.195	0.786	0	600159	1.014	0.817	0	600086	1.429	0.547	0.006	600238	1.584	0.663	0.001
600010	0.802	0.341	0.046	600163	1.314	0.251	0.097	600095	1.228	0.753	0	600246	1.357	0.899	0
600015	1.286	0.773	0	600170	1.067	0.311	0.06	600104	0.404	0.025	0.62	600599	1.479	0.734	0
600038	1.477	0.474	0.013	600175	0.594	0.404	0.026	600106	0.737	0.587	0.004	600605	1.468	0.727	0
600052	1.551	0.789	0	600177	1.223	0.777	0	600108	1.196	0.787	0	600613	1.715	0.491	0.011
600037	1.603	0.69	0.001	600184	1.428	0.482	0.012	600112	1.133	0.598	0.003	600618	1.45	0.76	0
600059	0.949	0.348	0.044	600190	0.027	0.001	0.926	600118	1.689	0.778	0	600620	1.176	0.307	0.061
600062	1.12	0.465	0.015	600196	0.914	0.586	0.004	600122	1.063	0.866	0	600628	1.043	0.894	0
600069	1.084	0.703	0.001	600197	1.643	0.776	0	600127	1.497	0.113	0.286	600637	0.131	0.008	0.785
600070	1.331	0.541	0.006	600202	1.602	0.469	0.014	6000129	1.11	0.321	0.055	600641	1.275	0.94	0

3. CAPM validity test of stock market

In order to study whether the classical CAPM model is effective for Chinese stock market, fifty stocks were selected for testing by regression from Shanghai A-share market [13]. To ensure the validity of experimental data, the stocks are chosen in various industries and introduced their monthly frequency data from September 2014 to September 2019 into the CAPM model. This observation can be directly used to represent the average level of the stock market due to the long period of monthly frequency data.

According to the return rate of each stock and the return rate of Shanghai Composite index, the regression equation is obtained by the least square method, and the significance of regression parameters are verified based on T test and heteroscedasticity test. Finally, by analyzing and comparing the determination coefficients of 50 stocks. Forty-five of chosen stocks had a deterministic coefficient of less than 0.5. According to the results, non-system risk accounts for a large proportion in China's stock market. It shows that China's stock market is still in a weak market state, which does not meet the premise of CAPM, and CAPM is not applicable to China's stock market. Meanwhile, different samples have different results, denoting that CAPM is not universally applicable in the Chinese market. Based on this research, four following suggestions and three prospects are provided. As for suggestions: (1) the government reduce administrative intervention; (2) strengthen supervision, prevent financial fraud (3) improve the stock market related laws and regulations; (4) cultivate institutional investors, increase professional talents, avoid the majority of individual investors random investment. Moreover, prospects are as follows: (1) one of the important reasons why CAPM is not applicable to the Chinese market is that the immature stock market is difficult to meet the premise assumptions of the model. (2) to improve the estimation method of β to improve the validity of the model. (3) the sample selection to verify the validity of the model needs to be more scientific and reasonable.

Deng selects 51 stocks from various industries in Shanghai Stock Exchange (from 600000-600645) to make linear regression on the monthly return rate of stocks and acquire the values of α and β based on the similar method mentioned above [14]. The results are summarized in Table I., where β reflects the systemic risk level of each stock, and R^2 is generally greater than 0.5, which indicates that the market's monthly expected return rate has a strong explanatory power on monthly return rate. P-value is generally small, indicating that most stocks are significant. As shown in Figure 1., systemic risk and stock market return rate are weakly linear correlation. It can be seen that the CAPM model is not particularly suitable for China’s stock market compared with the mature western stock market. According to the study, the author thinks that China promotes the development of China's stock market and put forward three Suggestions are given as follows: (1) Minimize the interference of the government for the stock market; (2) Perfect the information disclosure system, prevent the information was used to intervene in the stock market; (3) Cultivating institutional investors.

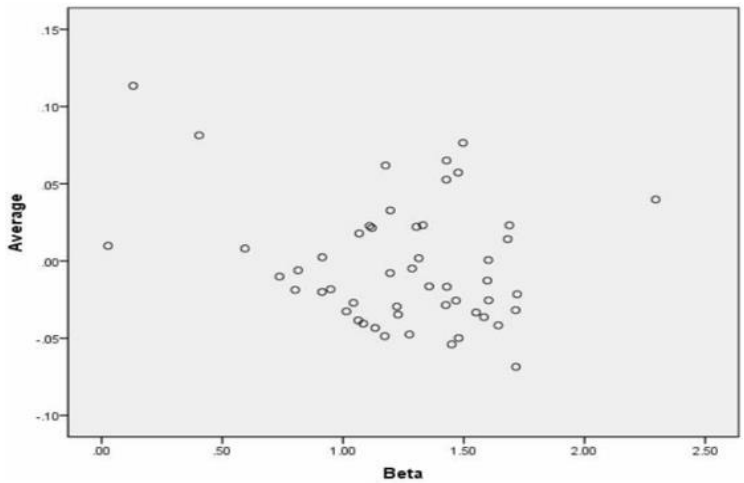

Figure 1. Risk and Return chart[14].

CAPM model has a simple form and strong practicability, it has some defects and limitations. So far, no model can replace CAPM and be widely used in the financial field. However, CAPM still has limitations, mainly reflected in the following three aspects: (1) assumptions are difficult to achieve; (2) the β value cannot be determined and can only be estimated; (3) expected returns are only related to systemic risk without considering other factors.

Some scholars are interested in the effectiveness of CAPM series models. Han et al. analyzed and compared the data from 2006 to 2018 of 29 industries in Shanghai and Shenzhen stock markets (represented by MC) and 4 industries in Hong Kong stock markets (represented by HKC), and used consumption and production data to predict ROA to test the forecasting effectiveness of different models in various markets and industries [15]. This series of models includes CCAPM, HCCAPM, HCCAPM and PCAPM, and habit factors are added for comparison. The R-square (regression goodness of fit) is adopted to represent the analytical ability of the model, in which the explanatory power of Shanghai and Shenzhen PCAPM was weak (0.027), and the explanatory power of HCCAPM with Habit was the strongest (0.097). For Hong Kong market, R-Square is generally larger than that of Shanghai and Shenzhen markets, indicating that CAPM series models have relatively high explanatory power for Hong Kong financial market. Besides, the prediction ability of the deviation value model is also analyzed. For Shanghai and Shenzhen markets, HCCAPM with Habit model has the strongest prediction ability (0.316). The deviation value of Hong Kong stock market is generally small, indicating less systemic risk. As can be seen from the Fig. 2, the slope of CAPM and PCAPM in the Chinese mainland market is contrary to expectations, while the slope performance of all models in the Hong Kong stock market is in line with expectations. On the whole, CAPM series models are more suitable for stable and mature Hong Kong stock market.

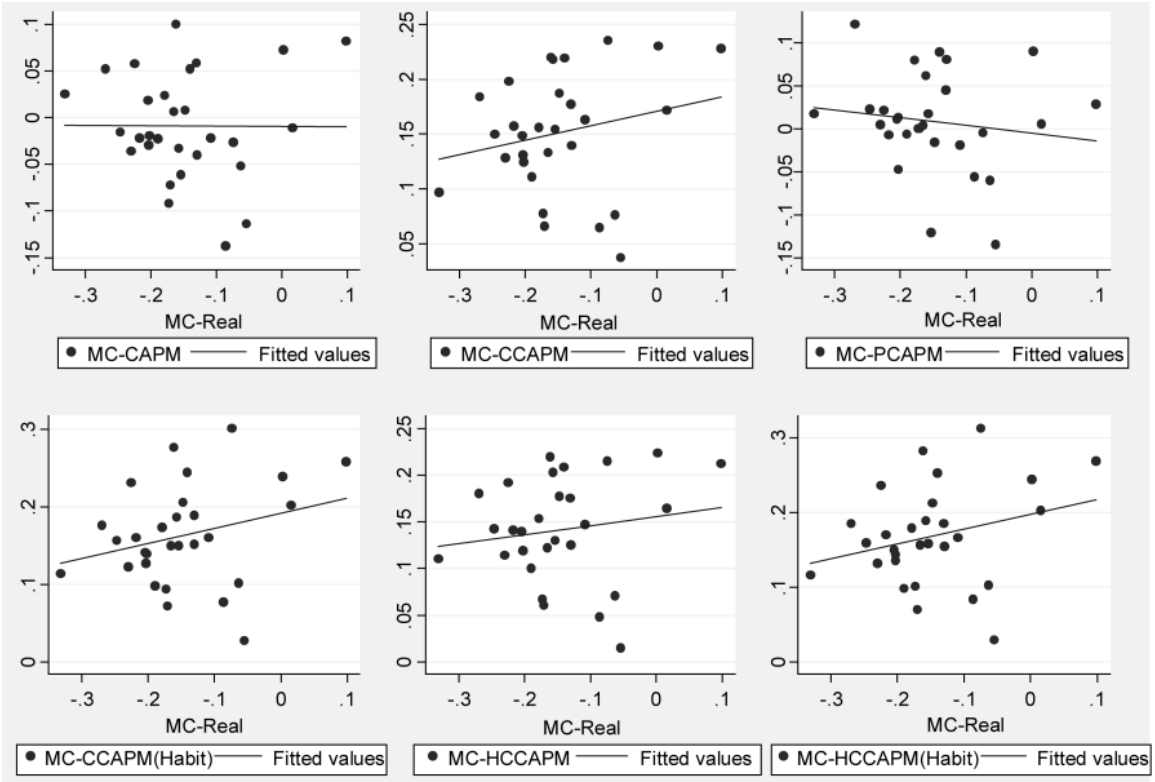

Figure 2. Comparison of the display value and forecast value of each model in Shanghai and Shenzhen stock markets [15].

4. Fama-French three-factor model

In order to improve accuracy of CAPM series model, Fama-French three-factor model is proposed, which can be mathematically descried as:

$$E(R_{it}) - R_{ft} = \beta_i\left[E\left(R_{mt} - R_{ft}\right)\right] + siE(SMB_t) + hiE(HMI_t) \quad (3)$$

Here, R_{ft} indicates the risk-free yield of time t. R_{mt} represents the return rate of market portfolio at time t according to weight. Rit indicates the return on the asset i at time t. $E(R_{mt}) - R_{ft}$ is the market risk premium, SMB_t is the simulated portfolio return rate of the market value factor at time t, and HMI_t is the simulated portfolio return rate of the book-to-market factor at time t.

As for the Model in Chinese Stock market, Yang et al. carry out regression analysis of 50 stocks in Shanghai Stock Exchange by establishing time series [16]. The significance of the model was tested by the residual and F test values. The Table II. shows partial analysis results of Fama-French three-factors model. All the CAPM model F tests passed, while part of the three-factor model F tests failed. Thus, it can be concluded that CAPM has universal applicability to China's A-share market. However, some models of The Fama-French three-factor Model failed the F test. On this basis, one can guess that the Fama-French three-factor model is partially effective for China's A-share market, and more accurate answers can be obtained only by further tests for certain industries. According to the analysis, it may not be more practical than CAPM in some markets and industries though Fama-French three-factor model is an improvement on CAPM model.

Table II. Analysis results.

alpha	beta1	beta2	beta3	res_var	f_test
0.0021	0.7549	-0.0443	0.1076	0.0001	32.7376
0.0008	0.6700	-0.0351	0.0423	0.0003	8.8299
0.0018	0.5339	-0.0535	0.1061	0.0001	18.4588
0.0007	0.5214	-0.1214	-0.0562	0.0001	23.4800
0.0000	1.7935	-0.1977	-0.0849	0.0002	114.4926
-0.0041	1.0543	-0.2915	-0.2122	0.0004	17.4984
-0.0005	0.9958	-0.1451	-0.0102	0.0002	27.7621
0.0007	0.8866	0.0212	-0.0288	0.0002	20.9979
0.0023	0.7348	0.0594	0.1118	0.0001	27.8833
-0.0024	1.0688	1.0688	-0.4088	0.0005	14.3304
-0.0029	1.1002	0.7033	-0.1528	0.0015	6.2899
-0.0007	0.6597	0.1572	0.1955	0.0003	9.87
-0.0043	1.0699	-0.7175	-0.2137	0.0005	16.9223
-0.0006	0.8798	-0.0013	0.2088	0.0002	30.0269
0.0059	1.0204	1.0204	0.352	0.0011	0.0011
0.0012	1.1692	-0.2957	-0.092	0.001	8.7425
0.0018	0.9236	-0.1188	-0.0159	0.0002	27.0507
-0.0002	1.3092	-0.0847	-0.0991	0.0006	20.0399
-0.0041	1.3064	-0.0627	-0.3763	0.0005	20.6908
0.0000	1.6183	-0.3711	-0.3224	0.0006	29.6976
0.0009	1.5368	0.1905	-0.3831	0.0007	23.4937
0.0018	1.4822	0.0915	0.1153	0.1153	68.5755
-0.0012	1.2336	0.0197	0.0799	0.0004	23.8100
-0.0045	1.9839	0.2343	0.1525	0.0014	19.1957
-0.0060	1.1248	0.5458	-0.0002	0.0010	9.5977

5. Fama-French five-factor model

In order to improve effectiveness of CAPM and Fama-French three-factor model, Fama-French five-factor model is proposed, which can be mathematically descried as:

$$r_{it} - r_{ft} = \alpha_i + \beta_{im}(r_{mt} - r_{ft}) + \beta_{iv}MV_t + \beta_{ib}BPR_t + \beta_{ir}ROE_t + \beta_{it}TAGR_t + \varepsilon_{it} \quad (4)$$

Here, r_{it} represents the return rate of individual stocks or portfolio i at time t. r_{ft} represents the risk-free rate of return at time t. α_i represents the intercept. β_{im}, β_{iv}, β_{ib}, β_{ir}, β_{it} represents the coefficient of the corresponding term. MV_t represents the difference between the market value of a larger stock and the market value of a smaller stock, BPR_t represents the difference in return between stocks with a high book to value ratio and stocks with a low book to value ratio. ROE_t represents the difference in return between a stock with a high net interest rate and a stock with a low net interest rate. $TAGR_t$ represents the difference in return between stocks with high asset growth rate and stocks with low asset growth rate. ε_{it} represents independently distributed Gaussian residual.

Table III. Comparison GRS test of model before and after improvement.

All Samples		GRS	$A\|\alpha_i\|$	$\frac{A\|\alpha_i\|}{A\|r_i\|}$	Adj-R^2
25 Size-BM Combination	HML	1.449	0.143	0.568	0.920
	HML, RMW CMA	1.862	0.170	0.673	0.923
	HML RMW TO	1.801	0.158	0.627	0.927
25 Size-OP Combination	HML	1.997	0.272	0.992	0.905
	HML RMW CMA	1.523	0.132	0.530	0.922
	HML RMW TO	1.444	0.126	0.126	0.925
25 Size-Inv Combination	HML	1.524	0.144	0.144	0.917
	HML RMW CMA	1.327	0.135	0.135	0.925
	HML RMW TO	1.119	0.129	0.129	0.925
25 Size-TO Combination	HML	1.914	0.280	0.280	0.903
	HML RMW CMA	1.424	0.129	0.129	0.921
	HML PMW TO	1.506	0.128	0.128	0.926

Regarding to the model in Chinese Stock market, a research team grouped the samples according to the 2 ×3, 2 ×2 and 2 ×2 ×2 grouping methods in the factor construction method proposed by Fama and French [17]. By calculating the R^2 of the other four factors and the CMA factor before and after the share reform, the R^2 is greater than 0.5 and the intercept term is close to zero, so the CMA factor is approximately linearly correlated with the other four factors. Therefore, CMA is A redundant factor for China's A-share market. In order to eliminate the effect of linear correlation, the CMA factor is normalized into CMAO. By comparing the significant number of regression coefficients of each factor before and after the share reform, it can be concluded that the CMAO factor is not applicable to China's A-share market. Combined with the characteristics of high liquidity of Chinese stock market, the paper proposes to replace the redundancy factor CMA with turnover factor (TO). The formula of TO is as follow:

$$TO_{it} = \frac{Volume_{it}}{Outshare_{it}} \times 100\% \quad (5)$$

Where $Volume_{it}$ is the trading volume of the turnover rate of stock *i* in the year *t*, and $Outshare_{it}$ is the number of outstanding shares of stock *i* in the turnover rate in the year t. After the model was improved, GRS test was performed on the samples. The results are listed in the Table III. By comparing the GRS statistics and the value of $A|\alpha_i|$, the improved model is generally more suitable for Chinese A-share market. Although neither of the two models can well explain the average

return rate, it proves that the turnover rate has a great impact on the changes of Chinese stock market, which provides some ideas for the improvement of CAPM model in the future.

According to the validity test of the model, CAPM is more widely applicable to China's stock market. In some cases, CAPM is even more suitable for China's stock market than the improved three and five factors. With this in mind, the increased factor does not represent the characteristics of China's stock market. According to the test results, compared with CAM factor, turnover rate has a more significant impact on China's stock market. Therefore, it is necessary to construct more suitable factors for China's stock market to improve the applicability of CAPM model.

6. Conclusion

In summary, this paper discusses the validity test of CAPM correlation model in Chinese stock market and the improvement of the model according to the characteristics of the market. As for the validity test of CAPM in China's stock market, the three articles mentioned in this paper all took Shanghai Stock market as samples and conducted regression analysis on samples. Attributed to different samples, there is sometimes a linear relationship between expected return rate and risk, but it is not obvious. R^2 is also very unstable and volatile for the regression models. Compared with China's inland, financial development of Hong Kong is more mature, and CAPM is obviously more suitable for Hong Kong's stock market. These results indicate that CAPM is not widely applicable in Chinese stock market due to the immature market. According to the analysis, the main problems include the main reasons include intervention of government departments, information asymmetry and large number of retail investors. For different sample selection, the conclusions are not completely consistent, i.e., this study cannot completely draw conclusions on the predictive ability and applicability of CAPM. Nevertheless, these studies point out the defects of Chinese stock market and provide some suggestions for the future improvement of Chinese stock market. In future studies, researchers can consider appropriate path and measure to select suitable representative samples as well as obtain better performances and more accurate regression models.

Owing to the limitations of CAPM model, Fama and French proposed three-factor model and five-factor model. Different from the west, the three-factor model and the five-factor model are not very suitable for Chinese stock market, and sometimes CAPM is more suitable than the two improved models. According to the results, CMA factors are redundant and can be replaced by other constructs. It shows that the investment ratio is not the main factor affecting stock returns in China's stock market. The TO factor constructed by turnover rate in this paper is more suitable for Chinese stock market. Although factors affecting the return rate except turnover rate have not been considered, the method of constructing new factors to replace redundant factors according to the characteristics of Chinese stock market provides ideas for future model improvement. Future scholars can use similar methods to construct different factors, so that CAPM model can be better applied to China's stock market. Overall, these results offer a guideline for further improvement of financial pricing models that adapt and implements to the characteristics of Chinese stock market.

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