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R&D Investment Enhance the Financial Performance of Company Driven by Big Data Computing and Analysis

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The application of computer technology, especially the emergence of some statistical software and graphic presentation technology, has enabled many areas of research that require a large amount of data analysis. This paper discusses the relationship between R&D investment and corporate financial performance, and further studies the effect of environmental regulations on this relationship through these technologies. The unbalanced panel data of listed companies from 2007 to 2016 were used as a sample, and then corresponding regression modelswere established through logical reasoning. Empirical analysis has found that there is an inverted U-shaped relationship between R&D investment and company financial performance, and there is a U-shaped relationship between the intensity of environmental regulations and companies' investment in R&D. Another finding is that the inverted U-shaped relationship between companies' R&D investment and financial performance is moderated by environmental regulations in such a way that greater environmental regulations is associated with a lower point of maximum efficiency in the inverted U-shaped curve. This indicates that the strengthening of environmental regulations will affect a company's resource allocation, which will lead to a reduced investment in production, R&D and so on, thus reducing the peak value of financial performance.

Keywords: R&D investment; Financial performance; Environmental regulations

1. INTRODUCTION

With the development of society, company competitiveness has become increasingly intensified, and R&D investment has great significance for the competitive edge and the financial performance of company. However, no consensus has been reached on the relationship between R&D investment and company financial performance, although several scholars believe that the two are positively related [1–2]. Other scholars believe that there is a negative correlation between R&D investment and company financial performance [3–5]. There are also some scholars who believe that the impact of R&D investment on the financial performance of company is multi-faceted [6].

Several scholars have considered the impact of adjustment factors on the relationship between the two, based on the theory of contingency, such as the regulatory effect of firm size, company governance, etc. [7–8]. The influence of environmental regulations on R&D investment and company financial performance has received extensive attention due to the "Porter Hypothesis". Research prior to the 1990s suggested that environmental regulation would lead to higher company costs and lower company productivity and profitability, thereby

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harming the company's international competitiveness. But in 1991, Porter proposed the opposite view, suggesting that appropriate environmental regulations can encourage companies to invest in R&D or adopt innovative technologies. Although it may increase a company's costs in the short term, it can increase production efficiency, improve competitiveness, and augment business performance in the long term. When there is appropriate environmental regulation, companies can boost their business performance through research and development activities [9].

The relationship between environmental regulations and companies' financial performance has received much attention in research literature and the results are still contradictory. Most of the findings have shown that in order to ensure the financial performance of the company, in the face of environmental regulation, the company will reconfigure its resources. Firms may choose to reduce R&D expenditure to offset increased costs caused by environmental regulations; they may also choose to increase R&D investment and improve their efficiency through technological innovation which will enhance performance. Some scholars have suggested that the relationship is neutral. Peng R.'s (2013) [10] analysis reveals that the relationship is influenced by several factors such as the environmental and financial performance measures, the regional differences, and the duration of the studies. In other words, when there is environmental regulation, how the R&D input of the enterprise will affect the performance of the enterprise, is still a question that scholars have been unable to answer satisfactorily.

With the rapid development of China's economy, the accompanying environmental issues have become more prominent. This requires China to change its economic development mode and reduce pollution while developing its economy. In the new development plan, the Chinese government has set clear targets to control the intensity and total amount of carbon emissions. China's economic structure is shifting towards low carbon, and green technology innovation will drive a decline in carbon intensity [11]. Therefore, the regulation of environmental pollution has become more and more stringent. As the main direct consumers of non-renewable resources and producers of waste emissions, companies are the main targets of environmental regulations. Most Chinese companies are not concerned with energy conservation and environmental protection in their manufacturing processes and operations. If they do not adjust their production and management strategies in time, they will be subject to severe economic sanctions. As environmental regulations become more and more stringent, companies' costs will increase due to these regulations. Companies face the urgent task of dealing with the internalization of the cost of environmental regulations, and developing an effective path that can resolve the contradiction between the growth of the company's operating performance and the reduction of the cost of environmental regulations. Today, with serious pollution, it is particularly meaningful to study the effect of R&D investment on the financial performance of severely polluting companies facing environmental regulations. Therefore, this article takes the polluting companies as the research object, examines the relationship between environmental regulations and R&D investment, establishes the environmental regulations as a regulatory variable, and then studies the relationship between R&D investment and companies' financial performance.

2. LITERATURE REVIEW AND RESEARCH HYPOTHESIS

2.1 R&D Investment and Company Financial Performance

Technological innovation is intended to improve existing products or create new ones, and to enhance production or services through technological activities. Companies use their innovative knowledge, technologies and processes to improve their products and services according to their own development objectives, or to occupy the market through the development of new products and services to achieve company value [12]. As a fundamental means whereby companies can achieve technological innovation, the amount of R&D input is an important indicator and measure of innovation.

The influence of R&D investment on companies' financial performance has attracted widespread attention from domestic and foreign scholars. Schumpeter's innovation theory suggests that innovation activities can foster company development, and technological innovation is often closely related to company performance [13]. ZviGriliches (1979) [14] improved the Douglas production function by using the technological knowledge stock as a factor of production, and obtained the model of $Y_t = AC_t^{\beta} L_t^{\alpha} K_t^{\gamma} (\beta + \alpha + \gamma > 1)$ to estimate the relationship between R&D investment and firm performance.

For the two relationships mentioned above, the existing research results are not the same. Most studies show that there is a positive correlation between company R&D investment and company financial performance. For example, Griliches' study (1986) [15] based on US manufacturing data found that company R&D investment will significantly increase productivity, which is consistent with the conclusion reached by Chinese researcher Wu Yanbing's (2006) [16] empirical research using Chinese manufacturing data. Li Yu and Zhang Yuting (2013) [17] pointed out that manufacturing companies' investment in R&D can improve their profitability. Brown et al. (2009) [18] found that R&D investment is positively related to the cash flow of high-tech companies; Du Yong et al.'s research (2014) [19] shows that high-tech R&D investment can improve the profitability of a company. In addition, some scholars believe that R&D investment has a negative impact on companies' financial performance [20–21]. Concerning the above contradictions, Wilbon (2001) [22] conducted more in-depth research, and the results show that due to the strong uncertainty associated with R&D investment, a certain degree of R&D investment will promote financial performance, while sustained and excessive R&D investment will negatively affect a company's financial performance. Zhang Qun et al. believe that investment in product quality and product innovation will not only retain existing customers, but will also attract additional customers and potential investors. In this way, companies can continue to expand market share and increase their visibility, thereby promoting the improvement of corporate financial performance. However, the investment in R&D is not as good as possible [BP1]. However, when the R&D investment reaches a certain amount, too much investment will damage the financial performance of the company. Hence, R&D investment and financial performance show an inverted "U" relationship [23].

Based on the above review of the literature, we can see that the relationship between R&D investment and a company's financial performance may be negatively or positively correlated, and continuous R&D investment will have a negative impact on the company's financial performance. This shows that R&D investment plays a critical role in financial performance. When the R&D investment is less than the critical value, it has a positive effect on financial performance. Once the R&D investment exceeds the critical value, it may become a financial burden on the company.

Based on the above analysis, this paper proposes Hypothesis 1:

H1: The relationship between R&D investment and company financial performance is represented as an inverted U-shape.

2.2 Environmental Regulation and R&D Investment

Environmental regulation is a non-market measure adopted by the government as a means of protecting the environment. Its specific methods include bans, restrictions and permits. In general, environmental regulations will lead to increased company environmental costs. With regard to the impact of environmental regulations on R&D investment, the early traditional neo-classical theory believed that environmental regulations would increase the production costs of the polluting companies, which would encourage companies to decrease R&D investment, thereby reducing their ability to innovate [24–25]. Jaffe (1995) [26] pointed out in a study of the US manufacturing industry that environmental protection produces a higher economic cost for a company and will hinder that company's development and productivity. Becher's (2011) [27] research on the US manufacturing industry further showed that environmental regulations reduce manufacturing productivity, although their impact is very small. Conversely, some scholars have pointed out that environmental regulations will have a positive impact on companies' R&D investment. For example, Li et al.'s (2012) [28] study of 28 manufacturing sectors in China found that the current environmental regulations for heavily polluting manufacturing can improve technological innovation and improve efficiency. Xu Weihua et al.'s (2015) [29] research based on panel data of resource-based companies from 2002 to 2012 shows that the increased level of environmental regulations helps companies to enhance their technological development capabilities. Through research on the industrial sectors in China's 30 provinces from 1998 to 2007, Zhang Cheng et al. (2011) [30] found that in the eastern and eastern [BP2] regions, the relationship between the intensity of environmental regulation and the rate of companies' technological advancement in production is a U-shaped relationship. In terms of the impact of environmental regulation on R&D investment, there is a critical point. When environmental regulations are less than the critical point, they are negatively related to R&D investment. When they are greater than the critical point, they are positively related to R&D investment. Researchers from various countries have found that the impact of environmental regulations on R&D investment performance can produce a crowding effect. Companies may reduce their R&D investment due to the increase in production costs, although this can also prove to be advantageous. When environmental regulation intensity exceeds the critical point, the environmental regulations inspire companies to respond to the constraints and adverse effects of environmental regulation through innovation. Therefore, this paper takes a sample of companies that produce serious amounts of pollution as a research sample to study the impact of environmental regulations on R&D investment.

Based on the above analysis, this paper proposes Hypothesis 2:

H2: The relationship between the intensity of environmental regulations and R&D investment is represented as a U-shape.

2.3 Regulation Effect of Environmental Regulation

Many factors affect the relationship between R&D investment and companies' financial performance. Here, we discuss the role of environmental regulations in determining the relationship between the two. Adopting different perspectives and methods, the academic community have drawn different conclusions on how environmental regulation affects the relationship between R&D investment and company financial performance. For example, Brannlund (1995) and Darnalld (2007) etc. [31–32], through an empirical analysis of the paper industry, found that environmental regulations do reduce the financial performance of the company. Some scholars have also pointed out that environmental regulations can inspire business innovation and then have a positive impact on companies' financial performance. Porter (1991, 1995) [33–34] believes that appropriate environmental regulations can: stimulate companies' innovative behavior; drive innovation that brings changes to productivity; make up for the additional costs due to environmental regulations; and improve company performance. Domazlicky and Weber (2004)[35] analyzed chemical companies in the United States from 1988 to 1993 and found that environmental regulations have a positive effect on productivity growth in chemical companies. Dechun. H et al. (2006) [36] found that by establishing a model with fewer restrictions, environmental regulations will increase the direct costs incurred by a company on the one hand, and on the other hand also drive innovativeness, thereby offsetting the costs of environmental regulations. These studies show that the application of environmental regulations will have a direct and adverse effect on the financial performance of the company, but the stimulation of R&D investment can improve the financial performance of the company.

The above study did not specifically consider the target of R&D investment: did companies invest in innovation in production and operations, or in technological innovation for pollution control?When Brunnermeier (2003) and Arimura (2007) [37–38] studied the impact of environmental regulations on production technology, they distinguished R&D innovation from the two dimensions of overall innovation and pollution control innovation. When studying the relationship between environmental regulation, technological innovation, and business performance, Yan Maohua et al. (2014) [39] classified the R&D investment of heavily polluting company into non-environmental R&D research and environmental protection

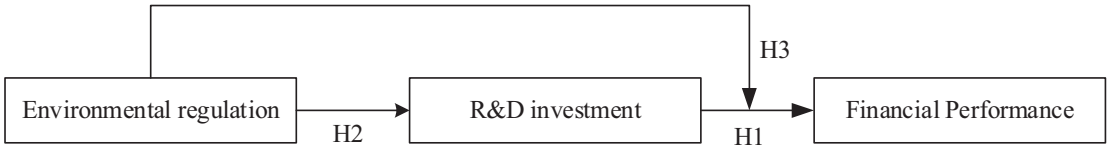

Figure 1 Structural Model of R&D Investment and Company Financial Performance Hypothesis under Environmental Regulation.

Table 1 Variables and variables represent symbols.

Variable Types	Variables	Definition	Symbols
Explained Variables	Company Financial Performance	Total market value of assets of the company/total assets	Fp
Explaining Variables	R & D Investment	Natural logarithm of R & D Investment Cost	Rd
	Environmental Regulation	Natural Logarithm of Environmental Expenditure	Envi
Control Variables	Operating profit ratio	Operating profit/Operating income	Profit
	Growth Rate	Growth Rate of Main Business Income	g
	Financial Leverage	Ratio of Liabilities to Assets	Lev
	Firm Size	Natural Logarithm of Total Assets	Size
	Cash Flow	Net Cash Flows from Operating Activities/Total Asset	Cf
	Company market life	Observation Year - Year of Listing	Age
	Index of Marketization	Build the Index of Marketization According to Fan et. al.	Market
	Industry	Industry code	Industry
	Company Codes	Stock Codes	Scode
	Year	Year of Database	Year

research driven by environmental regulations. The empirical results show that environmental R&D investment is a "non-benefit" investment for companies and does not improve financial performance. Only non-environmental R&D can have a positive impact on companies' financial performance. Therefore, when the intensity of environmental regulations is low, the R&D investment of companies is more purely used, and they can allocate more R&D funds to non-environmental R&D to boost financial performance. When the intensity of environmental regulation is high, companies need to pay greater attention to environmental regulations. Environmental regulations will encourage companies to allocate some of their R&D budget to environmental R&D. As a result, we believe that environmental regulation will affect the highest point of the "inverted U" of R&D investment and companies' financial performance. When the intensity of environmental regulation is high, the environmental regulations greatly constrain the financial performance of the company. R&D investment decreases a company's financial performance, so the highest point of the company's financial performance will be reduced.

Based on the above analysis, this paper proposes Hypothesis 3:

H3: Environmental regulation has an adjustment effect on the inverted U-shaped relationship between R&D investment and financial performance. The highest point of companies' financial performance is lower under high environmental regulations.

The proposed hypotheses are depicted in the following figure:

3. RESEARCH DESIGN

3.1 Variable Definitions

(1) Company financial performance. This references the existing literature on company financial performance including Tobin's q, Roa, Roe, and Eps. Accounting indicators, Roa, Roe, and Eps are easily manipulated by management. [40], while Tobin's q can reflect not only the inherent value of the firm, but also the expected future growth [41]. The paper chooses Tobin's q to represent company financial performance, and is denoted by Fp.

(2) R&D investment. R&D investment is the investment in human resources and financial resources for the creation and innovation activities of the company. This article selects R&D spending as a measure, and we take the natural logarithm of R&D investment as the R&D investment variable, which is denoted by Rd.

(3) Environmental regulation. The environmental protection investment of a company reflects the degree of severity of government regulation of the environment. Therefore, for the intensity of environmental regulation, this paper uses the environmental protection expenditures that are used by many scholars, which include the cost of sewage and greening costs. And we also take the natural logarithm for environmental protection expenditure as the environmental regulation variable (Envi).

(4) Control variable. For the purposes of this study, we conduct a regression analysis of the company financial performance and R&D investment respectively. Several different factors affect both variables, which need to be controlled for. The size, age, lev, profitability, cash ability and growth rate of a company are well-known factors that affect a company's R&D needs and performance [42–45]. The firm's size is determined by the natural logarithm of company's total assets. Age is calculated as the observing year for the company from the company listed. [BP3] Lev is the asset-liability ratio of the company. Profitability is expressed as operating profit margin. The cash flow can objectively and accurately reflect the financial results and operations of the company, and cash ability can affect investment decisions in regard to R&D, so the ratio of net cash flows from operating activities to total asset is controlled. Growth rate is calculated as the main business income growth rate of the company. Then, at the non-company level, we have controlled marketization index and industry. The marketization index, constructed by Fan Gang et al. (2003), reflects the regional development level [46]. Thus, we use the marketization index to represent the regional control variable (Market). Since the selected sample comprises unbalanced panel data, the time variable year (Year) is controlled.

3.2 Samples and Data

We selected [BP4] listed A-share companies from 2007 to 2016 as the research object. This study used 2007 as the starting year because of China's implementation of new accounting standards in that year, after which R&D expenditures could be capitalized, and then the disclosure of R&D and innovation information of listed companies was gradually standardized in China. In this study, we undertook the following steps: First, we batch-extracted companies' environmental protection input data from their annual reports and obtained 3491 original samples. Next, the R&D investment data was sourced from the csmar database. After combining the above samples, 1901 samples were obtained. Also, the control variables data was gathered from the csmar database. Next, we removed from the sample any that were missing significant control variables or were from unusual business companies. After screening and collating, 1802 annual observations were obtained. In addition, in order to eliminate the influence of outliers, we conducted a winsorize on the continuous variables in the model at the 1% and 99% levels. The sample data was unbalanced panel data. Excel and Stata 13.0 were used as our data processing tools.

3.3 Model Establishment

In order to determine the relationship between R&D investment and financial performance (Hypothesis 1), we established model 1 and model 2. For these, the dummy variables Industry and Year we generated by controlling industry and the year; Rd^2 is the quadratic term of the R&D investment variable; and ε is the residual item.

$$\mathrm{Fp} = \alpha + \beta_1 \times Rd + \Sigma\beta_j \times \mathrm{Control} + \Sigma\ \mathrm{Industry} + \Sigma\ \mathrm{Year} + \varepsilon \quad (1)$$

$$\mathrm{Fp} = \alpha + \beta_1 \times Rd + \beta_2 \times Rd^2 + \Sigma\beta_j \times \mathrm{Control} + \Sigma\ \mathrm{Industry} + \Sigma\ \mathrm{Year} + \varepsilon \quad (2)$$

To test Hypothesis 2, we established model 3 and model 4 based on the regression of environmental regulations and R&D investment. Envi^2 is the quadratic term of the environmental regulation variable, and ε is the residual term.

$$\mathrm{Rd} = \alpha + \beta_1 \times Envi + \Sigma\beta_j \times \mathrm{Control} + \Sigma\ \mathrm{Industry} + \Sigma\ \mathrm{Year} + \varepsilon \quad (3)$$

$$\mathrm{Rd} = \alpha + \beta_1 \times Envi + \beta_2 \times Envi^2 + \Sigma\beta_j \times \mathrm{Control} + \Sigma\ \mathrm{Industry} + \Sigma\ \mathrm{Year} + \varepsilon \quad (4)$$

For Hypothesis 3, we established model 5 and model 6 to test the effect of environmental regulations on the relationship between R&D investment and companies' financial performance. Here, Rd × Envi is the interaction term for environmental regulations and R&D investment, and ε is the residual item.

$$\mathrm{Fp} = \alpha + \beta_1 \times Rd + \beta_2 \times Envi + \beta_3 Rd \times Envi + \Sigma\beta_j \times \mathrm{Control} + \Sigma\ \mathrm{Industry} + \Sigma\mathrm{Year} + \varepsilon \quad (5)$$

$$\mathrm{FP} = \alpha + \beta_1 \times Rd + \beta_2 \times Rd^2 + \beta_3 Envi + +\beta_4 Rd \times Envi + \Sigma\beta_j \times \mathrm{Control} + \Sigma\ \mathrm{Industry} + \Sigma Year + \varepsilon \quad (6)$$

4. RESULTS AND DISCUSSION

4.1 Descriptive Statistics

Table 2 is a descriptive summary of the main variables. Fp ranges from 0.743 to 13.765 with a mean value of 2.297; its standard deviation is 1.418. Rd ranges from 8.453 to 21.830 with a mean value of 17.560; its standard deviation is 1.586, which means that the degree of R&D investment varies from company to company. Envi ranges from 1.609 to 18.016 with a mean value of 13.761; its standard deviation is 2.637, indicating that environmental protection investment fluctuates greatly between different years in different companies and, generally, the R&D

Table 2 Summary of descriptive statistics.

Variables	N	mean	sd	min	max
Fp	1802	2.297	1.418	0.743	13.765
Rd	1802	17.560	1.586	8.453	21.830
Envi	1802	13.761	2.637	1.609	18.016
Profit	1802	0.055	0.125	−0.473	0.435
g	1802	0.121	0.375	−0.433	2.376
Lev	1802	0.452	0.216	0.051	0.894
Size	1802	22.315	1.298	19.646	27.321
Cf	1802	0.045	0.072	−0.464	0.438
Age	1802	13.290	5.913	1.000	27.000
Market	1802	10.390	2.658	4.222	15.610

Table 3 Variable correlation coefficient list.

	Fp	Rd	Envi	Profit	g	Lev	Size	Cf	Age	Market
Fp	1									
Rd	−0.266**	1								
Envi	−0.164***	0.175***	1							
Profit	0.107***	0.03	−0.024	1						
g	−0.028	−0.043*	0.006	0.002	1					
Lev	−0.458***	0.178***	0.244***	−0.239***	0.054**	1				
Size	−0.311***	0.246***	0.075***	−0.001	0.344***	0.278***	1			
Cf	0.037	0.097***	0.067***	0.153***	−0.025	-0.123***	0.009	1		
Age	−0.254***	0.063***	0.139***	−0.098***	0.063***	0.437***	0.141***	−0.01	1	
Market	0.102***	0.155***	−0.036	0.061***	0.033	−0.112***	0.043*	0.080***	−0.139***	1

Note:*** represents P<0.01, ** represents P<0.05, * represents P<0.1.

investment amount is greater than the amount of environmental protection expenditure. The financial leverage appears to be 0.452 on average, with a minimum of 0.051 and a maximum of 0.894, which indicates Chinese seriously polluting companies rely on much debt financing to reduce capital costs but possibly face higher financial risks. Profit ranges from −0.473 to 0.435 with a mean value of 0.055; its standard deviation is 0.125, suggesting that most polluting companies have a low operating profit ratio. Market ranges from 4.222 to 15.610 with a mean value of 10.390. The maximum and minimum values are significantly different, which shows that Chinese regional market development is uneven. There is a large average degree of marketization, implying that Chinese serious pollution company exist in developed regions, which accounts for the poor air quality in big cities and developed regions.

4.2 Correlation Analysis

Table 3 lists the person [BP5] correlation coefficient of the variables. The correlation coefficient between company financial performance (Fp) and R&D investment (Rd) is negative, and has a 5% level of significance. The correlation coefficient between company financial performance (Fp) and environmental regulations (Envi) is negative, with a 1% level of significance. Therefore, the current environmental protection investment has a negative impact on the companies' financial performance. The correlation coefficient between R&D investment (Rd) and environmental regulations (Envi) is 0.175 has a 1% level of significance. Therefore, environmental regulations are positively related to R&D investment by polluting companies. The correlation coefficient between asset liability ratio (Lev) and company performance (Fp) is −0.458, which is a 1% level of significance. It shows that the high asset-liability ratio has a negative impact on companies' financial performance. Asset-liability ratio (Lev) and cash flow (Cf) are positively related to corporate R&D investment, with a 1% level of significance, which shows the importance of companies' internal and external financing capabilities for corporate R&D investment. The correlation coefficients among these variables are less than 0.5. To a certain extent, it is guaranteed that there is no [BP6] multicol linearity in the models. Except Model 1 and Model 3, other models are nonlinear regression equations that the collinearity test for VIF values is not applicable. Therefore, we measure only the VIF values of Model 1 and Model 3, which are found to be 1.19 and 1.17, respectively, both less than 10. The tests of the VIF further show that there is no multicol linearity problem in these models.

4.3 Empirical Results and Analysis

4.3.1 R&D Investment and Regression Results for Companies' Financial Performance

We tested the impacts of R&D investment on companies' financial performance and report the findings in Table 4. Company financial performance (Fp) is the explanatory variable of Model 1 and Model 2. In model 1, the coefficient of Rd is −0.070 and the statistical significance is at 1%, which

Table 4 Results of Rd and Fp regressions (Model 1 and 2).

Variables	Fp	
	Model 1	Model 2
Rd	−0.070***	0.208**
	(−4.48)	(2.25)
Rd2		−0.008***
		(−3.05)
Profit	0.046**	0.046**
	(2.04)	(2.13)
g	0.000**	0.000**
	(2.27)	(2.24)
Lev	−0.635***	−0.622***
	(−9.24)	(−9.00)
Size	−0.002***	−0.002***
	(−3.87)	(−3.75)
Cf	0.086	0.097
	(0.49)	(0.55)
Age	−0.006***	−0.005***
	(−2.96)	(−2.60)
Market	0.008**	0.007*
	(2.07)	(1.81)
Constant	2.741***	0.361
	(16.43)	(0.44)
Year	control	control
Industry	control	control
Adjusted R-squared	0.463	0.486
N	1802	1802
F	58.56***	60.01***

Note:***represents P<0.01, ** represents P<0.05,* represents P<0.1.

demonstrates that R&D investment can significantly weaken companies' financial performance. In model 2, the coefficient of Rd is 0.208 and the statistical significance is at 5%; the coefficient of Rd^2 is −0.008 and the statistical significance is 1% also. It shows that there is a significant inverted U-shaped relationship between R&D investment and companies' financial performance. Compared with model 1, model 2 has a larger adjusted R^2 value and a larger F value, which imply that model 2 has a better fit. The results support Hypothesis 1, showing that there is a critical value for R&D investment; when R&D investment is less than this critical value, it has a positive impact on company financial performance; when companies' R&D investment exceeds the threshold, their financial performance decreases with an increase in R&D investment. Consequently, an appropriate level of R&D investment is conducive to the improvement of companies' financial performance, while exorbitant R&D investment imposes a cost burden on the company and leads to poorer financial performance.

4.3.2 Environmental Regulations and R&D Investment Regression Results

Table 5 shows the regression relationship between environmental regulations and R&D investment. Company R&D investment (Rd) is the explanatory variable of Model 3 and Model 4. In model 3, the Envi coefficient is 0.077, which is at the 1% level of significance, suggesting that environmental regulations can encourage an increase of R&D investment. In model 4, the coefficient of Envi is −0.180, which is at the 1% level of significance. The coefficient of $Envi^2$ is 0.012 is significant at the 1% level. Compared with model 3, the adjusted R^2 and F value in Model 4 are both greater, so model 4 has a better fit. The results show a significant U-shaped relationship between R&D investment and companies' financial performance. Therefore, there is a critical value for environmental regulations. When environmental regulation is less than this critical value, environmental regulation has a negative effect on company R&D investment; when environmental regulations exceed the threshold, the company R&D investment increases as the intensity of environmental regulation increases. Thus, Hypothesis 2 is supported.

4.3.3 Moderating Effect of Environmental Regulations on R&D Investment and Companies' Financial Performance

To test Hypothesis 3, we designed models 5 and 6. Both models have the same explanatory variable, which is companies' financial performance (Fp). By adding the environmental regulations (Envi) and interaction item of environmental regulation and R&D investment (Rd×Envi) to model 1, we established model 5. In model 5, the coefficient of environmental regulations and the R&D investment interaction item Rd×Envi is 0.003, but this is not significant. Therefore, the linear model cannot

Table 5 Results of Envi and Rd regressions (Model 3 and 4).

Variables	Rd	
	Model 3	Model 4
Envi	0.077***	−0.180***
	(5.83)	(−3.09)
Envi2		0.012***
		(4.41)
Profit	0.515***	0.494***
	(2.64)	(2.65)
g	−0.004***	−0.003***
	(−3.27)	(−3.22)
Lev	0.898***	0.831***
	(3.94)	(3.7)
Size	0.011***	0.010***
	(3.77)	(3.63)
Cf	2.505***	2.267***
	(4.99)	(4.53)
Age	0.006	0.005
	(0.96)	(0.79)
Market	0.086***	0.083***
	(6.74)	(6.59)
Constant	14.280***	15.609***
	(39.67)	(34.77)
Year	control	control
Industry	control	control
Adjusted R-squared	0.323	0.343
N	1802	1802
F	15.8	17.08

Note:***represents P<0.01, ** represents P<0.05,* represents P<0.1.

explain the regulatory effect of environmental regulations on R&D investment and companies' financial performance. In the next step, in order to obtain model 6, we add Envi and the interaction item of environmental regulation and R&D investment (Rd×Envi) to model 1. In model 6, Rd has a coefficient of 0.166, yielding a10% level of significance. The Rd^2 coefficient is −0.008, which is a 1% level of significance. The inverted U-shaped relationship between R&D investment and companies' financial performance still exists. In addition, the coefficient of interaction item Rd×Envi is 0.003 and the statistical significance is 10%. The results show that environmental regulations not only influence a company's R&D investment, but also the relationship between R&D investment and the company's financial performance. However, this does not immediately reflect how environmental regulations affect the relationship between Rd and Roa.

Then, according to Aiken et al.'s (1993) [47] recommendations, we draw a picture to further explore the regulatory effects of environmental regulation. This study divides data into two groups according to the level of environmental regulations. The average value of the environmental regulations variables is the boundary; if Envi>13.761, the data is assigned to the high environmental regulations group; if Envi<13.761, the data belongs to the low environmental regulation group. We set the financial performance of the low environmental regulatory team to Fp1, and the financial performance of the high environmental regulatory team to Fp2. Finally, the two quadratic curves that we derive from R&D investment and company financial performance are shown in Figure 2. In Figure 2, the trends of the two curves are the same, both showing as inverted U-shapes. The highest financial performance point under the higher environmental regulatory measure is lower than that under the lower ones. As the investment in R&D increases, the two curves can exchange places, and the higher-Envi financial performance curve will be the one above. Combining with model 4, model 6 and Figure 2, we can conclude that environmental regulations can not only directly affect R&D investment, but also affect the relationship between R&D investment and companies' financial performance. It changes the highest point in the regression between the two. The higher environmental regulation is associated with lower financial performance at a greater level of R&D investment. This suggests that companies constrained by higher environmental regulations need relatively more R&D investment to effectively guarantee their performance. When subjected to high environmental regulations, companies tend to invest more in research and development. The findings suggest that Hypothesis 3 is supported.

4.4 Robustness Test

In this paper, firstly we performed clustering processing, thereby strictly controlling the company stock code from model 1 to model 6. As a result, it was found that the t-value slightly changed, but the level of significance of the original model remained the same and the coefficient sign of the model had

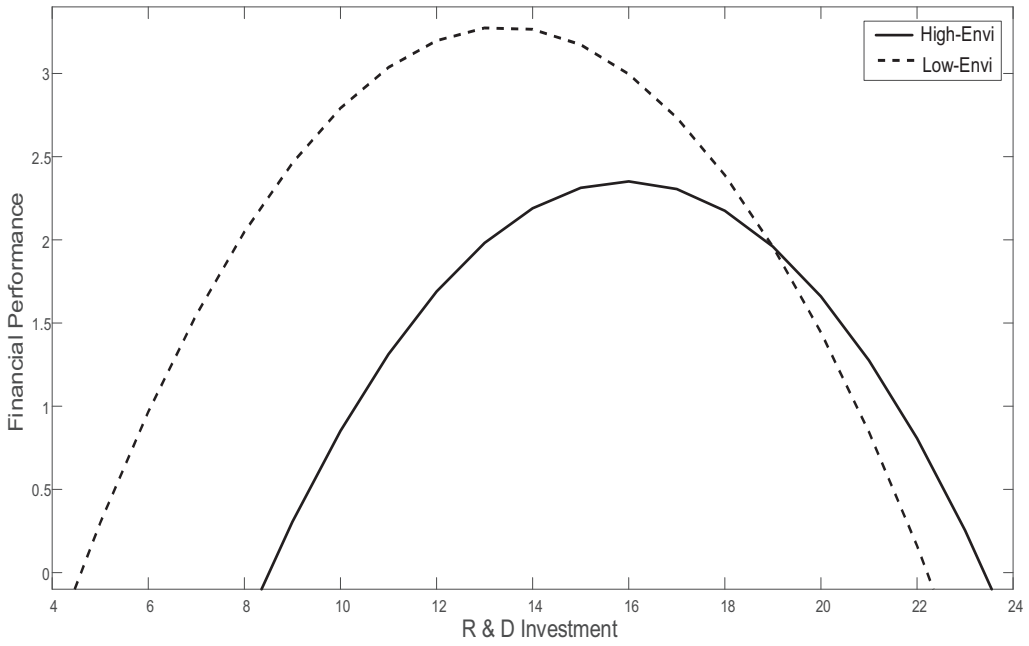

Figure 2 The moderating effect of environmental regulation on the relationship between R&D and financial performance.

Table 6 Results of Envi Regulates the relationship between Rd and Roa (Model 5 and 6).

Variables	Fp	
	Model 5	Model 6
Rd	−0.110***	0.166*
	(−4.03)	(1.75)
Rd2		−0.008***
		(−3.12)
Envi	−0.054	−0.043*
	(−1.60)	(−1.87)
Rd×Envi	0.003	0.003*
	(1.55)	(1.86)
Profit	0.046**	0.047**
	(2.09)	(2.19)
g	0.000**	0.000**
	(2.29)	(2.24)
Lev	−0.622***	−0.612***
	(−8.83)	(−8.63)
Size	−0.002***	−0.002***
	(−3.75)	(−3.57)
Cf	0.093	0.103
	(0.52)	(0.57)
Age	−0.006***	−0.005***
	(−2.99)	(−2.62)
Market	0.007*	0.006*
	(1.94)	(1.68)
Constant	3.501***	1.197
	(6.81)	(1.28)
Year	control	control
Industry	control	control
Adjusted R-squared	0.474	0.497
N	1802	1802
F	52.82	53.68

Note:***represents P<0.01, ** represents P<0.05,* represents P<0.1.

not changed. The clustering method solved the problems of heteroskedasticity and company-level autocorrelation, and the result showed that the model construction is more reasonable. Secondly, we randomly selected half of the sample companies for robustness testing, then we regressed model 2?? model 4 and model 6. In model 4, the coefficient of Envi is -0.164 and the coefficient of envi^2 is 0.009, and both of them are significant at 5%, which shows that there is a U-shaped relationship between environmental regulation and corporate R&D investment, and research hypothesis 2 was verified. In model, 2 the Rd's coefficient is 0.233 significantly at 5% and coefficient of Rd^2 is -0.009 significantly at 5%, which suggests that there is an inverted U-shaped relationship between environmental regulation and corporate R&D investment, and research hypothesis 2 was verified. The interaction term Rd$\times$Envi has a coefficient of 0.013, which is significant at the 1% significance level in model 6. These results confirmed and strengthened the explanatory power of the model.

There is no need to consider the endogeneity of environmental regulations because it is an exogenous variable which affects only the system without affecting the system.[BP7] Considering the endogenous problem of R&D, this study took the value of the lag one stage for the independent variable Rd in model 2 to reduce the influence of reverse causality on the result. The results show that the coefficient of R&D investment in the first stage of lagging is still significantly positive, and the square of the R&D investment in the first stage of lagging is still significantly negative. Therefore, the main regression results of this study are relatively stable.

5. CONCLUSION AND INSPIRATION

5.1 Conclusion

This study was based on Schumpeter's innovation theory and Porter's Hypothesis, combined with the situation in China, and collected data about A-share polluting companies from 2007 to 2016. Then we explored the relationship between R&D investment and companies' financial performance under the constraints of environmental regulations. The research results show that environmental regulations not only can affect R&D investment directly, but also can regulate the relationship between R&D investment and companies' financial performance. The main conclusions are stated below.

First, the relationship between R&D investment and companies' financial performance was represented as an inverted U-shape. R&D investment will promote the improvement of company financial performance, but there is a critical value; when R&D investment exceeds the critical point, as R&D investment increases, companies' financial performance will decrease. As we can see, R&D investment will not only bring innovative income to the company, but will also increase costs incurred by the company. Hence, companies need to strike a balance between the two. This confirms Liu Desheng et al.'s (2010) [48] conclusion that "To improve company performance, companies should control R&D investment within a reasonable range". Due to the strong uncertainty in R&D investment, companies should not blindly invest excessive amounts in R&D. Compared to the amount invested, companies should pay more attention to the quality of the input. While actively developing R&D, companies should cultivate and accumulate innovative talents and ensure the best financial performance through appropriate R&D investment.

Second, there is a U-shaped relationship between environmental regulations and R&D investment. The intensity of environmental regulations will reduce polluting companies' investment in R&D. However, there is also a critical value. When the intensity of environmental regulations exceeds the critical value, R&D investment will increase accordingly. This conclusion is consistent with the findings of Jiang Fuxin et al. (2013) [49] who used Jiangsu manufacturing as the research object, which implies that environmental regulations have the double effects of crowding and compensation. When the intensity of environmental regulations is weak, the strengthening of environmental regulations will lead to a reduction in R&D investment; when the intensity of environmental regulations is high, company will boost its R&D investment. Increasing the intensity of environmental regulations can indeed stimulate and promote the innovation of company.

Third, environmental regulations not only directly affect the R&D investment of the company, but also have a significant moderating effect on the inverted U-shaped relationship between R&D investment and financial performance. It can be seen from Figure 2 that the trend of the relationship between R&D investment and financial performance under high-intensity environmental regulations and low environmental regulations is the same. However, it is obvious that the same R&D investment in a high-regulations environment produces lower financial performance than does a low-regulations environment, and the highest point of the two curves is different. Under high environmental regulations, companies need to strengthen their investment in R&D, but the effect of R&D investment on companies' financial performance is reduced. This leads to a decrease in the peak value of financial performance, represented as an inverted "U" type.

5.2 Research Inspiration and Prospect

Based on the above findings, the following recommendations are made. First, the government should encourage innovation. Innovation can have a positive impact on company financial performance. The government should encourage companies to not only pay attention to the investment of short-term funds, but also to consider attracting innovative and talented personnel, and develop independent innovation without having to introduce new technology. In this way, innovation will become more efficient and effective. Second, judging from the degree of marketization of the sample, the polluting companies are mostly located in places with a high degree of marketization. The pollution is severe and the air quality is poor in these areas. To develop a sustainable and environment-friendly society, the government should formulate strict environmental regulations to strengthen environmental governance. Third, companies should improve their environmental innovation capabilities. The strengthening of environmental regulation can encourage companies to invest in innovation. Companies should increase

their investment in environmental protection innovation and R&D, to improve company pollution control capabilities and reduce the negative impacts that environmental regulations may have on performance. Fourth, the regulatory authorities should ensure the effective monitoring of company activities. Regulators must strictly require companies to comply with environmental regulations. At the same time, the regulatory agencies should require companies to fully disclose information such as emissions and environmental protection expenditures. This will encourage companies to assume environmental responsibility. Fifth, because a greater number of environmental regulations may cause a decline in company performance, the government should offer appropriate subsidies to companies. The mandatory nature of environmental regulations and the offer of a subsidy should encourage companies to take environmental responsibility. In order to achieve a positive two-pronged outcome -environmental responsibility and company performance -, it is recommended that companies be constrained to conduct pollution control technology research and develop innovative production practices [50].

In addition, there are still some deficiencies in this study. Due to the limited data currently disclosed by companies, it is very difficult for us to classify by pollution type. If we categorize the types of pollution, then there will be very little combined data of R&D investment and environmental input in each category. In the future, when companies disclose more complete data, research can be extended to different polluting companies. The paper also did not compare the company R&D and company performance of the disclosed environmental protection data firms and the undisclosed environmental protection investment firms. Therefore, in the future, two types of companies can be studied and compared.

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