

Empirical Test of the Effectiveness of CAPM for Shanghai Stock Market-Based on Industry Grouping

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Abstract—This paper selects the stock data of 18 industries based on the CSRC industry classification from June 2016 to 2018 from the Shanghai Stock Exchange and conducts two tests. (1) The time series test proves that the β values of different industries show significant differences, and there are β values that are negatively correlated with the market rate of return. (2) The cross-sectional data test proves that the CAPM is far from effective for Shanghai Stock Market.

Keywords—CAPM; β coefficient; time series test; section data test

I. INTRODUCTION

The capital asset pricing model (CAPM) put forward by William Sharp describes the relationship between the expected return rate of risky assets and risk in the equilibrium state of investment market. It was further studied and perfected by American economists such as John Lintner, Jack Treanor and Jesse Morson. Since the 1970s, western scholars have done a lot of empirical research. In 1976, Rolle questioned the empirical research and it was because of Rolle's criticism that the test changed from the simple test of the relationship between returns and systemic risk to the multivariate test, and became the mainstream of the recent test. Since the 1980s, some studies have questioned and challenged not only the model itself, such as the famous three-factor β model, but also the whole system of mainstream finance, such as behavioral finance. At present, the test of β validity and the influencing factors of asset return is still one of the academic focuses in the theoretical and application fields.

CAPM is a kind of financial asset pricing model that can be tested by measurement. The model explains the internal structure of security returns and analyzes the relationship between the expected return of capital assets and market risk. The CAPM describes the formation of market equilibrium when investors adopt Markowitz's theory for investment management, and considers that there is a positive correlation between the expected return rate of an asset and the β

coefficient, which is a yardstick to measure the risk of the asset. This not only greatly simplifies the operation process of portfolio selection, but also makes the securities theory turn from qualitative analysis to quantitative analysis, from normative to empirical, and then carries out theoretical research and practical operation on securities investment. Moreover, in China, the application areas of CAPM will become more and more extensive along with the development of the stock market. In recent ten years, some scholars have done some research on the applicability of CAPM in our country's stock market. However, with the development of China's stock market, especially the gradual increase of institutional investors, and with the improvement of financial supervision, China's stock market has gradually become mature. Therefore, the above conclusions can not reflect the latest development trend of China's stock market. Based on the data in recent years, in this paper we perform empirical tests and hopes to get new conclusions.

II. LITERATURE REVIEW

A. Research on the Efficiency of CAPM in Stock Market

Since the introduction of CAPM model, foreign scholars have done a lot of empirical tests on whether the CAPM model is effective in the real market. The earliest test of the CAPM model was Sharpe (1964), one of the proponents of the model. He selected data from 34 US mutual funds from 1954 to 1963 as samples, and used these data to calculate their annual average rate of return and yield. The standard deviations and regression analysis were carried out. The regression results show that there is a similar linear relationship between the average returns of these mutual funds and the β coefficient[1]. Black, Scholes and Jensen (1972) selected empirical data from stocks of all listed companies on the New York Stock Exchange between 1926 and 1966. The results showed that there is a positive linear relationship between the stock's return rate and the beta coefficient, and this linear relationship is significant[2]. Reinganum (1981) selected the stock's daily rate

of return as the sample data to empirically analyze the model. The result shows that the relationship between stock return and beta coefficient is reversed, so he questioned the validity of the CAPM model[3]. Basu's empirical results on CAPM model also found that the β coefficient if did not explain the relationship between stock returns and risk, while the price-earnings ratio could explain it well[4].

The domestic empirical study of the CAPM model began in the 1990s. The first scholars to empirically test the CAPM model were Yang Chaojun and Xing Jing (1998). The sample data they selected came from the Shanghai stock market, and the results showed that there were no relationship between the return rate of stocks and system risk, and there were other influencing factors in this market[5]. Later, Jin Yunhui (2001) also verified that the CAPM model was not suitable for the Chinese stock market and stock return rate was not only related to factors other than Beta, but also the relationship with Beta was not linear[6]. Zou Zhou(2013) found that the CAPM model was not suitable for China's stock market. There was not only a positive correlation between stock expected return and system risk, and there was no linear relationship, except for system risk. System risk also played a role in explaining stock returns[7].

B. Research on Multi-factor Risk of China's Stock Market

Yang Chaojun(2001) used the cross-sectional method to analyze the factors of capital stock pricing in Shanghai stock market. The results showed that the coefficient measurement method had an impact on the test results and the system risk in Shanghai stock market was not the only factor affecting the yield[8]. Xiao Junxi(2004) constructed a portfolio based on the market equity and book value ratio, and conducted a regression analysis using a two-step method. The empirical results showed that the traditional model cross-section regression had limited interpretation ability of Beta, and could only explain the cross-sectional change of excess expected return rate at most. And the cross-sectional regression of factor model showed that after adding two factors, Beta almost loses its explanatory ability and was absorbed. Compared with the Cross-sectional variation of excess expected return rate explained by cross-section regression, Fama-french's three-factor model cross-section regression interpretation ability has been greatly improved, reaching 65.6%[9]. Ma Jingru (2001) used the Shenzhen stock market data to test the market, and concluded that the model did not meet the conclusions of China's Shenzhen stock market. At the same time, it is found that the Shenzhen market also has the common small company effect in the developed western markets; The analysis shows that non-systematic risk has already occupied a considerable proportion in the total risk of individual stocks, and individual stock prices have divergent characteristics, which indicates that the Shenzhen market already has certain basic conditions for mature markets[10].

The above studies show that there are many factors in reality that can affect the market in addition to the β coefficient. System risk does not account for an important proportion of the rate of return. There are many other factors that have a significant impact on the rate of return.

III. CAPM AND EMPIRICAL TEST METHOD

A. Assumptions of CAPM

First, investors are defined as economic persons, that is, under the same risk level, they choose securities with higher returns while at the same level of return, they choose securities with lower risk. Second, given the number of assets in the capital market, all assets can be completely subdivided, and assets are fully liquid, marketable and decentralized. Third, the main factors affecting investment decisions are expected rate of return and risk. Fourth, all investors have the same view on the probability distribution of securities returns, so there is only one efficiency boundary in the market. Fifth, all investors can get full market information in time and free of charge. They have the same expected value for the expected rate of return, the standard deviation, and the covariance between securities. Sixth, there is no inflation, and the discount rate remains unchanged, and there is no tax and transaction costs when buying and selling securities.

B. Content of Capital Asset Pricing Model

The rate of return demanded by the investor on a single asset should be equal to the rate of return demanded by the market on a risk-free investment plus the risk premium of the asset.

$$r_a = r_f - \beta_a \times (r_m - r_f) \quad (1)$$

Here, r_f is the risk-free rate of return, β_a is the β coefficient of security a, r_m is the expected rate of return of the market.

$$\beta = \frac{\sigma_{am}}{\sigma_m} \quad (2)$$

σ_{am} represents the covariance between the return of stocks and the return of market portfolio and σ_m for the variance of the market portfolio return.

β coefficient is used to measure the degree of response of individual securities returns to the changes of market portfolio returns. Therefore, when making decisions, investors should regard β coefficient as an important measurement index. For example, when they have a good grasp of predicting the arrival of a certain stage of the market rise, they should choose those securities with high β coefficient, which will multiply the market return and bring high returns. On the contrary, when the market falls to a certain stage, choose those securities with low β coefficient to resist market risk and reduce losses.

C. CAPM Empirical Test Method

This paper uses time series test and cross section test to test CAPM. Time series uses BJS test, but build the combination in different ways, cross section test uses BJS test and FM test. Test steps are as follows:

1) *Portfolio construction*: All stocks excluded ST in Shanghai Stock Exchange are constructed according to the new industry classification of CSRC.

2) *Regression test of time series*: Regression analysis is used to estimate the β coefficient of the portfolio; the estimation equation is given in (3).

$$(R_{pt} - r_{ft}) = \alpha_p + \beta_p (R_{mt} - r_{ft}) - e_{pt} \quad (3)$$

R_{pt} is the rate of return of each portfolio at different times, R_{mt} is the return rate of the market index of time, r_{ft} is the risk-free rate of return of time, β_p is the estimated combination coefficient, e_{pt} is regressive residuals, α_p is the excess return on risk that can't be explained by β_p .

A T test is performed on the combinations α_p and β_p , as well as the regression of the R measure.

3) *Cross section regression test*: The relationship between the return rate of the portfolio and calculated by the time series test of the previous portfolio is tested.

Using the previously calculated β values of the time series test to test the relationship between the portfolio and the rate of return. The basic method are as follows:

- Select the sample interval different from the time series test to construct the investment portfolio according to the same method;
 - Obtain the average return rate of each investment portfolio;
 - Calculate the mean β value of each investment portfolio tested by the time series;
 - BSJ test
- Regression is performed according to (4).

$$\overline{R_p} = \gamma_0 + \gamma_1 \overline{\beta_p} + e_p \quad (4)$$

Among them, $\overline{R_p}$ is the average return of the portfolio, $\overline{\beta_p}$ is a portfolio, β_p is the mean of the time series test, $\gamma_0 \gamma_1$ are the estimated parameters.

- FM test

Regression is performed according to (5).

$$\overline{R_p} = \gamma_0 + \gamma_1 \overline{\beta_p} + \gamma_2 \overline{\beta_p^2} + \gamma_3 \overline{\sigma_{pe}} + e_p \quad (5)$$

Here, β_p^2 is the square of the mean of the time series test of the portfolio β_p , σ_{pe} is the standard deviation of the residual of a regression equation for estimating the β_p value.

IV. DATA PROCESSING AND PORTFOLIO BUILDING

A. Sample Selection and Data Processing

- Data Sources

The data in this paper comes from the CSMAR database, and the 1392 A-shares of were selected from the Shanghai Stock Exchange from January 2016 to December 2018 as a sample set, which is excluded of ST stock.

- Calculation of the rate of return

Calculation of individual stock return rate: This paper adopts the calculation formula of weekly individual stock return rate from January 2016 to December 2018 with cash dividend reinvestment.

$$r_{n,t} = \frac{p_{n,t}}{p_{n,t-1}} - 1 \quad (6)$$

$p_{n,t}$ is the comparable price of the closing price of stock n on the last trading day of week t, taking into account the reinvestment of the cash dividend, and $p_{n,t-1}$ is the comparable price of the closing price of a stock n on the last trading day of the t-1 week, taking into account the reinvestment of cash dividends.

Calculation of the rate of return on a portfolio: The portfolio return rate is the weekly return rate of individual stocks weighted by the circulation market value.

$$\overline{r_{n,t}} = \frac{\sum_{i=1}^m r_{n,t} \times v_i}{\sum_{i=1}^m v_i} \quad (7)$$

Here, $\overline{r_{n,t}}$ is the return rate of the portfolio in the nth week, v_i is the circulation weighted market value of a single stock in that week, and m is the number of companies in the industry.

- The determination of risk-free interest rate

The risk-free interest rate is selected according to the general standard, the risk-free interest rate is selected as the risk-free rate of return of the government bond yield with a maturity of one year, which is 0.000444.

- Calculation of market returns

This paper does not directly use the yield of Shanghai stock index as the market yield, because the weight of Shanghai stock index is close to but not exactly the same as the market, so this paper chooses the market yield weighted by the market value of circulation, which is just matched with the portfolio yield, and the data is more effective for time series test. The formula is obtained in (8).

$$R_{n,t} = \frac{\sum_{i=1}^n W_{n,t} r_{n,t}}{\sum_{i=1}^n W_{n,t}} \quad (8)$$

Here, $w_{n,t}$ represents the market capitalization of stock n at t-1 weeks, $r_{n,t}$ represents the return on individual stocks considering reinvestment of cash dividends, and $R_{n,t}$ is the weighted average market return rate of the market capitalization considering the reinvestment of cash dividends, among them:

$$w_{n,t} = v_{n,t} * p_{n,t} \quad (9)$$

$v_{n,t}$ is the Number of stock n shares outstanding in t-1 weeks, and $p_{n,t}$ is the closing price of a stock n in the week t-1.

B. Portfolio Establishment

Based on the above calculation method, according to the new industry classification of CSRC, 1392 Stocks of Shanghai Exchange is divided into different investment portfolios, excluding the stocks suspended during this period, and finally the portfolio is divided into 17 industry portfolios as follows: agriculture, forestry, animal husbandry, fishery, mining, manufacturing, electricity, heat, gas and water production and supply, construction, wholesale and retail trade, transportation, warehousing and postal services, accommodation and catering, information transmission, software and information technology services, financial services, real estate, leasing and business services, scientific research and technology services, water conservancy, environment and public facilities management, education, culture, sports and entertainment, comprehensive industry.

The results of descriptive statistics in Table I show that the investment returns of different industries in Shanghai Stock Exchange are still very different from 2016 to 2017, and there are huge differences among industries such as agriculture, forestry, animal husbandry and fishery. From the mean value, we can see that the difference between the average rate of return of each industry and the market is very obvious, which proves that capital does not effectively regulate the market.

V. AN EMPIRICAL TEST OF CAPM OF SHANGHAI STOCK MARKET

VI. Time Series Test

This paper selects the data from January 2016 to December 2018 to test the time series. We calculate β and α_p values of the time series of 16 portfolios using the CAPM model which is obtained in (10).

$$(R_{pt} - r_{ft}) = \alpha_p + \beta_p (R_{mt} - r_{ft}) - e_{pt} \quad (10)$$

TABLE I. DESCRIPTIVE STATISTICS OF INDUSTRIES

Industry	Sample Size	Mean Value	Standard Deviation	Minimum Value	Maximum Value
Agriculture, forestry, animal husbandry and fisheries	4	0.000722	0.026374	-0.06126	0.051412
Mining Industry	23	0.003806	0.018012	-0.0344	0.052303
Manufacturing Industry	253	0.006784	0.017403	-0.03192	0.060962
Production and supply of electricity, heat, gas and water	35	0.002016	0.013417	-0.03083	0.037253
Wholesale and retail trade	35	0.002016	0.013417	-0.03083	0.037253
Transport, warehousing and postal services	35	0.00209	0.020576	-0.04824	0.061206
Accommodation and catering	33	0.004522	0.01722	-0.03868	0.040946
Information transmission, software and information technology services	3	0.001006	0.029118	-0.07073	0.08858
Financial Industry	11	-0.00041	0.029432	-0.05804	0.080302
Real Estate	28	0.005555	0.018868	-0.04531	0.060318
Leasing and business services	31	0.002431	0.024308	-0.06803	0.099985
Scientific Research and Technological Services	4	0.006345	0.024428	-0.06931	0.074399
Water, environment and public facilities management	4	0.000492	0.030506	-0.07809	0.107987
Education.	7	-0.00095	0.026183	-0.05248	0.080512
Culture, sports and entertainment	2	-8.5E-05	0.017523	-0.0406	0.050689
Comprehensive industry	3	-0.00159	0.023719	-0.04853	0.084215
The whole market	516	0.003107	0.013357	-0.03414	0.02807

We excluded the construction sector from our portfolio at the end of the reporting period because of the closeness of the excluded electricity, heat, gas and water production and supply, and construction sectors. The Regression results are given in Table II.

From the results, we can see that the goodness of fit R of the portfolio of information transmission, software and information technology services, manufacturing, finance, cultural and sports industries and entertainment industries is better and close to 0.5, which proves that these industries are significantly affected by market returns. And the β values and alpha t-test are more significant, proving that these industries for the CAPM has a better explanation, such as agriculture, forestry, animal husbandry, fisheries, mining, education industry, cannot be well explained by the CAPM, and some even T test does not pass.

Generally speaking, the risk gap of each industry is large, different from the previous literature, the β value of each industry varies greatly, some even are negative, indicating that the effectiveness of the market for different industries is not the same. At the same time, we can also find that the β value of

emerging technology industries is particularly high, indicating that the market has been over-chasing technology stocks in recent years. As the sample data of the largest manufacturing population is close to 1, which shows that when the sample is sufficient, the interpretation ability of β has a certain degree of credibility.

Looking at the alpha value, the alpha value of different industries is different, but the positive and negative are generally close, which shows that the excess returns of the market will change with the different industries, but will offset on the whole. Moreover, industries with positive excess returns, such as the financial industry, have certain interests for investors. From the test results of time series, CAPM has a more effective explanation for some industries, but for the whole Shanghai stock market, the explanation is relatively lacking.

C. Cross Section Inspection

1) *BJS Test*: For the calculated time series β values, we now use the cross-section model of BJS test method to test them.

$$\bar{R}_p = \gamma_0 + \gamma_1 \bar{\beta}_p + e_p \quad (11)$$

TABLE II. REGRESSION RESULTS OF INDUSTRY PORTFOLIO

Industry	Value	T Value	Prob.	Alpha	T Value	R2
Agriculture, forestry, animal husbandry and fisheries	0.825117	3.01682	0.0035000	-0.002000000	-1.66968	0.110853
Mining Industry	0.273711	1.848407	0.0686000	0.002633000	4.060598	0.04471
Manufacturing Industry	0.91912	5.868287	0.0000000	0.003893000	5.501982	0.307115
Production and supply of electricity, heat, gas and water	0.656286	6.040102	0.0000000	-0.000176000	-0.36985	0.333229
Wholesale and retail trade	1.197401	6.279739	0.0000000	-0.001543000	-1.84802	0.350737
Transport, warehousing and postal services	0.286642	4.36809	0.0000000	0.003314000	11.53535	0.207213
Accommodation and catering	1.812172	8.029065	0.0000000	-0.004264000	-4.31463	0.468959
Information transmission, software and information technology services	2.194333	7.698753	0.0000000	-0.006699000	-5.36775	0.448102
Financial Industry	0.817368	8.513909	0.0000000	0.002934000	6.97942	0.498236
Real Estate	0.754571	5.324996	0.0000000	-0.000022100	-0.03556	0.279763
Leasing and business services	0.56717	3.554065	0.0007000	0.004390000	6.283132	0.147509
Scientific Research and Technological Services	1.382767	4.34568	0.0000000	-0.003634000	-2.60838	0.205528
Water, environment and public facilities management	1.082831	4.441701	0.0000000	-0.004278000	-4.00758	0.212757
Education.	-0.46142	-2.51117	0.0142000	0.000700000	0.869571	0.079515
Culture, sports and entertainment	1.449624	7.300627	0.0000000	-0.005896000	-6.78134	0.422007
Comprehensive industry	1.460733	7.837822	0.0000000	-0.005449000	-6.67746	0.449534

At this time, the portfolio return rate is the mean value (cross-section data) of the portfolio return rate from January 2016 to December 2018, $\bar{\beta}_p$ is the mean of the industry combination β tested in time series. The results are shown in Table III.

The section data proves that the risk-free return is positive value, but the whole coefficient is negative correlation. The section data proves that the β value of Shanghai stock is very significant in different time periods, and the γ_1 value is very small, which is not significant enough to prove that the system risk has a significant impact on Shanghai stock.

2) *FM test method*: The calculated β values are now checked by the FM test. The regression equation is as follows:

$$\bar{R}_p = \gamma_0 + \gamma_1 \bar{\beta}_p + \gamma_2 \beta_p^2 + \gamma_3 \sigma_{pe} + e_p \quad (12)$$

Where β_p^2 is the mean square of the time series test of the portfolio β_p . σ_{pe} is the standard deviation of the residual of the first regression equation for estimating the value of β_p . The results are shown in Table IV.

$\gamma_0 > 0$ indicates that the risk-free rate of return is positive. The test value is of γ_1 is -0.005341400, which shows that the regression coefficient is not significantly different from zero. Due to the result is negative, it can be seen that there is no positive correlation between systematic risk and expected return in Shanghai and Shenzhen stock markets, but a negative correlation, that is, stocks with higher systematic risk can only obtain lower expected return, and the negative effect of systematic risk on expected return is not statistically significant.

The known regression value of γ_2 is not significantly different from zero, which shows that there is a nonlinear relationship between system risk and expected return in statistical significance;

TABLE III. REGRESSION RESULTS OF BJS TEST

Coefficient	Coefficient Value	Standard Error	t	5% Check Value	R2
γ_1	-0.0022	0.002244	-0.98	0.344	0.0642
γ_0	0.002027	0.002555	0.79	0.441	

TABLE IV. REGRESSION RESULTS OF FM TEST

Coefficient	Value	Standard Error.	t	5% Check Value
γ_1	-0.005341400	0.005243	-1.02	0.328
γ_2	0.002423700	0.002738	0.89	0.393
γ_3	-0.677576400	0.91701	-0.74	0.474
γ_0	0.005655100	0.004831	1.17	0.265

The regression coefficient of γ_3 is negative, and not significantly different from zero, which shows that the return of non-systematic risk on stocks can not be determined by non-systematic risk.

VII. CONCLUSION

Based on 1392 stocks in Shanghai Stock Exchange, this paper constructs portfolio according to industry classification, and draws the following conclusions:

(1) The investment returns of stocks in different industries are quite different, and there are huge differences among industries such as agriculture, forestry, animal husbandry and fishery. From the mean value, we can see that the difference between the average rate of return of each industry and the market is very obvious, which proves that capital does not effectively regulate the market.

(2) Under the time series test, the β values of different industries show significant differences, And there is a negative β value associated with market return. Moreover, the coefficient of the tertiary industry and the emerging high-tech industry is significantly more than 1, while some old industries have a β value below 1, which is not in line with the hypothesis of effective market, and the industry rate of return does not converge to the market equilibrium rate of return. However, the performance of excess returns alpha is more uniform, which proves that the market has the ability to balance unexplained excess returns. At the same time, it also proves that some industries will enable investors to obtain excess returns. At the same time, the goodness of fit is also related to different industries, some industries can be well explained by CAPM, but some industries can not be explained by CAPM, especially in cyclical industries such as agricultural products.

(3) γ_1 is significantly not 0 under the test of BJS and FM, which proves the relationship between system risk and investment return, but it is not positive correlation but negative correlation, which violates the effectiveness of CAPM. At the same time, the FM test also proves that there is a non-linear relationship between investment return and system risk. The regression coefficient γ_3 is negative and not significantly different from zero, which shows that the return of non-systematic risk on stocks can not be determined by non-systematic risk.

To sum up, through the empirical study of Shanghai stock market in recent two years, it proves that CAPM has certain explanatory power for some industries, but for the whole Shanghai stock market, its effectiveness is far from enough.

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