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An Empirical Study on the Returns of Green Funds based on the Fama-French Three-factor Model

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Abstract
With the gradual enhancement of environmental protection concepts in recent years and the continuous implementation of the sustainable development concept by the country, the green financial system in the financial field is thriving. Many banks and other financial institutions have become important driving forces for green financial innovation. The green financial system contains many elements, with green funds being an important component that plays a significant role in promoting green environmental concepts. Therefore, this study used data from 34 open-ended environmental concept funds from the fourth quarter of 2017 to the second quarter of 2024 as sample fund data. Based on the Fama-French Three-factor model and considering the current market situation, mixed regression and quantile regression were conducted after adding variables such as shareholding ratio and subscription ratio. The final conclusions drawn are as follows: The Fama-French Three-factor model has explanatory power for the returns of green funds; green funds tend to invest in small-cap growth stocks; the subscription behavior of funds has a positive impact on returns, while redemption behavior does not have a significant effect; the model's explanatory power at higher quantiles is stronger than at lower.

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1. Introduction

Under the sustainable development strategy framework advocated and implemented by the government in China, various industries actively respond to the sustainable development strategy. Among them, green finance, as an effective lever to promote this strategy, has attracted much attention. In recent years, the Chinese government has continuously strengthened policy formulation and issuance in the field of green finance. In 2015, China proposed to build a green financial system; subsequently, in 2016, seven ministries including the People's Bank of China jointly issued the "Guiding Opinions on Building a Green Financial System"; this year, it once again introduced the "Guiding Opinions on Further Strengthening Financial Support for Green and Low-Carbon Development." Since the initial proposal to build a green financial system, green finance in China has achieved rapid development momentum. According to statistics, as of the end of June 2024, China's green loan balance has climbed to 34.5 trillion yuan; the cumulative issuance of green bonds has also reached 3.69 trillion yuan; in addition, according to data from the China Banking and Insurance Regulatory Commission, the total balance of green loans of 21 mainstream banks amounts to 31 trillion yuan, achieving a 25.9% growth compared to the previous year.
The subject of this study is green funds, which are an important part of the green financial system. China implements the concept of high-quality development, with environmental protection as a key focus indicator. Therefore, this paper conducts research and discussion on the return rate of green funds, which is the most concerning aspect for the majority of investors. In China, many scholars have applied the CAPM model and the Fama-French model to conduct empirical tests in the A-share market. The significance of this paper lies in introducing the three-factor model into the analysis process of funds and conducting empirical analysis. The empirical analysis section of this article focuses on studying and analyzing the return rate of green funds and

drawing corresponding conclusions. The selected sample consists of green fund data from the fourth quarter of 2017 to the second quarter of 2024. Panel regression analysis method is used to identify the factors influencing the return rate of green funds.

2. Literature Review and Theoretical background

2.1. Application and Development of the Fama-French Three-factor Model

After the release of the Fama-French three-factor model, numerous scholars have used this model for empirical analysis. Liu Hui and Huang Jianshan classified the selected samples into six investment portfolios based on the dimensions of book-to-market ratio and market value. They conducted empirical research using the CAPM model and the three-factor model, and the results showed that the stock returns of companies exhibited a negative correlation with market value and a positive correlation with book value. Tian Lihui and Wang Guanying established the "five-factor" model, which innovatively added turnover rate and trading volume as factors, making significant progress compared to the three-factor model. Their research conclusions indicated that the five factors have a significant impact on stock returns. Hou *et al*. (2015) [3] replaced the commonly used book-to-market ratio with return on equity (ROE) as a financial indicator and constructed a Q-factor model, which was more effective in explaining returns compared to traditional models. Harvey *et al*. (2016) [4] discovered several anomalies in the U.S. financial markets using multi-year stock market samples. They constructed anomaly factors and further optimized the five-factor model. Zhao Shengmin *et al* found that the Fama-French three-factor model is more suitable for the Chinese stock market compared to the five-factor model when analyzing stock returns in the A-share market from 1993 to 2014. Stambaugh *et al* studied the overvaluation and undervaluation of financial market products and established management and performance factors while retaining market and size factors to explain anomalies that the original model could not account for. Hou *et al*. (2019) [7] analyzed various pricing models and found that many factors in these models could be encompassed by other factors, except for their Q-factor model. Daniel *et al*. (2020) [8], in contrast to the traditional fundamental perspective, used behavioral finance theory to construct behavioral factors to expand the three-factor model, suggesting that market anomalies are due to investors' limited understanding of the stock market and excessive self-confidence in their choices. Zhang Shaohua (2021) [10] constructed a TFP (total factor productivity) factor using listed companies on the Shanghai and Shenzhen stock exchanges from 1999 to 2018. The results indicated that total factor productivity is an effective asset pricing factor, and empirical testing revealed that the three-factor model is more suitable for the Chinese stock market compared to the five-factor model.

2.2. Concept and Related Research of Green Funds

Compared to traditional funds, the development history of green funds is relatively short, belonging to an emerging category of funds. Jiang Xianling and Zhang Qingbo (2017) [10] pointed out that green funds, unlike traditional funds, need to maximize profits while also considering various aspects of social responsibility, focusing on environmental protection issues to promote sustainable development. Sun Qiufeng and Nian Zongqian stated that green funds raise funds and invest in fund projects in areas such as low-carbon emissions reduction and environmental governance. Therefore, this article focuses on open-end green public funds, which are closely related to environmental protection. Many scholars have conducted research on green funds. Liu Huajun and Zhang Yichen (2023) [12] found in their study on China's practice in green finance that different green funds have significant overlap in investment strategies and resource orientation, and the effectiveness of environmental information disclosure needs to be strengthened. Wei Ping and Shu Hao (2018) [13] evaluated the performance of green funds using single-factor models and the Carhart four-factor model, finding that the risk-adjusted returns of green funds are lower than market benchmarks and traditional fund markets. Risk factors, value factors, and momentum factors can objectively explain the returns of green funds, with investors in green funds showing low sensitivity to returns. Wang Huaiming and Wang Peng found in their study of socially responsible funds that investors in these funds are less concerned about short-term performance fluctuations compared to traditional funds, showing a higher sensitivity to long-term performance. This indicates that investors in these funds tend to lean towards a long-term value investment philosophy. Shi Yanping found, based on the CAPM theory and the Fama-French three-factor model, that the investment performance of China's green mutual funds showed no significant difference compared to other socially responsible investment funds and traditional mutual funds from 2015 to 2016. Tang Yahui *et al* found that net fund inflows are jointly driven by the improvement in green fund performance and increasing investor attention, with investors showing a preference for newly established and small funds. Li Zhiyu and Hong Shuai (2022) [17] analyzed the performance and influencing mechanisms of green funds based on a five-factor panel data model. The results showed that the environmental performance of green funds is significantly lower than financial performance, and environmental performance indicators have not been effectively incorporated into investment decisions. Further efforts are needed to define green investment standards, strengthen policy support combinations, and enhance the overall performance of green investment funds. Wang Huaiming and Zheng Yang (2021) [18] used unbalanced panel data and the Fama-Macbeth model to analyze investor preferences for green funds. They found that institutional investors prefer green funds with low sensitivity to performance, while individual investors are influenced by the disposition effect and have not formed a green value investment philosophy. The disposition effect of individual investors mainly focuses on funds with moderate performance, and in bear markets, green funds are considered as safe-haven investments.

Since the publication of the Fama-French three-factor model, the Carhart Four-factor model and the Fama-French Five-factor model have been derived. Both domestic and foreign researchers have mainly used these models to conduct empirical studies on the stock market. Studies have shown that the Fama-French Five-factor model has a stronger explanatory power for stock excess returns in foreign markets. However, in the A-share market, the Fama-French Three-factor model has better explanatory power. Therefore, this paper chooses the Fama-French Three-factor model as the benchmark model.In the research on fund returns by numerous scholars, it can be seen that the size, turnover rate, and industry allocation of funds are correlated with fund performance. In related studies on green funds, institutional investors tend to invest in green funds. Individual investors who prefer short-term investments do not show a clear preference for green fund investments, while individual investors with a long-term investment philosophy are more willing to invest in green funds. In addition, green funds are considered safe-haven assets in bear markets. Based on this, the significance of this study lies in introducing subscription ratio and redemption ratio as individual factors into the empirical analysis of green funds on the basis of the three-factor model. The results show that there is a correlation between the subscription ratio and the fund's return rate.

2.3. Theoretical background

With the vigorous development of the capital market and the deepening research on investment returns related to securities, many scholars have found that the explanatory power of CAPM is insufficient. Therefore, they have continuously developed and extended numerous theories. Fama and French, by using a large amount of data, conducted research and analysis on a large scale, considering systematic risk while introducing other indicators such as market capitalization and book-to-market ratio, thus constructing the famous three-factor model. The regression model is illustrated as follows:

$$E(R_{it}) = R_{ft} + \beta_i \times \left[E(R_{mt}) - R_{ft}\right] + s_i E(SMB_t) + h_i E(HML_t) + \varepsilon_{it} \quad (1)$$

In the above formula: $E(R_{it})$ refers to the expected return of stock i in a certain period t; β_i is used to indicate the degree of volatility of the return of stock i compared to the market portfolio, which is a factor used to estimate the systemic risk that stocks possess; $E(R_{mt})$ is the expected market return; R_{ft} is the risk-free return; $E(SMB_t)$ is used to show the impact of company size on stock return volatility compared to the original conditions; $E(HML)$represents the impact of the book-to-market ratio on stock return volatility compared to the original conditions; ε_{it} is the regression residual term. s_i is the regression coefficient of the size factor, and h_i is the regression coefficient of the book-to-market ratio factor.

3. Data, model specification, and methodology

3.1. Data

In order to avoid anomalies caused by short-term market fluctuations, this empirical study chose to use quarterly data, with the sample covering indicator data from 27 quarters. The sample of green funds consists of environmentally friendly concept funds, with a time range from the fourth quarter of 2017 to the second quarter of 2024. After excluding funds with missing data and funds that have been suspended from trading, a total of 34 green funds were included. The data selected for this study is sourced from the RESSET Database. The study selected a total of six variables for research, namely Rc, Rmc, SMB, HML, Buy, and Sell. The dependent variable is the quarterly excess return rate of the fund (Rc), which is obtained by subtracting the risk-free return rate from the fund's quarterly return rate. The risk-free return rate used in the study is derived by converting the one-year fixed deposit rate to a quarterly rate. The explanatory variables cover five factors: the market's quarterly excess return rate (Rmc), the size factor (SMB), the book-to-market ratio factor (HML), the purchase ratio (Buy), and the redemption ratio (Sell). Feng Jinyu (2009) [19] conducted panel data analysis on domestic open-end funds and found a positive correlation between fund redemptions and fund performance. Therefore, this study includes the purchase and redemption ratios in the variable system. The market's quarterly excess return rate (Rmc) is the difference between the market's quarterly return rate and the risk-free return rate, with the Shanghai and Shenzhen 300 Index return rate used as the benchmark for market returns. The size factor (SMB) represents the difference in returns between small-cap stock portfolios and large-cap stock portfolios. The book-to-market ratio factor (HML) is the difference in returns between growth stocks and value stocks. There are various ways to calculate SMB and HML. The study classifies listed company stocks into small-cap stocks (S), mid-cap stocks (M), and large-cap stocks (L) based on market capitalization size. Stocks are also classified as growth stocks (L, low book-to-market ratio) and value stocks (H, high book-to-market ratio) based on the book-to-market ratio. This results in the formation of six portfolios: large-cap value portfolio, large-cap growth portfolio, mid-cap value portfolio, mid-cap growth portfolio, small-cap value portfolio, and small-cap growth portfolio. The calculation formulas for SMB and HML are as follows:

$$SMB = \frac{1}{2} \times \left(\frac{S}{H} + \frac{S}{L}\right) - \frac{1}{2} \times \left(\frac{B}{H} + \frac{B}{L}\right) \quad (2)$$

$$HML = \frac{1}{3} \times \left(\frac{S}{H} + \frac{M}{H} + \frac{B}{H}\right) - \frac{1}{3} \times \left(\frac{S}{L} + \frac{M}{L} + \frac{B}{L}\right) \quad (3)$$

3.2. Model specification

The empirical analysis of this article adopts the method of panel regression analysis, and the meanings of each variable are as shown in Table 1. The model constructed in this article is as follows:

$$Rc_{it} = \beta_0 + \beta_1 Rmc_{it} + \beta_2 SMB_{it} + \beta_3 HML_{it} + \beta_4 Buy_{it} + \beta_5 Sell_{it} + e_{it} \quad (4)$$

Table 1: Variables and description

Variables	Description
Rc	Fund excess return rate
Rmc	Excess return rate of the CSI 300 Index
SMB	Size factor
HML	Book-to-market ratio factor
Buy	Logarithm of the ratio of fund subscription shares to initial shares
$Sell$	Logarithm of the ratio of fund redemption shares

3.3. Methodology

3.3.1. Stationarity Test

This article employs the unit root test method to evaluate the stationarity status of variables by detecting the presence of unit roots. If variables have unit roots, it may lead to the occurrence of spurious regression, affecting the accuracy of regression analysis. The purpose of the unit root test is to ensure that all variables possess stationarity characteristics because only regression models with stationary variables can produce valid results. Therefore, conducting unit root tests is a necessary step to eliminate the non-stationarity of variables, ensuring the effectiveness and reliability of the constructed model.

3.3.2. Model Effectiveness Test

This article judges the effectiveness of the model by the goodness of fit of the model. Evaluating the goodness of fit of the model, which measures the degree of matching between the sample regression line and the sample observed data, is an important means of assessing the effectiveness of the model. This article uses the R square as a measure, with a value range of [0, 1]. The larger the value, the better the fit of the model, indicating higher goodness of fit.

3.3.3. Stability Test

For empirical testing, the stability test of regression analysis model parameters is an indispensable link in explaining and predicting models. Only when each parameter in the model is stable can it be explained that the explanatory variables and the explained variables are consistent and can provide assistance for future predictions. If the parameters are not stable, the related predictions based on the model may be inaccurate, and the results and recommendations provided will

4. Empirical Research Results

4.1 Descriptive Statistics

To further investigate the impact of market excess return, size factor, book-to-market ratio factor, subscription ratio, and redemption ratio on fund returns, it is necessary to first conduct a preliminary examination of the distribution of each variable. The results of descriptive statistics can be found in Table 2.

Table 2: Variables and description

Variables	Sample	Mean	Standard Deviation	Minimum	Maximum
Rc	918	1.93	13.50	-25.40	51.10
Rmc	918	-0.32	9.45	-15.50	28.20
SMB	918	-0.94	5.67	-10.60	18.10
HML	918	0.41	7.56	-16.60	13.40
Buy	918	-2.15	1.52	-5.73	2.80
$Sell$	918	-1.72	1.08	-4.41	2.36

Data Resource: RESSET Database

From the Table 2, it can be observed that the returns of green funds fluctuate significantly compared to the market index, with a maximum value of 51.10%, a minimum value of -25.40%, and an average value of 1.93%. The returns of green funds exceed the average returns of the market.

4.2. Stationarity Test

Given that the sample data used in this study is short-term panel data, the Harris-Tzavalis test was selected to determine the presence of unit roots. By conducting tests on each variable in the model, the results indicate that all panel data variables exhibit stationarity, allowing for direct regression analysis. The results of the unit root test are shown in Table 3.

Table 3: Harris-Tzavalis unit root test

Variables	P value	Z statistic	Stationarity
Rc	0.0000	-26.7081	YES
Rmc	0.0000	-26.3874	YES
SMB	0.0000	-26.3874	YES
HML	0.0000	-26.3874	YES
Buy	0.0000	-14.3597	YES
$Sell$	0.0000	-26.7081	YES

4.3 Model Testing

In order to ensure that the model selected for regression analysis can properly adapt to and fully utilize the characteristics of panel data, providing more accurate and reliable statistical inferences, this study sequentially applies two statistical tools: the F-test (also known as the joint hypothesis test) and the LM (Lagrange Multiplier) test. The F-test aims to test the significance of fixed effects in the model, helping to determine whether a pooled model or a fixed effects model is more appropriate. The LM test is used to detect the presence of random effects, further distinguishing the applicability between fixed effects and random effects models. The test results are shown in Table 4 and Table 5.

Table 4: F test result

F statistic	P value	Result
0.54	0.9852	Pooled Regression

Table 5: LM test result

F statistic	P value	Result
0.0000	0.9999	Pooled Regression

From the Table 4 and Table5, it can be seen that the pooled regression model is the more suitable choice. Based on this, this study adopts the pooled regression model.

4.4. Regression Results and Analysis

This study utilized Stata16.0 software to conduct regression analysis at four quantile points: 0.25, 0.5, 0.75, and 0.9. The results are detailed in Table 6.

Table 6: Regression Result

Independent Variable	Pooled Regression	Quantile points			
	(1)	(2)	(3)	(4)	(5)
		QR_25	QR_50	QR_75	QR_90
Rmc	0.768***	0.644***	0.741***	0.916***	1.063***
	(23.45)	(18.27)	(18.91)	(17.51)	(15.70)
SMB	0.269***	0.072	0.150**	0.374***	0.587***
	(5.91)	(1.47)	(2.75)	(5.15)	(6.23)
HML	-0.671***	-0.679***	-0.662***	-0.630***	-0.581***
	(-16.65)	(-15.66)	(-13.74)	(-9.79)	(-6.97)
Buy	0.012***	0.006*	0.009**	0.013***	0.014**
	(5.21)	(2.52)	(3.02)	(3.42)	(2.82)
$Sell$	0.004	-0.003	0.000	0.005	0.013

	(1.17)	(-0.73)	(0.01)	(0.99)	(1.90)
Constant	0.061***	-0.016**	0.039***	0.113***	0.181***
	(12.88)	(-3.24)	(6.96)	(14.97)	(18.62)
N	918	918	918	918	918
R-squared	0.712	0.432	0.466	0.512	0.544

Note:1.In parentheses are the t-values.2.*** represents significance at the 1% level, ** represents significance at the 5% level, and * represents significance at the 10% level.

According to Table 6, the pooled regression results show an R square of 0.712, indicating that the model can partially explain the returns of green funds.The regression coefficient β_1 of Rmc is 0.768, significantly greater than 0 at the 1% significance level, indicating that the return of green funds is influenced by market factors, showing a positive trend. Furthermore, β_1 being less than 1 implies that the fluctuations in the returns of green funds are smaller than the fluctuations in market portfolio returns, suggesting lower systematic risk. The regression coefficient β_2 of SMB is 0.269, significantly greater than 0 at the 1% significance level, indicating a positive correlation, meaning that small-cap funds have higher returns than large-cap funds. The regression coefficient β_3 of HML is -0.671, significantly less than 0 at the 1% significance level, showing a negative correlation. This suggests that book-to-market ratio significantly affects the returns of green funds, specifically indicating that funds with lower book-to-market ratios outperform those with higher ratios. The regression coefficient β_4 of Buy is 0.012, significantly greater than 0 at the 1% significance level, meaning that the purchase behavior of green funds affects their returns, with an increase in fund purchases leading to higher green fund returns. The regression coefficient β_5 of Sell is 0.004, which is not significant.

The significant positive correlation between market excess returns and green fund returns indicates that green funds mainly allocate to pro-cyclical assets. The results of SMB and HML show that small-cap growth stocks are the primary investment targets of green funds. In the context of the new era, China actively promotes the development of the "green economy," leading green funds to primarily invest in low-carbon environmental stocks. These companies are typically smaller in size but have significant growth potential. Investor purchase behavior significantly impacts green fund returns, reflecting increasing investor interest in the green environmental industry and a growing awareness of green investments. Conversely, redemption behavior does not show significance.

According to the quantile regression results in Table 6, as the quantiles increase, the R square gradually increases, indicating that the model performs better in explaining at higher quantiles. At all quantiles, the constant term is significantly non-zero, suggesting the presence of other risk factors not considered by the model. The regression coefficient of market excess return increases with quantiles, indicating that green funds with higher returns also have higher systematic risk. The size factor is not significant at the 0.25 quantile but is significant at other quantiles, showing an increasing trend. This suggests that the fund size affects green fund returns, with higher-return funds being more impacted. Additionally, purchase behavior and book-to-market ratio factors are significant at all quantiles, with their regression coefficients decreasing as quantiles decrease. This indicates that as green fund returns decrease, the influence of book-to-market ratio and purchase behavior weaken.

4.5. Robustness Test

After excluding the green fund samples that have been established for less than a year, the regression is conducted again, and the robustness results are shown in Table 7.

Table 7: Robustness Test

Independent Variable	**Pooled Regression (1)**	**Robustness Test (6)**
Rmc	0.768***	0.765***
	(23.45)	(30.30)
SMB	0.269***	0.272***
	(5.91)	(4.75)
HML	-0.671***	-0.653***
	(-16.65)	(-10.66)
Buy	0.012***	0.011***
	(5.21)	(5.18)
Sell	0.004	0.005
	(1.17)	(1.59)
Constant	0.061***	0.059***
	(12.88)	(9.97)
N	918	837
R-squared	0.712	0.708

Note:1.In parentheses are the t-values.2.*** represents significance at the 1% level, ** represents significance at the 5% level, and * represents significance at the 10% level.

The results of the robustness test show that the significance levels of each variable remain stable without significant fluctuations, and the coefficient values also remain consistent, thereby confirming the reliability of the regression analysis.

5. Conclusions and Recommendations

Based on the three-factor model, this study conducted in-depth empirical research on the returns of green funds that uphold sustainable principles. Additionally, micro factors such as subscription ratio and redemption ratio were introduced to comprehensively analyze the returns of green funds. Moreover, quantile regression models were employed to explore the explanatory power of the model at different return percentiles. The main conclusions are summarized as follows:

1. Although the Fama-French three-factor model can partially explain the returns of green funds, there are other risk factors that significantly influence the returns.
2. The returns of green funds exhibit a significant positive correlation with market factors and size factors, and a significant negative correlation with the book-to-market ratio factor, indicating that green funds primarily invest in pro-cyclical assets, focusing on small-cap growth stocks.
3. Investor subscription behavior has a positive impact on fund returns, while redemption behavior does not have a significant effect. This suggests the emergence of a large number of investors in the capital market, leading to a continuous increase in total investment. With ample

funds driving fund managers to continuously purchase stocks, the net asset value of funds increases. In contrast, the redemption scale by investors is relatively small, indicating an improvement in investors' rationality in investment decisions.

4. The results of the quantile regression show that the explanatory power of the three-factor model is stronger at higher quantiles compared to lower quantiles, and the impact of each factor on fund returns exhibits heterogeneity, indicating varying effects at different quantiles.

Based on the above findings, the following recommendations are proposed

1. In China's financial market, to actively respond to the country's call for sustainable development and ecological civilization construction, efforts can be made to increase the issuance of green funds. The sustainable development concept upheld by green funds aligns well with China's policy orientation and actual situation, meeting the strategic needs of the country's long-term development and global trends in green finance. From an investment perspective, green funds focusing on environmental protection and new energy sectors with promising prospects generally have optimistic investment expectations. However, the current scale of green funds in China is relatively small and cannot meet the growing demand for green investments in the market. Therefore, fund companies can seize this market opportunity, increase the number of green fund issuances, optimize product design, enhance investment management capabilities, and promote the rapid development of the green fund market. This will contribute to the improvement of China's green financial system.
2. The government can further increase support for the green industry by providing policy incentives, financial support, tax benefits, and other measures to create a more favorable development environment for the green industry, thus driving a more vigorous development trend in the green industry. At the same time, the government should focus on enhancing public awareness of environmental protection by strengthening environmental education, promoting green lifestyles, and increasing public awareness and importance of environmental protection. As public awareness of environmental protection increases, investors' awareness of green investments will also be enhanced. This will help attract more social capital to flow into the green industry, providing ample momentum for the development of the green financial system. Through the collective efforts of the government, society, and investors, we can jointly promote the continuous development and improvement of the green financial system, contributing greater efforts to achieve sustainable development

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