Improvement of the Fama-French Five Factors Model in Terms of The US Dollar Index

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Abstract. Contemporarily, the Fama-French Five Factors (FF5) model is a well-known asset pricing model, which establishes a model with five fundamental factors of market in order to explain the return of stocks and has an excellent performance in the market. This paper attempts to improve the FF5 factors asset pricing model by introducing the macroeconomic factor of the exchange rate. Primarily, the monthly circulating market value, monthly book market value ratio, monthly profitability, and monthly total asset growth rate of all U.S. stocks are selected. The method in this paper calculates and processes it and obtains the time series of the FF5 basic factor. Afterwards, we use the monthly variation extent of the US dollar index to represent exchange rate changes to improve the model, select 22 representative stocks from U.S. stocks to test. Subsequently, the advantages and disadvantages of the new model are compared with the FF5 model. According to the analysis, the new model has enhanced the ability to interpret the yield of most stocks and greatly enhanced the ability to interpret the stocks of large international companies. These results shed light on guiding further exploration of asset pricing model.

Keywords: Fama-French Five-factor model; exchange rate factor; model improvement.

1. Introduction

Contemporarily, finding factors that determine the assets pricing and their effects remain a crucial issue for the field. This problem is undoubtedly long-lasting in finance. It is also a question that countless economists have been trying to answer all their lives. Lots of scholars proposed the famous CAMP model in 1964 [1], arguing that the proceeds of the asset depended on the risk of purchasing the asset. This concept is still the backbone of financial markets. When Fama and French studied the differences in the yields of different stocks in the U.S. market in 1992, they found that the beta coefficient of stocks in the CAMP model alone was difficult to explain the returns. Whereas, they found the some of the fundamental indicators of corporation do have some abilities to measure the differences (i.e., the market value and price-earnings ratio). On this basis, the well-known Fama-French three-factor model is established [2]. In 2018, Foye introduced two new variables, which generally performed better in financial markets than the FF3 factor model.

According to Fama and French pointed out in their 2018 paper, there are five major and effective factors affecting the company's stock yield, i.e., the risk factor represented by stock excess return, the scale factor represented by the difference in market value between companies, the book market value ratio factor represented by the difference in book market value ratio between companies, and the public [3]. The profit factor represented by the difference in yield between divisions and the investment factor represented by the difference in the growth rate of total assets between companies. However, it is difficult to explain the yields of small stocks with lower-than-average returns with high investment and low returns.

Based on the FF5 model, it is believed that the above five factors can better explain the gap between different stock yields. However, the FF5 model only focuses on the impact of micro-company financial indicators on stock yields, and ignores the impact of the macro-monetary market on stock yields. Therefore, this paper attempts to introduce the variation of the US dollar index as a new factor to optimize and improve the FF5 model. The model is judged by simple multivariate OLS

regression analysis and T-test, F-test, and other indicators. The new model is expected to perform better in the overall financial market or a specific financial field, and try to further explore the factors affecting stock yields.

2. Data & Method

2.1 FF5 model

Five-model factors are based on three-model factors. The three-factor model E(Rit)-Rf, which explains the excess return of the portfolio, is based on the risk factor represented by market excess earnings E(Rmt)-Rf, the scale factor represented by the company's market value, and the book market value ratio factor HML. Compared with the three-factor model, the five-factor model further introduces the profit factor RFM represented by the company's profitability and the investment factor CMA of the company's total assets to better explain the E(Rit)-Rf of the excess return of the portfolio. The specific five-factor formula is as follows:

$$Ri - RF = \alpha i + \beta 1(Mkt - RF) + \beta 2SMB + \beta 3HML + \beta 4RMW + \beta 5\,CMA + \xi i \quad (1)$$

Here, Market Factor (Mkt - RF) Model Factor SBM, Book Market Capitalization Ratio HML, Profit Factor RWM, Investment Factor CMA.

2.2 Data Collection & Processing

We have collected data from the wind on all U.S. stocks, including monthly circulating market value, monthly book market value ratio, monthly profitability, and monthly total asset growth rate. The data frequency is quarterly and is updated at the beginning of each month. It remains unchanged throughout the month [4].

- Monthly circulating market value (SIZE): the corresponding circulating market value of each stock t-1 after the last day of the month.
- Monthly book market value ratio (B/M): the total owner's equity published in the t-1 monthly quarterly report of each stock divided by the corresponding circulating market value after the closing of the last day of t-January.
- Monthly profitability (E/B): the operating profit announced in the t-1 month of each stock divided by the total owner's equity announced in t-January.
- Monthly total asset growth rate (TAG): the total assets announced in the t-1 monthly quarterly report of each stock minus the total assets announced in the t-2 monthly quarterly report, divided by the total assets announced in the t-2 monthly quarterly report.
- Monthly market yield (Rm): The monthly rise and fall of all eligible individual stocks are weighted and averaged according to the current market value at the end of the month.
- Risk-free interest rate (Rf): The yield of the ten-year treasury bond of the United States is converted to the monthly rate of return.

2.3 The Calculation of FF5 Factors

According to the grouping calculation method in the original FF5 model, this paper first sorts the return rate data of the company's stocks collected in descending order according to the market value, and divides them into two groups: the first 50% group and the last 50% group, which are respectively named as large (B) and small market value group (S). Aftewards, the book to market ratio at the end of the month is sorted in descending order, and is divided into three groups according to 30%: 40%: 30%: low book to market ratio group (L), medium book to market ratio group (M), and high book to market ratio group (H). Finally, two groups of data are integrated and grouped into six groups (combination of above two categories): S/L, S/M, S/H, B/L, B/M, and B/H. For the calculation and treatment of profit factors and investment factors, we adopted the same approach, and divided the profitability of the company's stocks and the growth rate of total assets into three groups according to

the order of 30%: 40%: 30%, resulting in six groups: low profit (W), medium profit (O), high profit (R), conservative investment style (C), neutral investment style (N), and aggressive investment style (A). Then, we combined with the market value group to get twelve groups. Finally, we obtained a total of 18 sets of data. Then, we carried out weighted average processing for each group. The specific weight depends on the percentage of the market value of a single company's stock in the market value of the whole group. The specific calculation formula and method are as follows:

$$w_i = CAPi/\Sigma CAPi \tag{2}$$

Here, CAPi is the year-end market value of stock i. The weight calculation is used to obtain the weighted monthly yield of the weighted combination, i.e., and finally 108 sets of data for 9 years are obtained. Then, we calculate the scale factor, book market value ratio, profit factor and investment factor according to the 108-group weighted portfolio monthly yield data obtained. Then, the 108 groups of weighted data are averaged according to the method in Table 1, and the relevant factors are finally obtained.

Table. 1. Calculation of risk factors

Model Category	Calculation of risk factors
Five factors	$SMB_{B/}=\frac{(S/H+S/M+S/L)}{3}-\frac{(B/H+B/M+B/L)}{3}$ $SMB_{OP}=\frac{(S/R+S/O+S/W)}{3}-\frac{(B/R+B/O+B/W)}{3}$ $SMB_{INV}=\frac{(S/C+S/N+S/A)}{3}-\frac{(B/C+B/N+B/A)}{3}$
	$SMB=\frac{SMB_{B/M}+SMB_{OP}+SMB_{INV}}{3}$ $HML=\frac{(S/H+B/H)}{2}-\frac{(S/L+B/L)}{2}$ $RWM=\frac{(S/R+B/R)}{2}-\frac{(S/W+B/W)}{2}$ $CMA=\frac{(S/C+B/C)}{2}-\frac{(S/A+B/A)}{2}$

3. The Impact of Exchange Rate on Stock Earnings

3.1 Profitability of Enterprises

According to the international trade effect previously proposed by Dornbusch and Fisher [6], the exchange rate is linked to the current account of the country, and the exchange rate fluctuations in the country reflect the enterprise. Business profitability and international competitiveness. Therefore, the US dollar index plays a role in realizing corporate profits [6]. The appreciation of the U.S. dollar has increased the sales and income for exporters, thus increasing the price of their shares and increasing the yield of stocks. For importers, the U.S. dollar appreciates the cost of their imports, which is detrimental to the profitability of enterprises. It is reflected in the decline in stock prices and stock returns. The rate decreased accordingly.

3.2 Short-term Supply

According to the supply relationship, we can infer that the exchange rate market will directly affect the cost of domestic and foreign investors buying shares in a certain country. When the U.S. dollar depreciates relatively and the U.S. dollar is relatively weak, people tend to be pessimistic about the domestic stock market in the short term, which leads to a decline in investors' willingness to invest, the overall weak stock market, and a decline in stock yields. International investors may increase or enter their investment plans in U.S. stocks, causing the demand for U.S. stocks to exceed supply in the short term, resulting in stock prices rising and stock yields. When the U.S. dollar appreciates relatively and the U.S. dollar is relatively strong, people tend to be optimistic about the domestic

stock market in the short term, which leads to an increase in investors' willingness to invest and stocks. The overall market was excited, and the stock yield rose. International investors may suspend or give up their investment plans in U.S. stocks, causing the supply of U.S. stocks to exceed demand in the short term, resulting in a decline in the stock price and a decline in stock yield [7].

3.3 Securities Market Expectations

In the long run, exchange rate changes can often reflect the future economic policy attitude and future economic development direction of a country or economy. Therefore, the exchange rate is also a compass for investors to determine the direction of future investment. When a country or economy adopts a tight monetary policy to resist inflation and reduce market demand, the currency of the country or economy will appreciate relatively, while promoting savings and combating investment, causing a downturn in the stock market. In the long run, investors will think that the country or economy tends to adopt a relatively tight monetary policy. When a country or economy adopts an expansionary monetary policy to promote economic development and stimulate market demand, the economy's currency will depreciate relatively, while promoting investment to suppress savings and promote investment, resulting in a stock market boom [8].

4. Results & Discussion

4.1 Model Construction

To quantify the impact of exchange rate factors, we introduced the US dollar index as an indicator. It calculates a specific value by mathematically calculating the exchange rate of the US dollar and the currencies of many major countries in the world. This value can indirectly reflect the changes in the export competitiveness and import costs of US dollars, as well as the purchase cost of U.S. stocks. The 2012-2022 US dollar index data RUDIt is obtained through the wind. We use the formula RUDI=(RUDIt-RUDIt-1)/RUDIt-1 to calculate it. On this basis, we build a new model based on the FF5 model:

$$Ri - RF = \alpha i + \beta 1(Mkt - RF) + \beta 2SMB + \beta 3HML + \beta 4RMW + \beta 5\,CMA + \beta 6RUDI + \xi i \quad (3)$$

Table. 2. FF5 causes correlation analysis.

	MKT_RF	SMB	HML	RMW	CMA
MKT_RF	1.00000	0.31354	0.05222	0.04067	-0.19799
SMB	0.31354	1.00000	0.26056	-0.37049	0.00543
HML	0.05222	0.26056	1.00000	0.13629	0.63935
RMW	0.04067	-0.37049	0.13629	1.00000	0.14493
CMA	-0.19799	0.00543	0.63935	0.14493	1.00000

Table. 3. Correlation analysis after the introduction of the RUDI.

	MKT_RF	SMB	HML	RMW	CMA	RUDI
MKT_RF	1.00000	0.31354	0.05222	0.04067	-0.19799	-0.29428
SMB	0.31354	1.00000	0.26056	-0.37049	0.00543	-0.07911
HML	0.05222	0.26056	1.00000	0.13629	0.63935	-0.10143
RMW	0.04067	-0.37049	0.13629	1.00000	0.14493	0.11835
CMA	-0.19799	0.00543	0.63935	0.14493	1.00000	0.02131
RUDI	-0.29428	-0.07911	-0.10143	0.11835	0.02131	1.00000

Table 4. Unit root test.

Variable name	MKT_RF	SMB	HML	RMW	CMA	RUDI
T-test value	-13.08094	-11.20856	-9.38783	-8.359624	-9.279354	-7.458537
P-test value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

4.2 Covariance & Correlation and Stability of the Model

In the original FF5 factor, the market factor MKT-RF has a strong correlation with the scale factor SMB and the investment factor CMA [9]. The specific results are shown in Table. 2. Therefore, the investment factor and the book market value ratio factor HML also have a strong correlation. The RUDI US dollar index factor has a strong correlation with the market factor MKT-RF, and the correlation with the other four factors is weak. The specific results are shown in Table. 3. Hence, the introduction of RUDI is more reliable and will not become a redundant factor. The unit root test is presented in Table. 4.

Table. 5. Summary of models' performances for different stocks.

Stock name	FF5 Model			New Model			More excellent
	Adj. R^2	F-Score	Prob	Adj. R^2	F-score	Prob	
AAPL(BM)	0.458	21.993	0	0.462	18.756	0	NM
AMD(SL)	0.265	9.510	0	0.297	7.884	0	NM
AMZN(BL)	0.491	22.607	0	0.518	18.950	0	NM
AUY(SH)	0.0933	3.388	0.007	0.180	4.029	0.001	NM
BABA(BM)	0.306	8.860	0	0.338	8.559	0	NM
BAC.N(BH)	0.695	57.531	0	0.697	48.591	0	Be equal
CCL(SH)	0.445	20.845	0	0.471	17.545	0	NM
CSCO.O(BM)	0.328	12.819	0	0.322	10.597	0	Be equal
F(SH)	0.398	16.61	0	0.438	14.535	0	NM
GFI(SH)	0.386	2.643	0.053	0.401	2.229	0.083	NM
GOOGL(BM)	0.455	21.206	0	0.454	17.788	0	Be equal
ITUB(SH)	0.142	2.457	0.050	0.310	2.851	0.022	NM
MSFT.O(BM)	0.493	25.141	0	0.490	20.855	0	FF5
NIO(SL)	0.220	3.480	0.011	0.272	3.743	0.005	NM
NVDA(BM)	0.280	10.397	0	0.316	8.851	0	NM
PBR(SH)	0.239	6.583	0	0.382	10.490	0	NM
PLTR(SL)	0.390	3.425	0.031	0.350	2.705	0.063	FF5
SQ(SL)	0.500	15.211	0	0.526	14.110	0	NM
SYNH(SM)	0.357	7.222	0	0.367	6.413	0	NM
TEAM(SL)	0.401	11.306	0	0.393	9.292	0	FF5
TSL(BL)	0.191	6.869	0	0.197	6.082	0	NM
VALE(SH)	0.171	6.104	0	0.266	8.471	0	NM
XPEV(SM)	0.335	2.711	0	0.276	2.080	0.139	FF5

4.3 Comparison of the Return of 22 Stocks

This paper selects 22 corporate stocks from various industries, sectors, and different sizes and types from all eligible U.S. stocks, hoping to test the application ability of the new model in the whole financial market [10]. The specific results are shown in Table. 5. In the OLS regression comparison of the monthly data of 22 stocks 2012-2022, the new model has won 15 times, the FF5 original model has won 4 times, and it is difficult to judge the winner three times. Therefore, this paper believes that the new model is better than the FF5 model to a certain extent. However, this article also found that the advantages in most of the victories of the new model are very weak, and only a few have achieved an overwhelming advantage. This may be related to the business type and capital situation of the

selected company. When the company's business type and capital situation are highly correlated with international capital flows, the RUIDI dollar index factor is relatively good for improving the FF5 model. Whereas when the company's business type and capital situation are less correlated to international capital flows, the RUIDI US dollar index factor improves the FF5 model is relatively poor.

5. Conclusion

To sum up, this paper concludes that the dollar index, namely the exchange rate changes of the dollar relative to other currencies, affects the stock returns of the US stock to some extent. When the RUDI dollar index factor is introduced into the FF5 model as a new factor, the new model has enhanced the explanatory ability for most stock returns and greatly enhanced the explanatory ability for some stocks. Therefore, it is believed that the new model will have significant advantages over the FF5 model when exploring the stock returns of some companies engaged in transnational trading and investment.

Nevertheless, since the exchange rate has different effects on different enterprises, the new model can only be used to explain the return of a single stock. Moreover, it is difficult to explain it of a stock portfolio with different types of enterprises. In addition, the impact of the exchange rate on the stock return rate is uncertain in the long run, which may be affected by the adjustment of the company's business model and the change of investment strategy. Therefore, the new model is difficult to explain the change in stock return rate in the longer run. Besides, the new model does not have a strong ability to explain the changes in corporate stock returns that are not involved in cross-border trading and investment, and the dollar index factor may become a miscellaneous factor.

Overall, this paper proposes the introduction of macroeconomic factors to improve the asset pricing model, which is a potential new direction for studying the asset pricing model. Investor sentiment may be an important factor affecting asset pricing, and the development of behavioral economics may make a significant contribution to the improvement of asset pricing models. With the rapid development of financial technology, the continuous leapfrogging of the field of financial research, and the continuous innovation of financial research methods, there will be a better and more meaningful asset pricing model in the future with effectiveness factors. These results explore the way forward for the improvement and development of the asset pricing model in the future, providing a new perspective and direction for enhancing the performances of the models.

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