

On the Impact of Enterprise Green Innovation Investment on Stock Return Taking the Steel Industry as an Example

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Abstract: This paper selects the data publicly disclosed by 16 listed companies in the steel industry in China's stock market from 2015 to 2021, adds the green innovation investment factor to the traditional Fama-French three factor model, and constructs a Fama-French four factor model to conduct empirical test and regression analysis on the listed steel enterprises. Through the analysis results of the explanatory power of the four factor model to the company's stock return, this paper studies the impact of the company's green innovation investment on the company's stock return, and finds that there is an obvious positive correlation between the listed company's green innovation investment and the stock return. The research results will guide the inflow of capital into the green field, help traditional enterprises to increase investment in green innovation, transform to green industry, and promote the realization of the "double carbon" goal and industrial transformation and upgrading.

Keywords: Green innovation investment, Fama-French model, Stock return, Steel industry.

1. Introduction

Since green development has become one of the five development concepts, the proposal of the "double carbon" goal has pushed China's social green development to a new climax. For more developed countries, China's stock market started late, its development is not mature, and the relevant systems, laws and regulations are not perfect. At present, there are still many problems, such as more retail investors and serious speculation psychology of investors.

The academic research on asset pricing has never stopped. Among them, Fama-French three factor model proposed in 1993 has been widely spread and highly recognized. Carhart (1997) constructed the dispatch factor and expanded the three factor model into a four factor model [1]. Fama-French adds profit factor RMW and investment factor CMA on the basis of the original three factor model and expands it into a five factor model. Its performance is generally better than the three factor model in the practical test in the foreign market, realizes a new breakthrough in the field of factor model, and makes people have a deeper understanding of asset pricing and capital market risk. However, in China, the asset pricing in the securities market is still based on the three factor model. There are also great differences on the applicability of the five factor model in the domestic capital market. In addition, there are relatively few studies on factor models of specific industries in China. In recent years, China's iron and steel industry has developed very rapidly, and its iron and steel output has ranked first in the world for 20 consecutive years. It is a major carbon emitter. Under the requirements of the "double carbon" goal, actively promoting green and low-carbon development has become a hard requirement. Therefore, this paper adds green innovation investment factors to the three factor model and constructs a four factor model, which is of great significance for the empirical analysis of iron and steel enterprises in China's A-share market [2].

2. Literature Review

In terms of concept, Braun (2007) defines green innovation as the activity of enterprises to develop or improve technologies, products or processes to reduce environmental pollution, energy and raw material consumption [3]. In terms of classification, Stephen Wilkins (2014) believes that enterprise green innovation can be divided into innovation in technology, production and marketing to reduce environmental pollution through multiple channels [4]. Li Jieyi, Zhang mercury and Xie Linna (2019) believe that green innovation is divided into product and process innovation, which are described from the aspects of product itself and the process, method and equipment of producing products [5].

As a developing country and a large manufacturing country, manufacturing plays an important role in China's national economic system. For the heavily polluting steel industry, green innovation is to reduce the damage to the environment through innovation and realize green development. Jiang Yuhan, Luo Yangmei and Yun Ruili (2018) measured green innovation investment in terms of the proportion of R & D personnel, the ratio of green R & D funds, the profit margin of green product sales and the market share of green products [6]. Wang Caiming and Li Jian (2019) believe that green innovation investment capacity refers to the ability of enterprises to invest substantive resources in the process of green innovation activities, and set the indicators to measure enterprises' green innovation investment as R & D personnel, R & D funds, new product development funds, technology introduction and transformation funds, environmental pollution control funds, energy consumption, etc. [7]. Scholars have made detailed research on the impact of green innovation investment on enterprise management, but the relevant conclusions have not yet formed a unified conclusion. Bosoworth and Rogers (2001) found a positive correlation between green innovation investment and financial performance through empirical analysis [8]. Zhang Xiaoyun

(2019) focused his research on listed manufacturing enterprises and selected R & D personnel and R & D capital investment as indicators to measure green innovation investment. Through empirical test, it was found that the more green innovation investment, the higher the financial performance of enterprises, and the promotion of capital investment is due to the number of personnel [9]. Xu Xiuyan (2019) concluded that there was a significant positive correlation between green innovation investment and environmental accounting information disclosure through the analysis of the empirical data of A-share industrial listed enterprises in Shanghai and Shenzhen. However, some scholars believe that there is great uncertainty in the impact of green innovation investment on enterprise financial performance and operating efficiency. Even if it exists, it also lags behind, that is, it is difficult to show it in a short time [10].

Wu Jianzu and Fan Huiling (2021) found through empirical research that the relationship between green innovation investment and enterprise financial performance is not linear, but the result of the joint influence of multiple complex factors [11].

3. Research Design

3.1. Research Data Selection and Processing

In order to analyze the impact of green innovation investment on the stock price of listed enterprises in the steel sector of A-share market, this paper introduces the green innovation investment factor on the basis of Fama-French three factors to construct a four factor model, and selects 16 representative listed steel stocks in the steel sector of A-share market. The specific stock information is shown in Table 1.

Table 1. Representative stocks of steel sector on January 5, 2018

Securities code	Abbreviation	Listing date	Total market value of individual shares per day (thousand yuan)
000709	Hegang Co., Ltd	1997-04-16	24316611.98
000717	Shaogang Songshan	1997-05-08	8323163.97
000778	Xinxing cast pipe	1997-06-06	18996589.64
000825	Tisco stainless steel	1998-10-21	31785062.7
000898	Angang Steel Co., Ltd	1997-12-25	27330863.14
000932	*ST Valin	1999-08-03	36615752.24
000959	Shougang Co., Ltd	1999-12-16	33237379.09
002075	Shagang Co., Ltd	2006-10-25	10393895.05
002110	Sanminguang	2007-01-26	16352013.51
600010	Baotou Steel Co., Ltd	2001-03-09	83876460.07
600019	Baosteel Co., Ltd	2000-12-12	134946574
600022	Shandong Iron and steel	2004-06-29	17405013.89
600282	Nangang Co., Ltd	2000-09-19	22245881.38
600782	Xingang Co., Ltd	1996-12-25	17665523.74
600808	Ma'anshan Iron and Steel Co., Ltd	1994-01-06	22617776.99
601005	*ST heavy steel	2007-02-28	14833440.87

Source: Guotai'an database

This paper is based on previous studies. In order to make the collected data more effectively test the relevant conclusions, the selected sample interval is from January 2015 to December 2021. Each stock has 84 monthly yield data (considering cash dividend reinvestment). This period includes bull and bear markets, showing a relatively complete stock market cycle. The data related to individual stocks involved in the empirical analysis of this paper comes from Guotai'an database, and the enterprise financial data comes from the information disclosure of listed companies and local statistical yearbooks. The original data are preliminarily sorted out by using Excel 2019 software.

The risk-free rate of return in this paper must be the interest rate of one-year time deposit. In the sample range, one-year time deposit has been adjusted for five times. The interest rate shows a downward trend on the whole. The interest rate of one-year time deposit is monthly as the use cost of funds.

Due to the differences in the nature and dimension of indicators of different green innovation investment factors, it is impossible to directly synthesize comprehensive evaluation indicators. In order to eliminate the impact of this difference on the results, it is necessary to deal with each evaluation index dimensionless. The specific formula is as follows:

$$v_{ij} = \frac{x_{ij} - \min(x_j)}{\max(x_j) - \min(x_j)} \quad (1)$$

$$v_{ij} = \frac{\max(x_j) - x_{ij}}{\max(x_j) - \min(x_j)} \quad (2)$$

Where, v_{ij} is the dimensionless of the i -th evaluation object and the j -th index, x_{ij} is the original value of the j th index of the i th evaluation object, and $\max(x_j)$ and $\min(x_j)$ are the maximum and minimum values respectively.

3.2. Factor Construction

This paper selects the index sample to measure the size of the stock. The total market value is the circulating market value of individual shares in the month, which is obtained by multiplying the stock price at the end of the month by the total number of shares. Taking this as the standard, this paper constructs the scale factor (SMB). The book to market ratio factor (HML) is the ratio of book value (BE) to market value (ME). The book value is the net assets per share in the fiscal year $t-1$ published in t , and the market value is the stock price at the end of $t-1$. Then the scale factor and book to market value ratio are introduced into the CAPM model to form a three factor model [12]. The basic formula is:

$$E(R_{it}) - R_{ft} = \beta_i E(R_{mt} - R_{ft}) + \gamma_i E(SMB_t) + \delta_i E(HML_t) + \varepsilon_{it} \quad (3)$$

Where, $E(R_{it})$ represents the actual portfolio yield; R_{ft} stands for risk-free rate of return; $E(R_{mt} - R_{ft})$ represents the return rate of market risk portfolio; $E(SMB_t)$ represents the return rate of market value scale factor in period t ; $E(HML_t)$ represents the yield of the book to market ratio factor in period t ; β_i represents the risk coefficient of the stock

market; δ_i represents the market value scale factor coefficient; γ_i represents the book to market ratio factor coefficient; ε_{it} stands for residual term [13].

As for the construction of green innovation investment factors, based on comprehensiveness and scientificity, this paper selects three primary indicators of human resources, capital and energy, and six secondary indicators under three primary indicators to establish a comprehensive evaluation system of green innovation investment (see Table 2).

Table 2. Evaluation index system of green innovation investment

Evaluation object	Primary index	Secondary index
Green Innovation Investment	Manpower input	Full time equivalent of R & D personnel
	Capital input	Internal expenditure of R & D funds
		New product development funds
		Technology introduction and transformation funds
	Energy input	Environmental pollution control funds
		Total industrial energy consumption

The entropy weight method is used to give the corresponding weight to the selected input indexes, synthesize each index and calculate a comprehensive index, and then rank all target stocks according to the green innovation input index from large to small to define the green innovation input factor variables.

① Calculate the characteristic proportion of the i -th evaluation object under the j -th index of the object to be evaluated.

$$p_{ij} = \frac{v_{ij}}{\sum_{i=1}^m v_{ij}} \quad (4)$$

Due to $0 \leq v_{ij} \leq 1$, so $0 \leq p_{ij} \leq 1$.

② Calculate the entropy value of the j -th index by using the calculated characteristic proportion of the index.

$$e_{ij} = -\frac{1}{\ln m} \sum_{i=1}^m p_{ij} \ln p_{ij} \quad (5)$$

When $p_{ij}=0$, or $p_{ij}=1$, $p_{ij} \ln p_{ij}=0$.

③ Calculate the entropy weight of the j -th index.

$$w_{ij} = \frac{1-e_{ij}}{n-\sum_{j=1}^n e_{ij}} \quad (6)$$

④ Determine the comprehensive score of each evaluation object.

$$z_i = \sum_{j=1}^n w_{ij} v_{ij} \quad (7)$$

The weight of each evaluation index of green innovation investment is shown in Table 3:

Table 3. Weight of each index of green innovation investment evaluation

Evaluation object	Primary index	Weight	Secondary index	Weight
Green Innovation Investment	Manpower input	0.3622	Full time equivalent of R & D personnel	1.0000
	Capital input	0.4264	Internal expenditure of R & D funds	0.2622
			New product development funds	0.4105
			Technology introduction and transformation funds	0.1601
	Energy input	0.2114	Environmental pollution control funds	0.1672
			Total industrial energy consumption	1.0000

3.3. Construction of Model

This paper infers that the green innovation investment factor can directly affect the change of portfolio return. On the basis of FF three factors, the green innovation investment factor (GII) constructed by the enterprise's green innovation investment is introduced to test whether the change of enterprise's green innovation investment can cause a significant change in the return of stock portfolio.

$$GII_t = \frac{gii_t - gii_{t-1}}{gii_{t-1}} \quad (8)$$

Where, GII_t is the change rate of investment in month t compared with the previous month, gii_t is the investment factor index of green innovation in month t . The four factor model formula after adding the green innovation input factor (gii_t) is as follows:

$$R_{it} - R_{ft} = \theta_i + \beta_j (R_{mt} - R_{ft}) + \gamma_i SMB_t + \delta_j HML_t + \theta_i gii_t + e_{it} \quad (9)$$

Where, $R_{it} - R_{ft}$ is the excess return of stock portfolio i in period t , $R_{mt} - R_{ft}$ is the market premium factor in period t , SMB_t is the scale factor of t period, HML_t is the ratio factor of book value to market value in period t , θ_i is the intercept term, e_{it} is the residual term, β_j , γ_i , δ_i , θ_i are the factor coefficients.

Based on the results of regression analysis, this paper puts forward the following assumptions:

H0: green innovation investment factor is an important factor affecting the return of stock portfolio.

4. Empirical Analysis

4.1. Stationarity test and factor correlation analysis

The stability test of the newly added green innovation

investment factor (GII) is carried out, and the results are shown in Table 4:

Table 4. ADF test results of green innovation input factors

Variable	ADF value	P value	1% critical value	5% critical value	10% critical value	Conclusion
GII	-9.378	0.0000	-3.732	-2.670	-2.879	stable

The test result of green innovation input factor is less than the critical value of 1% confidence interval, which proves that it is stable at 1% confidence level. The multicollinearity test after correlation test and regression analysis of the four explanatory variable factors in the four factor model is shown in Table 5:

Table 5. Results of four factor correlation test

	$R_m - R_f$	SMB	HML	DII
$R_m - R_f$	1.0000	0.1975	0.0193	-0.3507
SMB	0.1975	1.0000	-0.6137	0.3757
HML	0.0193	-0.6137	1.0000	-0.4682
DII	-0.3507	0.3757	-0.4682	1.0000

Table 6. Results of four factor multicollinearity test

	VIF	1/VIF
$R_m - R_f$	1.32	0.757576
SMB	1.78	0.561798
HML	1.83	0.546448
DII	1.39	0.719424
Mean VIF	1.58	0.632911

Table 7. Regression results of four factor model

Investment portfolio	BH	BM	BL	MH	MM
∂_i	-0.0058*** (30.38)	-0.0095*** (34.16)	-0.0049*** (28.39)	-0.0093*** (38.19)	-0.0079*** (31.02)
β_j	0.9602*** (30.38)	1.1375*** (34.16)	1.0287*** (28.39)	1.1938*** (38.19)	1.0387*** (31.02)
γ_i	-0.1870*** (-3.64)	-0.0698 (-1.23)	-0.9848*** (-5.43)	0.6736*** (10.19)	0.6754*** (10.35)
δ_i	0.3675*** (-3.87)	-0.0756*** (-3.87)	-0.9754*** (-11.97)	0.0873 (1.45)	-0.4466*** (-5.79)
θ_i	0.00004 (0.79)	0.00019*** (3.97)	0.00021*** (3.07)	0.00014*** (2.75)	0.00029*** (3.56)
R^2	0.9586	0.9443	0.9385	0.9740	0.9592
	ML	SH	SM	SL	
∂_i	-0.0213*** (-5.97)	-0.0049** (-2.49)	-0.0052** (-2.97)	-0.0069*** (-3.98)	
β_j	1.0977*** (43.87)	1.0983*** (34.76)	1.0286*** (28.49)	1.0497*** (29.49)	
γ_i	0.6043*** (9.86)	0.9865*** (19.54)	0.9098*** (17.66)	1.0587*** (23.87)	
δ_i	-0.9876*** (-15.39)	-0.0287 (-0.34)	-0.3672*** (-4.86)	-0.6544*** (-6.76)	
θ_i	0.00009** (2.56)	0.00028*** (4.76)	0.00037*** (4.97)	0.00017** (2.86)	
R^2	0.9765	0.9667	0.9759	0.9874	

Note: *, ** and *** represent significance levels of 10%, 5% and 1% respectively.

From the regression results of the four factor model, the overall goodness of fit of the model is higher than 0.9,

indicating that the fitting effect of the model is very good. The fluctuation range of $R_m - R_f$ regression coefficient is within 0.9-1.1, and the P values of t test are less than 0.01, indicating that the market premium factor has a significant impact on the stock return. The overall regression coefficient of SMB is less than 1.1, and the p value is less than 0.01, indicating that the scale factor has a significant impact on the stock return. HML rejects the original hypothesis when the significance is 1%, indicating that the book to market ratio factor has a significant impact on the stock return. Among the regression results of DII, the regression coefficients of 8 portfolios are significant at the significant level of 5%. Rejecting the original hypothesis H0 and accepting the alternative hypothesis H1, it shows that the investment factor of green innovation is an important factor affecting the excess return of portfolio. Because the regression coefficients of green innovation investment factors are positive, it shows that the change of green innovation investment is positively correlated with the return of portfolio.

5. Conclusions and Suggestions

5.1. Conclusion

Based on the monthly market transaction data of 16 representative listed companies in the iron and steel industry in the A-share market from January 2015 to December 2021, this paper selects six green innovation investment agency indicators in the same period, including R & D personnel full-time equivalent, internal expenditure of R & D funds, new product development funds, technology introduction and transformation funds, environmental pollution control funds and total industrial energy consumption, and uses entropy method to construct green innovation investment factors, Empirical analysis of the impact of green innovation investment on stock returns. The main conclusions are as follows:

Green innovation investment factor is an important factor affecting the return of stock portfolio. Green innovation investment factor is positively correlated with the excess return of investment portfolio, that is, the change of enterprise green innovation investment is positively correlated with the excess return of investment portfolio. When the enterprise's investment in green innovation increases, it will develop more products with green elements and obtain sustainable competitive advantages. At the same time, it will also help to establish a good corporate image with responsibility, improve the trust of investors in the enterprise, accelerate the capital inflow and improve the excess return of shares. This shows that China's iron and steel enterprises should pay attention to green innovation investment, invest more funds and personnel to transform production processes and production equipment, reduce damage to the environment, and promote a virtuous cycle of green innovation investment and stock return of listed companies.

5.2. Suggestions

5.2.1. Government

Establish and improve laws and regulations on the development of green finance to prevent and resolve systemic risks. In recent years, in order to speed up the green transformation and continuously strengthen environmental regulation, China has put forward a series of requirements for the green and low-carbon development of enterprises, but the reward and punishment mechanism for enterprises to achieve

green innovation and development is not perfect. As an emerging development field, the relevant laws and regulations of green finance are not perfect enough. It still needs to be further improved in combination with the actual situation to make a code of conduct for all walks of life.

We will improve the regulatory system for environmental information disclosure and increase penalties for violations of laws and regulations. The regulatory authorities need to improve the regulatory system, strengthen the review of the content and quality of the financial statements of listed companies, and strengthen the punishment for financial fraud and disclosure of false information. Especially for heavily polluting industries such as steel, we should ensure the authenticity and effectiveness of the environmental information disclosed by them and protect the legitimate rights and interests of investors.

Build a green economic development system and give full play to the regulatory role of the financial market on the environment. The 14th five year plan proposes to implement the new development concept and the two important goals of "carbon peak" and "carbon neutralization". China is vigorously developing a green and low-carbon economy, gradually improving the infrastructure and supporting policy system of low-carbon economy, escorting the development of green economy and continuously promoting the development of green and low-carbon economy. As an important part of the national economy, the financial market plays an important role in environmental protection. Relevant departments can guide enterprises to accelerate green transformation, form a green and low-carbon circular economy system and help environmental protection with the help of green finance and green industry certification mechanism.

Guide enterprises to increase investment in green innovation and adhere to the coordinated development of economy and ecology. Heavy polluting industries, including the steel industry, are a major source of environmental pollution and an important barrier in the environmental protection war. The government should accelerate the transformation of such industries with high energy consumption and high pollution to efficient and clean energy, optimize the efficiency of resource allocation, improve energy utilization efficiency, give preferential policies, guide enterprises to carry out green innovation, and realize the "win-win" of national strategy and sustainable development of enterprises.

5.2.2. Enterprise

As the main body of the market, enterprises play a vital role in social and economic development. They need to ensure the sustainability of green innovation investment, fundamentally improve R & D and innovation ability, enhance their competitiveness, introduce professional knowledge talents, improve personnel's innovation consciousness and inject vitality into enterprises. While innovating, enterprises should also consciously perform their responsibilities of environmental protection, actively disclose real and effective environmental information, reduce environmental pollution and improve resource utilization efficiency.

5.2.3. Investor

Investors should deepen their understanding of the market, comprehensively consider risks and benefits, take into account environmental benefits while pursuing financial benefits, and actively pay a premium for environmental benefits. While being enthusiastic about the green cause, carefully identify the "green drift" projects and protect their

own legitimate rights and interests. At the same time, we should respond to the policy call, take the initiative to shoulder the burden of environmental protection, timely report to the relevant departments if we find that heavy polluting enterprises pollute the environment in violation of regulations, cooperate with the government to force enterprises to transform, increase investment in green innovation and improve resource utilization efficiency.

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