

Analysis of the Impact of Environmental Regulation on the Green Innovation R&D Mechanism of Equipment



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ABSTRACT: As a critical part of promoting the transformation of China's traditional manufacturing industry to intelligent manufacturing, the equipment manufacturing sector has the problems of high consumption and high pollution, which brings enormous environmental pressure and intensifies the contradiction between economic growth and environmental protection while rapidly boosting China's economic growth. To effectively deal with the relationship between economic development and environmental protection and achieve sustainable economic development, the Chinese government has introduced a series of environmental protection policies to promote the transformation of heavily polluting enterprises to green development with technological innovation as the intrinsic driving force.

This paper analyzes the annual report data of 508 listed equipment manufacturing enterprises on the main board of Shanghai and Shenzhen A-shares from 2010 to 2019, explores the current situation of R&D investment of relevant enterprises, and analyzes the influence of different factors on R&D investment rate according to the model. The study concludes that there is a significant positive correlation between the equity financing rate and environmental regulation and the R&D investment rate of enterprises. Environmental regulation can significantly enhance the correlation between the equity financing rate and the R&D investment rate of enterprises.

KEYWORDS: environmental regulation; equipment manufacturing; technological innovation; R&D investment

I. INTRODUCTION

Environmental regulation refers to the government's direct or indirect control and intervention in the resource use of enterprises for environmental protection and resource conservation ^[1]. The main instruments of government environmental regulation measures include administrative regulations, economic tools, and market mechanisms. Since the 13th Five-Year Plan, the Party Central Committee has attached great importance to the environmental problems of human existence, promoted the improvement of highly polluting enterprises through technology, and made green economic development a long-term strategy for national economic development. However, it is still controversial whether implementing environmental regulations will indirectly affect the R&D capital investment of enterprises due to the increased cost of pollution control. The Porter hypothesis suggests that implementing appropriate environmental regulations can indirectly promote enterprises' R&D and innovation activities. These R&D activities conducted by enterprises can increase their productivity in the future to offset the cost burden caused by implementing environmental regulations.

China's equipment manufacturing industry belongs to the new drive, with high-end technology levels and high value-added products. China's economic construction is essential to the strategic industrial chain support. Although China is the world's factory, the equipment manufacturing industry started late. The low-end manufacturing industry with a low profit margin accounts for a large proportion of the overall domestic demand is insufficient, and the growth rate is slow. Besides, Chinese equipment manufacturing enterprises' R&D activities mostly rely on outsourced research institutions or universities, which means the enterprise's innovation capacity is not high. High precision and core zero components depend highly on imports, and the external environment dramatically affects corporate profits.

China's manufacturing industry is in a period of intelligent and green transformation. As the backbone of the manufacturing industry, the equipment manufacturing industry is bound to be vigorously developed. However, the large amount of waste emitted in the production process causes enormous environmental pollution, contrary to the original intention of green economic development. There is an urgent need for the green transformation of the equipment manufacturing industry to alleviate the contradiction between economic growth and environmental protection. However, in green innovation, enterprises will face the limitations of low financing efficiency, differences like enterprises, and lack of risk resistance. To promote the internal driving force of enterprises to carry out green innovation, the government has introduced a series of environmental regulation policies

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from tax relief to innovation subsidies to encourage enterprises to carry out R&D activities and help them to Green innovation is a win-win situation for both economic development and environmental protection.

II. LITERATURE REVIEW

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III. EMPIRICAL ANALYSIS

1. Model variables selection

This paper selects the data from the 2010-2019 annual reports of 508 listed equipment manufacturing companies in Shanghai and Shenzhen A shares to study the impact of environmental regulations on the R&D investment of equipment manufacturing companies. It establishes a multiple regression model for regression analysis to study the influence of various factors on the equipment manufacturing industry. The degree of R&D investment of listed companies and the variables is shown in Table 1.

2. Model Establishment

(1) To investigate the relationship between equity financing ratio and R&D investment and to determine whether the amount of R&D investment of enterprises is significantly affected by financing constraints, equity financing ratio is used to explain R&D investment. We constructed Model 1.

$$R\&D = \beta_0 + \beta_1 Efr + \beta_2 Lev + \beta_3 Si + \beta_4 Own + \beta_5 Reve + \sum Year + \varepsilon \quad (1)$$

(2) To study the relationship between R&D investment and environmental regulation and verify whether environmental regulation significantly affects R&D investment. We used environmental regulation to explain enterprise R&D investment and constructed Model 2.

$$R\&D = \beta_0 + \beta_1 Regu + \beta_2 Lev + \beta_3 Si + \beta_4 Own + \beta_5 Reve + \sum Year + \varepsilon \quad (2)$$

(3) To explore whether the relationship between enterprise R&D investment rate and equity financing rate is more closely related to the existence of environmental regulations, we constructed model 3 to multiply the R&D investment rate as the dependent variable, equity financing rate as the explanatory variable, and environmental regulation intensity as the moderating variable.

$$R\&D = \beta_0 + \beta_1 Efr + \beta_2 Regu + \beta_3 Regu * Efr + \beta_4 Lev + \beta_5 Si + \beta_6 Own + \beta_7 Reve + \sum Year + \varepsilon \quad (3)$$

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Among them, $\beta_0, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7$ is the model parameter, ε is an error term.

Table 1: Variable Description

	Name	Symbol	Explanation
Explained Variables	R&D investment ratio	<i>R&D</i>	R&D Expenses/Operating Income
Explanatory variables	Equity Financing Ratio	<i>Efr</i>	Paid-in Capital/Total Assets
Adjustment variables	Environmental Regulation Intensity	<i>Regu</i>	Pollution Control Completed/Industrial added value
	Asset-liability ratio	<i>Lev</i>	Total Liabilities/Total Assets
	Total Assets	<i>Si</i>	Total Assets
	Enterprise Nature	<i>Own</i>	State-owned is 1; the rest are 0
	Operating Income Growth Rate	<i>Reve</i>	Operating Income Growth Rate
	Year	<i>Year</i>	Virtual Variable

3. Descriptive Statistics

According to descriptive statistics on the selected data indicators, the average R&D investment ratio (R&D) of the overall data of the sample enterprises is 0.047862, indicating that the R&D investment rate of the selected sample enterprises is relatively low. Therefore, further improvement of relevant R&D investment is needed in the future enterprise development process. The maximum value of Environmental Regulation Intensity (Regu) is 50.7, the minimum value is 2.43, and the average value is 21.72. Therefore, the overall sample enterprises are affected by the intensity of environmental regulations, but there are specific differences in the power of environmental regulations faced by enterprises in different regions. The maximum value of the asset-liability ratio (Lev) is 0.956, the minimum value is 0.0244, and the average value is 0.42966. The overall asset liability of the selected sample enterprise is within the normal range of change. The maximum value of the equity financing ratio (Efr) is 1.6532, the minimum value is 0.0061, and the average value is 0.140384. Currently, the equity financing ratio of the sample enterprises is generally small, indicating that the enterprises' paid capital is relatively small.

Table 2: Descriptive Statistics of Various Variables

	<i>Efr</i>	<i>Lev</i>	<i>Own</i>	<i>R&D</i>	<i>Regu</i>	<i>Si</i>	<i>Reve</i>
Mean	0.140384	0.429660	0.588583	0.047862	21.71900	1.66E+10	0.180895
Median	0.122150	0.432700	1.000000	0.039800	25.48500	3.85E+09	0.124550
Maximum	1.653200	0.956000	1.000000	0.467200	50.70000	8.49E+11	6.431400
Minimum	0.006100	0.024400	0.000000	0.000000	2.430000	1.39E+08	-3.450000
Std. Dev.	0.090773	0.184833	0.492139	0.040273	17.55284	5.49E+10	0.389470
Skewness	3.029675	0.000966	-0.360026	4.309007	0.320768	9.575191	3.881384
Kurtosis	35.17218	2.252353	1.129619	31.99479	1.817387	116.5357	47.61215
Observations	5080	5080	5080	5080	5080	5080	5080

Data source: Eviews test, 2022.

4. Correlation analysis

By combining relevant indicator variables for correlation analysis and organizing them into Table 3, we can conclude:

(1) The correlation coefficient between equity financing ratio (Efr) and R&D investment ratio (R&D) is 0.122343, with significant significance. This indicates a specific positive correlation between the equity financing ratio and R&D investment ratio, indicating that an increase in enterprise equity financing ratio will encourage enterprises to strengthen R&D investment.

(2) The correlation between Environmental Regulation Intensity (Regu) and R&D investment ratio (R&D) is 0.129347. There is a positive relationship between Environmental Regulation Intensity and the R&D investment ratio, meaning that the more environmental planning affects a company's development, the more R&D investment will increase.

(3) The correlation coefficient between the asset-liability ratio (Lev) and R&D investment ratio (R&D) is -0.178011. A negative correlation exists between a company's asset-liability ratio and its R&D investment ratio, meaning that an increase in its asset-liability ratio will lead to a decrease in the company's investment in product research and development.

(4) The correlation coefficient between the total assets (Si) and R&D investment ratio (R&D) of the enterprise is -0.062557. Therefore, it can be seen that there is a negative correlation between the enterprise's total assets and R&D investment ratio; that is, an increase in the enterprise's total assets will lead to a decrease in the R&D investment of the enterprise.

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Table 3: Correlation Analysis of Various Variables

<i>Correlation Probability</i>	<i>Efr</i>	<i>Lev</i>	<i>Own</i>	<i>R&D</i>	<i>Regu</i>	<i>Reve</i>
<i>Efr</i>	1.000000					

<i>Lev</i>	-0.452192	1.000000				
	0.0000	-----				
<i>Own</i>	0.136641	-0.122196	1.000000			
	0.0000	0.0000	-----			
<i>R&D</i>	0.122343	-0.178011	0.011644	1.000000		
	0.0000	0.0000	0.4067	-----		
<i>Regu</i>	0.061152	0.113096	2.88E-17	0.129347	1.000000	
	0.0000	0.0000	1.0000	0.0000	-----	
<i>Reve</i>	-0.026536	-0.003883	0.088582	-0.062990	-0.100670	1.000000
	0.0586	0.7820	0.0000	0.0000	0.0000	-----
<i>Si</i>	-0.233452	0.246338	-0.089755	-0.062557	0.103385	-0.039006
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0054

Data source: Eviews test, 2022.

5. Regression analysis

5.1 Regression Analysis on Equity Financing Ratio and R&D Investment Ratio

Table 4 shows that the regression coefficient between the equity financing ratio and R&D investment ratio is 0.021665, with a P-value of 0.0018, indicating a significant positive correlation between the equity financing ratio and R&D investment ratio of the selected sample of related enterprises. When the equity financing ratio of a company increases, the relevant investment in product research and production will also increase.

In the process of product research and development, the innovative behavior of enterprises requires a large amount of capital investment support, and the funds owned by enterprises often cannot meet the existing product research and development activities. Therefore, enterprises need external capital investment to conduct product research and development. The increase in capital of enterprises can attract investors to participate in investment, bring more capital investment to the R&D process of enterprises, and further help enterprises smoothly carry out product research and development.

Table 4: Regression Analysis Results of Equity Financing Ratio and R&D Investment Ratio

<i>Variable</i>	<i>Coefficient</i>	<i>Std. Error</i>	<i>t-Statistic</i>	<i>Prob.</i>
<i>C</i>	0.061002	0.002262	26.96263	0.0000
<i>Efr</i>	0.021665	0.006950	3.117286	0.0018
<i>Lev</i>	-0.033391	0.003415	-9.778159	0.0000
<i>Si</i>	-1.22E-14	1.05E-14	-1.161613	0.2454
<i>Own</i>	-0.000798	0.001146	-0.696481	0.4862
<i>Reve</i>	-0.006419	0.001432	-4.483541	0.0000
<i>R-squared</i>	0.038096	<i>Mean dependent var</i>		0.047862
<i>Adjusted R-squared</i>	0.037148	<i>S.D. dependent var</i>		0.040273
<i>S.E. of regression</i>	0.039518	<i>Akaike info criterion</i>		-3.622961
<i>Sum squared resid</i>	7.923765	<i>Schwarz criterion</i>		-3.615245
<i>Log-likelihood</i>	9208.320	<i>Hannan-Quinn criteria.</i>		-3.620259
<i>F-statistic</i>	40.19066	<i>Durbin-Watson stat</i>		0.270914
<i>Prob(F-statistic)</i>	0.000000			

Data source: Eviews test, 2022.

5.2 Regression Analysis on Environmental Regulation and R&D Investment Ratio

Table 5 shows that the regression coefficient between environmental regulation and R&D investment ratio is 0.000342, with a p-value of 0. Therefore, environmental regulation and R&D investment have a significant positive correlation. When the intensity of environmental regulation in the business process, the enterprise will invest more in product research and development.

Equipment manufacturing enterprises emit pollutants during production, affecting urban residents' lives and health. As a result, the local government where the enterprise is located has introduced relevant policies for mandatory control, thereby achieving the goal of environmental protection. The government imposes fines on enterprises that exceed their emission limits due to regulatory and financial penalties for their pollution emissions, increasing their environmental costs. While the operating income of enterprises remains unchanged, the increase in enterprise costs will lead to a decrease in their net profit. Therefore, in the process

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of enterprise development, to better maintain its earnings and enhance its competitiveness, it is necessary to increase investment in product research and development, improve product quality and enterprise research and development capabilities, and minimize waste emissions as much as possible in the essential links, thereby reducing the environmental costs of the enterprise itself.

Table 5: Regression Analysis Results of Environmental Regulation and R&D Investment Ratio

<i>Variable</i>	<i>Coefficient</i>	<i>Std. Error</i>	<i>t-Statistic</i>	<i>Prob.</i>
<i>Regu</i>	0.000342	3.17E-05	10.78967	0.0000
<i>Lev</i>	-0.040918	0.003094	-13.22444	0.0000
<i>Si</i>	-2.53E-14	1.04E-14	-2.443446	0.0146
<i>Own</i>	-0.000822	0.001130	-0.727553	0.4669
<i>Reve</i>	-0.005083	0.001423	-3.572968	0.0004
<i>C</i>	0.059832	0.001719	34.81223	0.0000
<i>R-squared</i>	0.057870	<i>Mean dependent var</i>	0.047862	
<i>Adjusted R-squared</i>	0.056941	<i>S.D. dependent var</i>	0.040273	
<i>S.E. of regression</i>	0.039109	<i>Akaike info criterion</i>	-3.643732	
<i>Sum squared resid</i>	7.760876	<i>Schwarz criterion</i>	-3.636016	
<i>Log-likelihood</i>	9261.079	<i>Hannan-Quinn criteria.</i>	-3.641030	
<i>F-statistic</i>	62.33332	<i>Durbin-Watson stat</i>	0.281013	
<i>Prob(F-statistic)</i>	0.000000			

Data source: Eviews test, 2022.

5.3 Regression Analysis on Environmental Regulation, Equity Financing Ratio, and R&D Investment Ratio

According to the regression results, the regression coefficient between equity financing ratio and R&D investment is 0.010055, and the regression coefficient between the cross term between equity financing ratio and environmental planning and R&D investment is 7.01E-05. The p-values of both regression coefficients are less than the critical value, indicating a significant correlation.

With the improvement of China's economic level, the increasing production activities of enterprises have accelerated waste discharge. The government has issued targeted environmental protection policy documents to protect the local environment. When enterprises regulate their emissions following government regulations, they can reduce their costs to a certain extent and establish a good corporate image. When the equity financing ratio of the enterprise increases, it means that the funds received by investors are also increasing. Therefore, to some extent, more investment can be made in product research and development, And reduce the planning and restrictions brought about by the external policy environment. In other words, environmental planning and regulations can better promote the relationship between equity financing ratio and enterprises' product research and development investment.

Table 5: Regression Analysis Results of Environmental Regulation, Equity Financing Ratio, and R&D Investment Ratio

<i>Variable</i>	<i>Coefficient</i>	<i>Std. Error</i>	<i>t-Statistic</i>	<i>Prob.</i>
<i>Efr</i>	0.010055	0.012139	0.828332	0.4075
<i>Lev</i>	-0.038463	0.003414	-11.26488	0.0000
<i>Own</i>	-0.000979	0.001135	-0.862063	0.3887
<i>Regu_Efr</i>	7.01E-05	0.000383	0.182822	0.8549
<i>Regu</i>	0.000325	6.15E-05	5.289714	0.0000
<i>Reve</i>	-0.005003	0.001423	-3.515386	0.0004
<i>Si</i>	-2.25E-14	1.05E-14	-2.146455	0.0319
<i>C</i>	0.057545	0.002625	21.92198	0.0000
<i>R-squared</i>	0.058419	<i>Mean dependent var</i>	0.047862	
<i>Adjusted R-squared</i>	0.057120	<i>S.D. dependent var</i>	0.040273	
<i>S.E. of regression</i>	0.039106	<i>Akaike info criterion</i>	-3.643528	
<i>Sum squared resid</i>	7.756347	<i>Schwarz criterion</i>	-3.633240	
<i>Log-likelihood</i>	9262.562	<i>Hannan-Quinn criteria.</i>	-3.639925	
<i>F-statistic</i>	44.95525	<i>Durbin-Watson stat</i>	0.279756	
<i>Prob(F-statistic)</i>	0.000000			

Data source: Eviews test, 2022.

CONCLUSIONS

This article provides a descriptive analysis of past literature from enterprise R&D investment and environmental regulation perspectives. From the standpoint of enterprise R&D investment, China's industrial enterprises generally maintain a steady upward trend in R&D investment. However, although the R&D investment of listed equipment manufacturing enterprises has increased, the R&D investment is still insufficient. The research proves that:

(1) The increase in the equity financing ratio of enterprises will increase their R&D investment ratio. When the equity financing ratio of a company grows, the company's cash flow is abundant, and the investment in product research and development also increases. For modern enterprises to maintain good operations and avoid the problem of fund chain breakage during the research and development process, more funds are needed to ensure the steady progress of production and research activities.

(2) Enhanced environmental regulations will increase the R&D investment ratio of enterprises. When a company is greatly affected by the intensity of environmental regulations during its operation, the investment in product research and development will also increase. To avoid financial penalties for enterprises exceeding emission limits and establish a positive image of the enterprise, enterprises will try their best to increase investment in product research and development to improve product quality and R&D capabilities.

(3) Environmental regulations can significantly enhance the correlation between equity financing and R&D investment ratios. Under environmental regulations, enterprises can reduce pollutant emissions and invest funds in pollution control. At the same time, it helps enterprises establish a positive image and guide investors to invest more in the enterprise. Once the enterprise has sufficient funds, it can invest more in research and development.

(4) Environmental regulations directly and indirectly impact the investment of R&D funds in enterprises. The direct impact is reflected in enterprises' innovating technology and energy use methods through complicated policies and environmental regulations. In contrast, the indirect effect of environmental regulations has made the relationship between equity financing ratio and enterprise R&D investment close. Environmental regulations affect the amount of enterprise R&D investment, and the amount of R&D investment is a meaningful indirect way to affect enterprise financing. The smooth progress of enterprise research and development activities sends a signal to investors that the enterprise is operating well, which is conducive to attracting investors' capital investment, facilitating the development and research of new projects and technologies, and maintaining a win-win situation between China's environmental governance work and the steady growth of national economic construction, ultimately achieving the goal of sustainable development in China.

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