ENERGY AND INNOVATION AT IFP ENERGIES NOUVELLES

IFPEN ECONOMIC PAPERS

IFP SCHOOL - IFPEN N° 162 FEBRUARY • 2025

RESEARCH

EXPLAINING GREEN EXCESS RETURNS IN THE STOCK MARKET: A FIVE-FACTOR MODEL APPROACH

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Explaining Green Excess Returns in the Stock Market: A Five-Factor Model Approach

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Abstract: The study examines stocks in the new energy, energy-saving, and environmental protection industries to explain green excess returns in the case of Chinese stock market. The green four-factor model is constructed by introducing the green factor based on the Fama-French three-factor model. Empirical results show that this model better explains the risk-return of green concept stocks compared to the three-factor model by verifying the existence of green excess returns, though its explanatory power still needs improvement. Therefore, the study uses stock turnover rate and the firm's return on investment as indicators of the sentiment factor and the efficiency factor, respectively, from the perspectives of green investment sentiment in behavioral finance and positive externalities in microeconomics. The green five-factor model is then constructed by introducing the green sentiment factor and green efficiency factor. Empirical results show that the green five-factor model better interprets the risk-return of green concept stocks compared to the three-factor model and the green four-factor model, with the green sentiment factor and green efficiency factor having a significant positive effect on the return of green concept stocks.

Keywords: Green excess returns; Fama-French three-factor model; Green five-factor model.

Introduction

Under the guidance of the theory of sustainable development in China, the "green economy" has become the focus of China's economic development, energy saving and emission reduction at the industrial level has become the focus of industrial upgrading, and green development has become the core element of the values and investment concepts of the securities market. In August 2016, China's seven ministries and commissions jointly issued *the Guiding Opinions on Building a*

Green Financial System in which they explicitly proposed to promote the securities market to support green investment. The green industry is gradually becoming a supporting industry in China, people are confident in its development as well as the government is supporting its growth. How has the concept of "green development" affected the stock market? What are the advantages of "green production" for green industries? We examine the performance of green stocks in China's Shanghai and Shenzhen stock markets, explore the impact of the concept and practice of green development on asset pricing, improve the Fama-French three-factor model, and analyze the implementation effects of China's green industrial policies to provide policy references for green production and green financial development.

We constructed a green four-factor model by introducing green factors on the basis of the Fama-French three-factor model, and obtained the conclusion that there is an excess return on green concept stocks by testing the redundancy and significance analysis of the green factors. However, the significant constant of the green four-factor model indicates that the green factor does not fully explain the excess returns generated by green concept stocks， so we look for the factors that constitute green excess returns from the perspective of behavioral finance and microeconomics. The introduction of social capital in green investment is increasing, and investors' views on environmental investment have shifted from passive avoidance to active social responsibility. Investors no longer limit their evaluation of companies to economic benefits but pay equal attention to the potential investment that can be brought about by positive external benefits. This is changing the general investment ideas of investors and forming the concept of green investment. Environmentally friendly companies are facilitated by policies and attraction bonuses to make more efficient technological innovations, which can bring not only economic benefits, but also positive social and environmental benefits. Governments will subsidize green production to compensate for this positive externality, resulting in an increase in both demand and supply faced by environmentally friendly firms. This led to excess profits above the general level of the market. All these aspects make up the excess returns of green concept companies.

The expected return in the traditional discounted dividend model only considers the economic benefits of the listed company, and with the rise of the green development concept, the unique green risks faced by green concept companies will also bring some economic benefits(Criscuolo and Menon, 2015). (Oestreich and Tsiakas, 2015) in their study of the European carbon emissions

market, found that the cost of carrying out productive activities is reduced due to the fact that carbon-emitting firms can obtain free carbon credits. Environmental companies, on the other hand, have significantly underperformed carbon emitters, and there is a clear "carbon premium", so investors holding shares in environmental companies need additional returns to compensate for the risk of the "carbon premium". (Chia et al., 2009)found that some green portfolios in the market are not explained by traditional pricing factor models, but rather there exists an environmental factor tied to the firm's own green attributes, which explains most of the unexplained excess returns. (Ciarreta et al., 2014)in their study of the renewable energy market found that as renewable energy companies become more efficient in their production, the positive benefits to society increase. (Naqvi et al., 2021), in their study of new green fund markets in 27 countries, found that green equity funds did not earn as much as traditional equity funds and that green equity funds showed investment drag during the epidemic. (Chung et al., 2012)used a factor model to study green funds and found that green excess returns are highly sensitive to the market and size factors are less sensitive to the value and momentum factors. (Chan and Walter, 2014) observed through a study of environmental firms listed on the American Stock Exchange that environmental firms received green overshoots in both the initial public offering and stock issuance phases.

Faith is more important than gold. (Lee et al., 2002) used an index of investor sentiment to examine the effect of noise trading on the expected returns of securities. They demonstrated that investor sentiment, as a systematic risk, does affect the pricing of securities. And the higher the investor sentiment, the higher the future excess return of the security. However, a study by (Kim and Kim, 2014) showed that it is not investor behavior that affects the price of a stock, but the past performance of the stock price that affects the investor's investment behavior. (Ruland, 1989) in his study mentioned that the companies that are willing to make more predictive environmental disclosures are the ones that have more outside equity. It can be seen that the environmental behavior of enterprises is one of the key types of information that external investors focus on, and accordingly, this green investment behavior of investors also has a positive impact on the environmental behavior of enterprises.

Technological innovation in green enterprises improves the utilization efficiency of resource inputs and increases the economic efficiency of their production activities. Firms located in cities with higher levels of fintech development gained greater scale and efficiency in green innovation

and received more financial support from the government(Liu et al., 2022). (Xia et al., 2022)confirmed that green technology innovation and government subsidy have a curvilinear relationship. When green technology innovation reaches a certain level, the government subsidy will become higher as well. Furthermore, the green-specific risk of carrying out this green technological innovation is often related to the social and environmental benefits brought about by the enterprise. The government's green subsidy brings financial support to enterprises' green innovation, compensates the economic compensation needed for green innovation to bring positive external benefits to the society, and reduces the production cost of green enterprises, so that green enterprises can obtain excess external benefits (Montmartin and Herrera, 2015).

Theoretical models and data

Theoretical models

1. How Investors' Green Investment Mood Affects Green Concept Stock Returns

(MacAskill et al., 2021) verified the existence of a "green premium" in their study of the bond market. According to China's green stock market, green concept companies face special green risks due to their own green development and production technology innovations, and green investments may yield lower economic returns to investors. The Chinese government's promotion of the green economy and the proactive disclosure of green concept companies' own environmental benefits in recent years have reduced the information asymmetry effect of green concept stock trading. Green investors who have access to such company information are not only concerned with the current return and risk profile of green companies, but they are more likely to accept high green risks as they judge the future returns of green stocks based on the future development of green concept companies and expect to be compensated for green risks in the future. And they are willing to hold green concept stocks for a longer period of time, thus providing green concept companies with long-term stable R&D funding, making it more likely that green concept companies will earn excess returns.

(Bauer and Smeets) pointed out in their study that different investors have different beliefs about environmental protection, different perceptions of environmental pressures and different costs

and benefits of environmental investments. Therefore, some investors will show investment sentiment and behavior that prefers an environmental direction. Although the majority of investors in the Chinese stock market exhibit speculative behavior with a large follow-the-wind effect and this makes stocks deviate from their real prices. However, with the development of China's green economic system and the improvement of social and cultural standards, investors have become more proactive in obtaining fundamental information about green concept companies and have rationally selected green concept stocks based on their own beliefs in environmental protection and expected returns. A bias towards investing in stable and long-lasting investments in green concept stocks can provide continuous and stable funding for the development of green concept companies, which in turn affects the price and returns of green concept stocks.

Based on the characteristics of green investors such as risk appetite and environmental awareness preference, green investors can be attributed to the following categories of characteristics: Green investors are bullish on the future returns of green stocks and do not currently value speculative behavior. Green investors generally favor long and stable holdings of green concept stocks. These types of investment sentiment characterize what we call green investment sentiment. Learning from (Polk and Sapienza, 2004) and (Kim and Lee, 2022), the turnover rate of a company's stock is used as an indicator of the green sentiment factor. The smaller the turnover rate, the higher the green investment sentiment.

2. Theory of positive external benefits

Microeconomics[1] gives a definition of a positive externality: a phenomenon in an economy in which production and consumption give an additional benefit to others without the beneficiary having to pay for this additional benefit. The presence of positive externalities makes the market's allocation of resources inefficient, and even if the economy as a whole is perfectly competitive, the presence of externalities prevents the economy from reaching Pareto optimality. For green businesses that generate positive externalities for society and the environment, they produce products at lower prices and produce them in smaller quantities, preventing the green businesses from capturing this portion of the benefits due to less production. Currently the Chinese government supports the development of a green economy, giving many preferential policies and subsidies to

[1] Microeconomics from the Eighth Edition by Robert S. Pindyck.

enterprises that develop green businesses. Consequently, green investors will increase their investment in green enterprises by considering their positive benefits to society and the environment as their future earnings. Therefore, the positive externalities generated by green enterprises can be compensated through the government subsidy effect and the investor demand increase effect. Part of this compensated positive externality is the excess profit earned by the green concept company and thus the excess return on the green concept stock.

Positive externalities generated by green concept firms are difficult to measure, although government subsidies and higher prices for the products of green firms are indicative of the existence of positive externalities for green concept firms. However, since policies and investor behavior do not always identify green concept firms that generate positive externalities, the use of these two indicators can bias the subsequent empirical results. Considering the green concept enterprises carry out technological innovation in production, which makes the production higher than the general level of social production. This efficient production makes the utilization of resources higher, reduces the amount of resources used and improves the environment, and provides a more efficient way of production for social production, which brings positive benefits to the society and the environment. We therefore use the green firm's productivity indicator as a proxy variable for the positive externalities of the green firm. The return on investment (ROI) of the stock company is used as an indicator of the green efficiency factor; the larger the ROI, the higher the degree of green efficiency of the company.

3. Dividend discount model

(Fama and French, 2015) further proposed the existence of profitability factor and investment factor based on the dividend discount model on top of the three-factor model, thus creating a five-factor model. In this paper, we continue to propose the sentiment factor and efficiency factor for green stocks using the dividend discount model.

$$M_t = \sum_{i=1}^{\infty} \frac{E(I_{t+i})}{(1+r)^{-i}} \quad (1)$$

M_t is the firm's market capitalization in period t, $E(I_{t+i})$ is the firm's expected earnings in period $t+i$, and r is the long-run average expected stock return. We divide both sides of equation (1) by the book value of the firm in period t, B_t to obtain equation (2).

$$\frac{M_t}{B_t} = \sum_{i=1}^{\infty} \frac{E(I_{t+i})/B_t}{(1+r)^{-i}} \quad (2)$$

According to equation (2), when the market capitalization and book-to-market value of the firm are brought under control, the stock return is only affected by the firm's expected earnings. When the firm's expected earnings are greater; the stock return is higher.

For a perfectly efficient market, the expected return $E(I_t)$ of all firms should be equal to the market's average expected return $\mathrm{M}I_t$, meaning that holding a firm's stock exposes it only to the market's systematic risk, which is the idea of the CAPM[2] model. For green concept companies, in addition to receiving market average economic benefits, the green investment sentiment of investors will also have an impact on green concept stocks as they become more aware of the rise of the green investment concept and social responsibility; When a green concept company produces more efficiently than the general level of production in society through high technology, it generates positive external benefits to society and the environment, which are treated as potential benefits of the green concept company. Therefore, compared to the non-green concept company, the green concept company face should get higher than the market general level of expected return. So for the green company's dividend discount model we have:

$$\frac{M_t}{B_t} = \sum_{i=1}^{\infty} \frac{[E(\mathrm{M}I_{t+i}) + MOOD_{t+i} + EFFET_{t+i}]/B_t}{(1+r)^{-i}} \quad (3)$$

Where $E(\mathrm{M}I_{t+i})$ is the expected return at the market average in period $t+i$. $MOOD_{t+i}$ is the additional expected return due to investors' green sentiment in period $t+i$. $EFFET_{t+i}$ is the additional expected return in period $t+i$ due to the positive externalities generated by green firms. Eq. (3) is the formula for the dividend discount model for the green concept company. When we control for the average expected return of the market $E(\mathrm{M}I_{t+i})$, the market capitalization of green concept firms M_t, the book value of green firms B_t, and thus the book-to-market ratio of green concept firms M_t/B_t, the increase in the return on the shares of green concept firms is brought about precisely by the green sentiments of the investors and the positive externalities generated by the green concept firms.

4. Green Four Factor Model

[2] Capital Asset Pricing Model (William Sharpe)

Before verifying whether the green sentiment factor and the green efficiency factor can better explain the excess returns of green concept stocks, the hypothesis of the existence of green incentives in the Chinese stock market should be confirmed. It means that the existence of excess returns of green concept stocks compared to non-green concept stocks, is first verified. In order to verify this hypothesis, we introduce the green factor to construct the green four-factor model on top of the FF three-factor model.

$$R_{i,t} - R_{ft} = a + \beta_{mkt}\left(R_{Mt} - R_{ft}\right) + \beta_{smb}SMB_t + \beta_{hml}HML_t + \beta_G GF_t + \varepsilon_t \quad (4)$$

where $R_{i,t}$ is the stock portfolio return, R_{ft} is the risk-free rate of return, R_{Mt} is the market return, SMB_t is the market capitalization size factor, and HML_t is the book-to-market ratio factor. GF_t is the green factor, which is the difference in returns between green concept stocks and non-green concepts after controlling for the market capitalization size factor and the book-to-market ratio factor. The coefficient of the green factor, β_G, is the object of our focus; green-concept stocks should have higher return returns compared to non-green-concept stocks, so we anticipate $\beta_G > 0$.

5. Green Five-Factor Model

Our main focus is to unfold the factors that make up the green excess returns. After verifying the existence of the green factor, the green sentiment factor and the green efficiency factor were further introduced. Green concept stocks earn higher returns than non-green concept stocks due to high green investor sentiment and high productivity. To test this hypothesis, we construct a green five-factor model by expanding the green factor in the green four-factor model.

$$R_{i,t} - R_{ft} = a + \beta_{mkt}\left(R_{Mt} - R_{ft}\right) + \beta_{smb}SMB_t + \beta_{hml}HML_t + \beta_M GMF_t + \beta_E GEF_t + \varepsilon_t \quad (5)$$

where $R_{i,t}$ is the stock portfolio return, R_{ft} is the risk-free rate of return, R_{Mt} is the market return, SMB_t is the market capitalization size factor, and HML_t is the book-to-market ratio factor. GMF_t is the green sentiment factor and GEF_t is the green efficiency factor. The green sentiment factor is the difference between the returns of green concept stocks with high green sentiment and non-green concept stocks with low green sentiment after controlling for the other four factors. The green efficiency factor is the difference between the returns of highly efficient green concept stocks and inefficient non-green concept stocks after controlling for the other four factors. Both the Green Sentiment Factor and Green Efficiency Factor are supposed to be factors of excess return for green

concept stocks, so in this paper we expect β_M and β_E to be greater than zero.

（2）Data and factor construction

1.Data

Currently, there is no clearly defined green stock in China's stock market, so this paper divides listed companies into green and non-green based on the green concept segment. In August 2016, seven ministries and commissions jointly issued the *Guiding Opinions on Building a Green Financial System*, pointing out the significance of building a green financial system. Since then, the green industry has been developing rapidly in China. Therefore, we selected July 2016 as the starting point of the sample period and June 2023 as the end point of the sample period. Based on the Wind database and Choice Financial Terminal, listed companies in the energy-saving and environmental protection industry sector of China's Shanghai and Shenzhen A-share markets were selected as green companies, The rest of the stocks in China's Shanghai and Shenzhen A stock markets were selected as non-green stocks. Stocks with data missing for more than one year are excluded, and stocks of companies with operating anomalies that are suspected to be shells are also excluded. To prevent the effect of extreme values of stock returns, we winsorize the entire stock sample by 1% and 99%. Finally, 145 green concept stocks and 1789 non-green concept stocks are selected. The market portfolio return is the monthly return of CSI 300 index. Risk-free rate is the 3-month return to maturity of China Bonds. The data comes from CSMAR database.

2. Construction of green factor

In order to eliminate the correlation between the green sentiment factor and the green efficiency factor and green stock returns within the same green sector, all stocks within the sample are used in the construction of the factors. In order to allow for an even distribution of green concept stocks in each portfolio, the divisions used in the construction of the factors are based on the median of the green concept stock index. The construction of the Green Sentiment and Green Efficiency factors below continues to follow this methodology.

We choose a $2 \times 2 \times 2$ method for grouping. The book-to-market ratio $\frac{B_{t-1}}{M_{t-1}}$ of green concept stocks in December of year t-1, and the market capitalization$M_t$of green concept stocks in June of year t are used as the basis for grouping all stock samples for the period from July of year t to June

of year t+1 . The median market capitalization of green concept stocks M_t is used to classify all stock samples into small and large market capitalization groups: B, S. The median book-to-market ratio of green concept stocks $\frac{B_{t-1}}{M_{t-1}}$ is used to classify all stock samples into low and high groupings: L, H. A total of four stock portfolios are obtained: S/L, S/H, B/L, B/H. Based on whether or not the stocks in the 4 groups are green concept stocks: G, NG. The 4 groups of stock combinations are further divided into two separate groups, resulting in 8 groups of combinations: S/L/G, S/L/NG, S/H/G, S/H/NG, B/L/G, B/L/NG, B/H/G, B/H/NG. The observed value of the value factor is the difference in return between the stock portfolios of firms with small market capitalization and firms with large market capitalization each month. Observations for the book-to-market ratio factor are the monthly difference in returns between the stock portfolios of companies with high book-to-market ratios and those with low book-to-market ratios. The observed value of the green factor is the difference in return between a portfolio of green concept stocks and a portfolio of non-green concept stocks each month. The formulas are as follows:

$$SMB_1 = \frac{1}{4}(\mathrm{S/L/G} + \mathrm{S/L/NG} + \mathrm{S/H/G} + \mathrm{S/H/NG}) - \frac{1}{4}(\mathrm{B/L/G} + \mathrm{B/L/NG} + \mathrm{B/H/G} + \mathrm{B/H/NG}) \quad (6)$$

$$HML_1 = \frac{1}{4}(\mathrm{S/H/G} + \mathrm{S/H/NG} + \mathrm{B/H/G} + \mathrm{B/H/NG}) - \frac{1}{4}(\mathrm{S/L/G} + \mathrm{S/L/NG} + \mathrm{B/L/G} + \mathrm{B/L/NG}) \quad (7)$$

$$GF = \frac{1}{4}(S/L/G + S/H/G + B/L/G + B/H/G) - \frac{1}{4}(S/L/NG + S/H/NG + B/L/NG + B/H/NG) \quad (8)$$

3. Construction of Green Mood Factor and Green Efficiency Factor

We choose a $2 \times 2 \times 2$ method for grouping. The book-to-market ratio $\frac{B_{t-1}}{M_{t-1}}$ of green concept stocks in December of year t-1, and the market capitalization$M_t$of green concept stocks in June of year t are used as the basis for grouping all stock samples for the period from July of year t to June of year t+1, The median market capitalization of green concept stocks M_t is used to classify all stock samples into small and large market capitalization groups: B, S. The median book-to-market ratio of green concept stocks $\frac{B_{t-1}}{M_{t-1}}$ is used to classify all stock samples into low and high groupings: L, H. A total of four stock portfolios are obtained: S/L, S/H, B/L, B/H.

According to the characteristics of green sentiment: low stock turnover represents high green sentiment and high stock turnover represents low green sentiment. Therefore, based on the median rate of turnover of green concept stocks, the above four stock portfolios are subdivided into a high green sentiment group and a low green sentiment group: M, NM. Get 8 stock combinations: S/L/M, S/L/NM, S/H/M, S/H/NM, B/L/M, B/L/NM, B/H/M, B/H/NM. Then, based on whether the stocks in the 8 groups are green concept stocks G, NG, there are 16 groups of stock combinations: S/L/M/G, S/L/M/NG, S/H/M/G, S/H/M/NG, B/L/M/G, B/L/M/NG, B/H/M/G, B/H/M/NG and S/L/NM/G, S/L/NM/NG, S/H/NM/G, S/H/NM/NG, B/L/NM/G, B/L/NM/NG, B/H/NM/G, B/H/NM/NG. The observed value of the green sentiment factor is the monthly green sentiment high portfolio return on green concept stocks minus the green sentiment low portfolio return on non-green concept stocks:

$$GMF = \frac{1}{4}(S/L/M/G + S/H/M/G + B/L/M/G + B/H/M/G) - \frac{1}{4}(S/L/NM/NG + S/H/NM/NG + B/L/NM/NG + B/H/NM/NG) \quad (9)$$

According to the characteristic that efficient companies can generate positive externalities: high ROI represents high efficiency and low ROI represents inefficiency. Therefore, based on the median ROI of green concept stock companies, the above four stock portfolios are subdivided into high efficiency and low efficiency groups: HE, LE. We obtained 8 stock combinations: S/L/LE, S/L/HE, S/H/LE, S/H/HE, B/L/LE, B/L/HE, B/H/LE, B/H/HE, and 16 stock combinations based on whether or not the stocks in the 8 combinations are the green stocks G, NG: S/L/HE/G, S/L/HE/NG, S/H/HE/G, S/H/HE/NG, B/L/HE/G, B/L/HE/NG, B/H/HE/G, B/H/HE/NG and S/L/HE/G, S/L/HE/G, B/L/HE/G, B/H/HE/NG. HE/NG, B/L/HE/G, B/L/HE/NG, B/H/HE/G, B/H/HE/NG and S/L/LE/G, S/L/LE/NG, S/H/LE/G, S/H/LE/NG, B/L/LE/G, B/L/LE/G, B/L/LE/NG, B/H/LE/G, B/H/LE/NG. The observed value of green efficiency factor is the efficient portfolio of green concept stocks minus the inefficient portfolio of non-green concept stocks each month:

$$GEF = \frac{1}{4}(S/L/HE/G + S/H/HE/G + B/L/HE/G + B/H/HE/G) - \frac{1}{4}(S/L/LE/NG + S/H/LE/NG + B/L/LE/NG + B/H/LE/NG) \quad (10)$$

Then the market capitalization factor and book-to-market ratio factor are:

$$SMB_{\mathrm{E}} = \frac{1}{8}\ (\mathrm{S/L/HE/G} + \mathrm{S/L/HE/NG} + \mathrm{S/H/HE/G} + \mathrm{S/H/HE/NG} + \mathrm{S/L/LE/G}, + \mathrm{S/L/LE/NG} + \mathrm{S/H/LE/G} + \mathrm{S/H/LE/NG}) - \frac{1}{8}(\mathrm{B/L/HE/G} + \mathrm{B/L/HE/NG} + \mathrm{B/H/HE/G} + \mathrm{B/H/HE/NG} + \mathrm{B/L/LE/G} + \mathrm{B/L/LE/NG} + \mathrm{B/H/LE/G} + \mathrm{B/H/LE/NG})\ (11)$$

$$HML_{\mathrm{E}} = \frac{1}{8}\ (\mathrm{S/H/HE/G} + \mathrm{S/H/HE/NG} + \mathrm{S/H/HE/G} + \mathrm{S/H/HE/NG} + \mathrm{S/H/LE/G}, + \mathrm{S/H/LE/NG} + \mathrm{S/H/LE/G} + \mathrm{S/H/LE/NG}) - \frac{1}{8}(\mathrm{B/L/HE/G} + \mathrm{B/L/HE/NG} + \mathrm{B/L/HE/G} + \mathrm{B/L/HE/NG} + \mathrm{B/L/LE/G} + \mathrm{B/L/LE/NG} + \mathrm{B/L/LE/G} + \mathrm{B/L/LE/NG})\ (12)$$

$$SMB_{\mathrm{M}} = \frac{1}{8}\ (\mathrm{S/L/M/G} + \mathrm{S/L/M/NG} + \mathrm{S/H/M/G} + \mathrm{S/H/M/NG} + \mathrm{S/L/NM/G}, + \mathrm{S/L/NM/NG} + \mathrm{S/H/NM/G} + \mathrm{S/H/NM/NG}) - \frac{1}{8}(\mathrm{B/L/M/G} + \mathrm{B/L/M/NG} + \mathrm{B/H/M/G} + \mathrm{B/H/M/NG} + \mathrm{B/L/NM/G} + \mathrm{B/L/NM/NG} + \mathrm{B/H/NM/G} + \mathrm{B/H/NM/NG})\ (13)$$

$$HML_{\mathrm{M}} = \frac{1}{8}\ (\mathrm{S/H/M/G} + \mathrm{S/H/M/NG} + \mathrm{S/H/M/G} + \mathrm{S/H/M/NG} + \mathrm{S/H/NM/G}, + \mathrm{S/H/NM/NG} + \mathrm{S/H/NM/G} + \mathrm{S/H/NM/NG}) - \frac{1}{8}(\mathrm{B/L/M/G} + \mathrm{B/L/M/NG} + \mathrm{B/L/M/G} + \mathrm{B/L/M/NG} + \mathrm{B/L/NM/G} + \mathrm{B/L/NM/NG} + \mathrm{B/L/NM/G} + \mathrm{B/L/NM/NG})\ (14)$$

Then SMB_2 and HML_2 are：

$$SMB_2 = \frac{1}{2}(SMB_M + SMB_E)\ (15)$$

$$HML_2 = \frac{1}{2}(HML_M + HML_E)\ (16)$$

Results and discussion

Table 1 Mean Monthly Returns of 25 Groups of green concept companies stock in the Sample Interval (%)

	Low	2	3	4	high
Panel A: SIZE-BM					

small	9.69	9.46	9.37	9.07	8.86
2	9.65	9.41	8.83	8.60	9.16
3	9.87	9.40	8.89	8.47	8.40
4	9.57	9.34	8.89	8.33	8.17
big	8.99	8.48	8.23	7.18	5.56
			Panel B: SIZE-MOOD		
small	8.61	9.01	9.42	9.40	10.13
2	8.27	8.50	9.28	9.26	9.97
3	8.01	8.68	9.24	9.11	10.04
4	7.84	8.83	8.96	9.47	9.73
big	6.15	8.01	8.87	9.20	8.96
			Panel C: SIZE-EFFECT		
small	9.04	9.34	9.85	9.61	9.53
2	9.22	8.82	8.98	8.90	9.78
3	9.10	9.03	8.95	9.04	8.82
4	9.00	8.82	8.97	8.98	8.57
big	8.43	8.51	8.13	7.88	6.13

Table 1 reports the average monthly returns of each group after the 145 listed company stocks selected by the Green Concepts sector were categorized into 25 groups based on the market capitalization to book-to-market ratio, market capitalization size and green sentiment indicator, and market capitalization size and green efficiency indicator, respectively, from July 2016 to June 2023. From Panel A, it can be seen that the market capitalization size and book-to-market ratio of green concept companies change inversely with stock returns have obvious scale and value effects, which is consistent with the findings of the traditional FF three-factor model. From panel B, it can be seen that the green sentiment indicator of green concept companies changes positively with stock return has a significant green sentiment effect. This indicates that the green sentiment factor positively affects the stock return of green concept companies. From panel C, it can be observed that when the market capitalization is small, the green efficiency index of green concept companies has a significant green efficiency effect with positive changes in stock returns. When the market

capitalization is large, the green efficiency indicators of green concept companies change inversely with stock returns, and the green efficiency effect is not obvious. This may be due to the fact that when green concept companies are small in size, they do not attract the attention of the society, and their green technological innovations will not be emulated by most companies. Therefore, they will gain more excess returns by virtue of their productivity that is better than the average level of the society. When the green concept company is large, its technology can represent the technological direction of this industry to a certain extent, and technological innovation will cause small companies in the industry to follow and imitate. This makes the production efficiency brought by technological innovation to be captured by most of the companies and makes it difficult to obtain excess returns.

Table 2 FF three-factor model regression results for green concept companies

explanatory variable	(1)	(2)	(3)
Equity Portfolio Returns	SIZE-BM	SIZE-MOOD	SIZE-EFFECT
β_{MKT}	1.012^{***}	1.014^{***}	1.011^{***}
	(41.99)	(46.21)	(40.50)
β_{SMB}	0.342^{***}	0.327^{***}	0.327^{***}
	(6.37)	(5.68)	(5.47)
β_{HML}	-0.029	-0.091^{***}	-0.820^{*}
	(-0.44)	(-2.88)	(-1.85)
c	0.006^{***}	0.007^{***}	0.006^{***}
	(2.82)	(4.12)	(3.99)
sample size	1925	1925	1925
Adjust R^2	0.5064	0.5642	0.5734

The t-statistics are in parentheses. ***, **, * indicate significant at the 1%, 5%, and 10% levels, respectively.

Table 2 was further analyzed by regression using the Fama-French three-factor model. Column 1 shows the regression results for the grouping of stocks based on market capitalization size and book-to-market ratio. Column 2 shows the regression results for the grouping of stocks based on market capitalization size and green sentiment indicator. Finally, column 3 shows the regression

results for the grouping of stocks based on market capitalization size and green efficiency indicator. All three columns are regressed with random effects, applying panel regressions. The empirical results show that the market factor, market capitalization size factor and book-to-market ratio factor in the regressions of the other groups significantly affect the return of green concept stocks, except for the book-to-market ratio factor which is not significant under the grouping of column 1. It supports the empirical findings of Panel A in table 1. The significant constant term is inconsistent with the theoretical assumptions of Fama-French, which suggests that the FF three-factor model does not adequately explain the excess return of green concept stocks, and that there should be other factors affecting the return of green concept stocks other than the three factors.

Table 3 Green four-factor redundancy test

Explanatory variable	MKT	SMB	HML	GF
alpha	0.073^{***}	0.006^{***}	0.015^{***}	0.016^{***}

***, **, * indicate significant at the 1%, 5%, and 10% levels, respectively.

The above analysis shows that the FF three-factor model does not fully explain the excess returns of green concept stocks. Therefore, a green four-factor model is constructed by introducing the green factor based on the three-factor model, which is used to strengthen the explanation of the excess returns of green concept stocks. Before conducting the empirical analysis, we first verified that the green factor is not redundant relative to the three FF factors. The "green four-factor model redundancy test" is a regression of the returns of three factors to explain the return of the fourth factor, with the constant term representing the risk premium of the factor after risk adjustment for the other four factors. If the constant term in a regression on a factor is significantly non-zero, it means that the other factors do not fully explain this factor, indicating that this factor is not redundant. The regression results indicate that after the risk adjustment of several other factors, green concept stocks still have significant market risk, size effect, book-to-market ratio effect and green factor effect. The risk premium of the green factor is still significantly greater than 0 after the adjustment of the three FF factors, which preliminarily indicates that the green factor significantly and positively compensates for the unique risks faced by green concept stocks. The fact that the green factor is not a redundant factor also indicates the existence and independence of the green factor.

Table 4 Green four-factor model regression results for green concept companies

explanatory variable	(1)	(2)	(3)
Equity Portfolio Returns	SIZE-BM	SIZE-MOOD	SIZE-EFFECT
β_{MKT}	0.986^{***}	0.990^{***}	0.989^{***}
	(43.36)	(44.88)	(40.01)
β_{SMB}	0.311^{***}	0.299^{***}	0.301^{***}
	(6.16)	(5.34)	(5.35)
β_{HML}	0.099	0.025	0.027
	(1.35)	(0.80)	(0.52)
β_{GF}	0.183^{***}	0.166^{***}	0.156^{***}
	(5.50)	(6.08)	(4.17)
c	0.009^{***}	0.009^{***}	0.009^{***}
	(4.44)	(6.08)	(5.82)
sample size	1925	1925	1925
Adjust R^2	0.5168	0.5736	0.5820

The t-statistics are in parentheses. ***, **, * indicate significant at the 1%, 5%, and 10% levels, respectively.

Table 4 Green four-factor model constructed using equation (4). Column 1 shows the regression results for the grouping of stocks based on market capitalization size and book-to-market ratio. 2nd column shows the regression results for the grouping of stocks based on market capitalization size and green sentiment indicator. And finally, column 3 shows the regression results for the grouping of stocks based on market capitalization size and green efficiency indicator. All three columns are regressed with random effects and panel regression is applied. The results of the three-column regression show that there is a significant positive effect of the green factor on the returns of green concept stocks, which also indicates that green concept stocks have higher returns in relation to non-green concept stocks. The effect of market factor and market capitalization size factor on the portfolio of green concept stocks did not change significantly. However, the effect of book-to-market ratio factor on the return of green concept stocks changed from significant for both groups in table 2 to non-significant for all in table 4. The increased adjusted R^2 compared to table2

likewise suggests that the green four-factor model has stronger explanatory power for the excess returns of green concept stocks. However, the three sets of regression constant terms are still significantly greater than 0 at the 1% level, indicating that the green factors are not yet able to fully explain the excess returns of green concept stocks. Therefore, we refine the factors constituting green excess returns into green sentiment factor and green efficiency factor, and construct a green five-factor model to explain the excess return of green concept stocks.

Table 5 Green five-factor redundancy test

explanatory variable	MKT	SMB	HML	GMF	GEF
alpha	0.074^{***}	0.012^{***}	-0.018^{***}	0.023^{***}	0.017^{***}

***, **, * indicate significant at the 1%, 5%, and 10% levels, respectively.

Similarly, before empirically analyzing the green five-factor model, it is first necessary to verify whether the green sentiment factor and the green efficiency factor are redundant factors with respect to the other four factors. The regression results show that after risk adjustment for several other factors, green concept stocks still have significant market risk, size effect, book-to-market ratio effect, green sentiment effect and green efficiency effect. The risk premiums of the green sentiment factor and the green efficiency factor are still significantly greater than 0 after the FF three-factor adjustment, which preliminary suggests that these two factors have significant positive return compensation for people's green investment beliefs and the positive externalities brought by green companies through efficient production. The fact that the green sentiment factor and the green efficiency factor are not redundant also indicates the existence and independence of these two factors.

Table 6 Green five-factor model regression results for green concept companies

explanatory variable	(1)	(2)	(3)
Equity Portfolio Returns	SIZE-BM	SIZE-MOOD	SIZE-EFFECT
β_{MKT}	1.005^{***}	1.007^{***}	1.005^{***}
	(43.12)	(48.36)	(48.54)
β_{SMB}	0.290^{***}	0.281^{***}	0.273^{***}
	(12.25)	(13.30)	(13.00)

β_{HML}	0.610^{*}	-0.106	0.010
	(1.78)	(-0.34)	(0.33)
β_{GMF}	0.041^{**}	0.042^{**}	0.032^{*}
	(2.03)	(2.32)	(1.77)
β_{GEF}	0.089^{***}	0.076^{***}	0.097^{***}
	(4.00)	(3.90)	$(5..02)$
c	0.009	0.009^{*}	0.009
	(0.91)	(1.77)	(1.07)
sample size	1925	1925	1925
Adjust R^2	0.5788	0.6274	0.6235

The t-statistics are in parentheses. ***, **, * indicate significant at the 1%, 5%, and 10% levels, respectively.

Table 6 Green four-factor model constructed using equation (5). Column 1 shows the regression results for the grouping of stocks based on market capitalization size and book-to-market ratio. Column 2 shows the regression results for the grouping of stocks based on market capitalization size and green sentiment indicator, and in column 3 we observe the regression results for the grouping of stocks based on market capitalization size and green efficiency indicator. All three columns are regressed with random effects, applying panel regressions. The green sentiment factor is significantly positive at the 5% level in the regression results in columns 1 and 2. The regression results in column 3 are significantly positive at the 10% level. The green efficiency factors are all significantly positive at the 1% level. The regression results show that green concept stocks rely on investors' green investment behavior and positive externalities in return compensation to have higher rates of return compared to non-green concept stocks, even after taking into account the market factor, size factor, and book-to-market ratio factor. This rate of return essentially compensates for the investment risk and business risk of green concept stocks. In addition, compared to the FF three-factor model and the green four-factor model, the constant term of the green five-factor model is basically insignificant, while the adjusted R^2 increases. This suggests that the factor model after the addition of the green sentiment factor and the green efficiency factor has a stronger explanatory power for the excess return of green concept stocks.

Our green five-factor model also further describes that green investors' green investment

behavior based on their own green sentiment and green policy orientation exposes green investors to specific green investment risks, which come from the uncertainty of the development of green industries. However, the fact that the green sentiment factor is significantly greater than 0 also indicates that green investors are compensated for this specific risk, which allows them to gain more than investing in general securities. Green companies rely on their own innovations in production technology to enable production that exceeds the general level of production in society and contributes to environmental protection and the efficient use of resources. This efficient production behavior brings positive externalities to society and the badlands, and green companies are undervalued and expected to see their earnings rise. This comprise the excess returns of green concept companies, which cannot be fully captured by a single green factor, so a green sentiment factor and a green efficiency factor should be introduced to explain green excess returns in more detail. Investors' green investment sentiment comes from investors' own environmental investment beliefs, confidence in green concept companies and policy orientation. It can be explained by the theory of behavioral finance, which is highly subjective. Therefore, the green sentiment factor is a non-systematic risk pricing factor, which portrays the return and risk characteristics associated with green concept companies and investors' psychological attributes. And in a longer period of time, green technology will coexist with traditional technology, and it takes time for green and efficient technology to replace traditional technology. This is the uncertainty of green development, therefore, the green efficiency factor derived from the risk of green development is a systematic pricing factor that portrays the return and risk characteristics of listed companies related to environmental attributes.

Conclusion

We test whether there is a green sentiment effect and a green efficiency effect for green concept stocks in the Chinese stock market. Using the theory of green investment sentiment in behavioral finance and the theory of positive externalities generated by green firms in microeconomics, and with reference to FF's stock discount model, the basis for adding the green sentiment factor and green efficiency factor is discussed. Then the green five-factor model is constructed by introducing the green sentiment factor and green efficiency factor based on FF's three-factor model. The stocks

market data from July 2016 to June 2023 are used to empirically test the excess return of green concept stocks in China. Two research conclusions are obtained:

(1) The green factor is constructed based on our selection of green concept stocks, which in turn yields the green four-factor model. Through the factor redundancy test, it can be seen that the green factor is not explained by the FF three factors, indicating the independence of the existence of the green factor. The empirical results show that the green factor significantly and positively affects the return of green concept stocks, indicating that green incentives do exist in green concept stocks. However, the green factor cannot fully explain the excess return of green concept stocks.

(2) We use investors' green investment behavior and positive external benefits generated by green companies as the basis for green companies to obtain excess returns. The green factor is further subdivided into the green sentiment factor and green efficiency factor by using the stock turnover rate and the company's return on investment as the proxy variables for the green sentiment factor and green efficiency factor. The factor redundancy test shows that the green sentiment factor and the green efficiency factor cannot be explained by the three FF factors, which signifies the independence of the existence of the two factors. The empirical results show that the green sentiment factor and green efficiency factor significantly and positively affect the return of green concept stocks. It reveals that investors recognize the growth of green concept listed companies and the formation of green investment culture. It also implies that the production high efficiency brought by the production technology innovation carried out by green concept listed companies creates future expected returns. And the green five-factor model can better explain the risk premium of green concept stocks. However, whether the green sentiment effect and green efficiency effect are effective in the long run needs to be further verified.

Overall, China has made great progress in upgrading green industries and guiding green development, and the difficulties faced by green concept companies, such as difficulties in financing and R&D, are being eliminated. In order to better guide the development of green industries in the future, the government and the financial system need to formulate and introduce relevant policies and adjustment mechanisms to promote the construction of basic conditions for the development of green finance. It should be the case especially for green technology assessment and environmental risk evaluation, so as to guide the market to incentivize companies with a high green content and to form a green investment culture across the whole market, the whole industry, and even the whole

financial system. And it will help to improve the business ecology of green development in industrial upgrading.

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