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The Effect of R&D Input on Operating Income of Chinese Wastewater Treatment Companies—With Patent Performance as a Mediating Variable

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Abstract: The Chinese government is actively promoting green and low-carbon transformation for economic and social development, especially in the wastewater treatment industry. This article uses regression analysis to study the impact of company R&D input on patent performance and company operating income for different regulatory environments and regions. Companies in the wastewater treatment industries of the Shanghai and Shenzhen stock exchanges from 2013 to 2020 are selected as research samples. The results show that there is a partial mediating effect of patent performance between company R&D input and company operating income; the stimulative effect of company R&D input is strongest in a high external-high internal environment; this stimulative effect is also more significant in the three strategic regions when compared with other regions. The findings suggest that company R&D input can promote company operating income. Thus, wastewater treatment enterprises should establish complete R&D systems to improve their innovative output capabilities. Enterprises in more developed regions should play a leading role in undertaking technological innovation. Furthermore, the government should formulate policies to improve the capacity of companies to conduct wastewater treatment and continue down the road of green development.

Keywords: company R&D input; company operating income; patent performance; internal and external regulations

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1. Introduction

China has shown great industrial achievements and accelerated its urbanization plans during its continuous economic development. However, environmental pollution problems have become more severe [1]. Chinese water resources are relatively scarce and strengthening the control of wastewater management plants can reduce energy consumption and carbon emissions in the water treatment process. This plays an important role in energy savings and emission reduction while improving ecological and environmental quality [2,3].

Recently, China has introduced a variety of policies to give strong backing to the development of the wastewater treatment industry and encourage the construction of wastewater treatment facilities [4]. In 2021, the National Development and Reform Commission and ten departments jointly released the "Guidance on Promoting the Resourceful Utilization of Wastewater". In June of the same year, the 14th 5-Year Plan for development of urban wastewater treatment processes and resource utilization was released. This directs the comprehensive deployment of wastewater treatment and resource utilization resources at a national strategic level.

Domestic and foreign research on listed companies in the wastewater treatment industry has mainly focused on environmental regulation and business performance. For example, Porter proposed the famous "Porter Hypothesis" in 1991, which argues that strengthening of environmental regulation can promote research and development (R&D) investment in companies. This is because companies try to improve their ability to combat pollution and product technology through R&D input [5]. Gray et al. found paper mills in the United States have shifted their inputs from production in order to pollution control to satisfy environmental regulatory rules that affect corporate performance [6]. Researching wastewater treatment technology, Kyriakopoulos comprehensively analyzed current corporate wastewater treatment methods and their applications in different environments in the context of a circular economy [7]. Kapsalis explored the relationship between ecosystem services and a circular economy from a macro perspective [8]. In addition, scholars have conducted multifaceted studies on whether R&D input affects the relevance of enterprise value. Griliches proposed the Griliches model based on Tobin's Q value theory and used OLS to estimate the correlation between R&D expenditures and the number of patents with Tobin's Q market value in large U.S. firms. A positive and significant correlation was obtained [9]. Kothari verified the connection between R&D expenditures and corporate earnings. The connection between R&D expenditure and corporate earnings showed that a portion of corporate earnings comes from this source [10]. There was also a later series of studies which proved that R&D input has a promotive effect on firm performance [11–14].

However, there are few studies on operating income of wastewater treatment enterprises themselves. Based on this, this paper takes the operating income of enterprises as the theme and starts from the perspective of enterprise R&D input. It explores the relationship between operating income, R&D input and patent performance. The R&D input of wastewater treatment enterprises is closely related to the green development of enterprises. This research perspective is relatively new and it follows in the footsteps of existing research directions that are popular. In terms of research methods, this paper selects business income, R&D input, patent applications and other indicators for quantification of enterprises and seeks to improve indicator reliability as much as possible. Meanwhile, the empirical evidence in this paper is divided into two parts: the former focuses on the correlation study between R&D input and patent applications to business revenue; the latter divides the sample into four sub-groups based on the internal and external environment in which the enterprises are located. This is to understand how much enterprise R&D input contributes to operating income of enterprises under different environments. The results of this study complement existing theory regarding this topic.

First, this paper supplements previous research by using multivariate regression models in an attempt to elucidate the role of corporate R&D input on the operating income of corporate development. Excluding the introduction, the rest of the paper is structured as follows: The Section 2 puts forward relevant hypotheses combined with existing research results; the Section 3 introduces the selection of variables and model design for this study; the Section 4 presents the results of the empirical analysis and the Section 5 concludes the paper. The conclusion provides relevant suggestions for the future green development of wastewater treatment enterprises in combination with Chinese industrial policies.

2. Hypothesis

2.1. Company R&D Input and Company Operating Income

Company innovation activities take the form of a dynamic and continuous cycle [15,16]. When there is a demand for a new product or technology in the market, companies will consider their resource availability and assess whether they have sufficient resources to ensure the completion of their innovation goals. As such, innovation inputs constitute an important part of their innovation activities [17]. These inputs include research funding, inspiration and ideas as well as relevant information. However, inputs like inspiration and information are difficult to quantify and cannot be analyzed through data analysis [18], so we select quantifiable R&D cost input as the index to measure company R&D input. In

addition, operating income is the core indicator of financial health for a company [19], and this indicator reflects the size, profitability and survivability of the company. To improve the accuracy of the study, we select the operating income of companies as an indicator to measure the company operating income.

The progress of sewage treatment technology is the inevitable requirement to support the development of the sewage treatment industry [20]. For now, Chinese wastewater treatment technology mainly utilizes treatments based on biology, chemistry, physics, etc. [21]. However, with increased water pollution in China and an increase in the difficulty and intensity of treatment, it is difficult to modify ordinary technology for wastewater treatment needs [22]. In this context, in order to improve the comprehensive level and status quo of wastewater treatment in China, improving company R&D input is key [23]. Griliches (1979) introduced the R&D variable into the production function as an input factor to examine the effect of R&D input on productivity. He found that R&D input had a significant impact on increase in company competitiveness [24]. Morbey (1989) used a sample of 800 firms in the United States that spent more than one million dollars on R&D and the results of the study showed that R&D intensity is positively related to profitability [25]. Sougiannis (1994) conducted an empirical study with a 10-year sample of R&D data from US companies and showed that, for every $1 a company invests in research in the present, it will gain $2 over the next seven years [26].

Therefore, we propose the hypothesis.

Hypothesis 1 (H1). *The improvement in R&D input of companies can contribute to operating income in the wastewater treatment industry.*

2.2. Patent Performance Mediates between Company R&D Input and Company Operating Income

On one hand, the R&D input of companies can directly affect company operating income [27,28]. On the other hand, the R&D input of companies may also have an impact on their patent performance [29]. This impact runs through the entire process, from increasing R&D input to improving company operating income. By increasing R&D input, companies can obtain more innovation outputs including invention patents and utility models [30]. These innovation outputs can then be utilized in production and operation processes [31,32], which can enhance the profits of companies and thus improve their operating income.

Ernst (2001) selected 3 years of data from manufacturing companies to study the relationship between patent level and sales revenue for a sample containing 50 companies. The results showed that the number of patents for manufacturing companies was positively related to the growth rate of their sales revenue, and the number of patents of manufacturing companies with a 2–3 period lag helped to enhance company sales revenue [33]. Zhang (2009) empirically demonstrated that an increase in the number of patents granted to companies also helped boost their technological innovation performance [34]. Victor (2017) explored the impact of patent performance, R&D capacity and employee productivity on company performance. The results showed the positive impact of patent performance, R&D capacity and employee productivity on company performance [35].

This leads to Hypothesis 2:

Hypothesis 2 (H2). *Patent performance mediates between the R&D input of a company and its operating income.*

2.3. The Contribution of Company R&D Input to the Company Operating Income Varies across Internal and External Regulations

We divide the environment in which companies are involved for their innovation processes into internal and external regulations and consider the role of company R&D input in contributing to company operating income from both perspectives.

For the study of internal regulations, two indicators are considered, namely, the R&D intensity index and the ratio of the number of company employees with undergraduate degrees and above [36]. R&D intensity plays an important role in enhancing the competi-

tiveness of enterprises, safeguarding their long-term development, promoting economic growth and improving comprehensive national power [37]. R&D intensity reflects the intensity of investment by an enterprise in innovation. As R&D intensity increases, the enterprise becomes more innovative, allowing it to gain an advantage over the competition and thus ultimately improving its business performance [38]. In addition, human capital investment is one of the most important factors in the R&D process for companies. High-quality professionals are the soft assets of companies, which are conducive to achieving major breakthroughs in technology. They are the key to the formation of core competitive teams in companies [39]. The overall quality of employees can be reflected by their educational level, so we choose the ratio of the number of graduates to those with doctoral degrees as another variable [40,41].

For external environments, we select two indicators. One is the number of patent applications in the provincial administrative region where the company is registered and market power. The other is the Lerner index. In the context of accelerating the construction of an innovative country in China, the role of innovation and patent applications has become increasingly prominent [42]. The patent standard is relatively objective and stable while the relevant data is also easily accessible and is closely related to innovation activities [43]. This can better encompass the direct and indirect outputs of innovation activities. As such, we select the index of patent application ratio by comparing regions as a variable to explain the regional innovation environment [44]. At the same time, the intensity of market competition is also one of the factors affecting company operating income [45]. Companies that can survive under conditions of high market competition intensity tend to have greater market power and stronger R&D input [46].

Based on this, we propose Hypothesis 3:

Hypothesis 3 (H3). *For the wastewater industry, the contribution of company R&D input to company operating income varies across different internal and external regulations.*

2.4. The Contribution of Company R&D Input to Company Operating Income Differs among the Three Strategic Development Areas

The Central Economic Work Conference in 2018 decided to promote the three regions of Beijing-Tianjin-Hebei, the Greater Bay Area and the Yangtze River Delta as important hubs of economic power to lead high-quality development. In the past three years, the synergistic development strategy of these three regions has yielded fruitful results. They have had increasing economic influence on the national economy and the construction of demonstration zones for integrated regional development has been effective. This has formed a regional economic layout with complementary advantages and high-quality development, effectively bringing into play the comparative advantages of each region. A regional economic map has formed with a more optimized spatial layout of the country and clear demarcation of the main functions for each region [47]. As a result, compared with other regions, the three regions have more developed economies, are more open to business and therefore tend to have ample resources and stronger R&D input [48–50].

Based on this, we propose Hypothesis 4:

Hypothesis 4 (H4). *The contribution of company R&D input to company operating income differs among the three strategic development areas.*

3. Research Design and Model

3.1. Sample Selection and Data Sources

In this study, a total of 69 companies listed on the Shanghai and Shenzhen Stock Exchanges in China in the wastewater treatment category are studied and panel data of these firms from 2013 to 2020 are selected. We excluded companies with incomplete data on corporate R&D input, operating income and patent performance, and eventually obtained 429 samples. The data involving patents were all obtained from the Chinese Research

Data Services (CNRDS) Platform and the remaining data were obtained from the WIND database. This paper uses Stata for statistical analysis and Winsorizes the data.

3.2. Variable Selection

3.2.1. Dependent Variable: Company Operating Income (OPE)

In order to avoid the impact of different sources of revenue on the conclusions of the study, the operating income (OPE) of the company is selected to measure company operating income. To reduce absolute differences between the data and to avoid the influence of individual outliers, we applied logarithms to all values.

3.2.2. Independent Variables

(1) R&D input of companies (RD)

R&D input refers to research and development input, including the various costs incurred by enterprises in the research and development of products, technologies, materials, processes and standards. Since company R&D input includes several aspects that cannot be specifically quantified and most studies show that R&D input is positively related to company R&D input, we select company R&D input (RD) as an explanatory variable to measure company R&D input. In order to reduce absolute differences between the data and avoid the influence of individual outliers, we applied logarithms to all values.

(2) Patent performance (PTF)

We measure patent performance in terms of the number of patent applications that a company files each year. Since the number of patent applications for some companies is 0, we have taken the logarithm of each patent application value after adding 1. This is to reduce the absolute difference between data points and avoid the influence of individual outliers.

(3) Internal and external regulations

We select four indicators reflecting the strength of external and internal regulations based on a search and review of the literature. After multiple attempts, we finally constructed the external regulation—PAP and LER as well as the internal regulation—RDI and GRA.

(a) PAP—This is measured by the number of patent applications in the provinces where a company is located to quantify the regional innovation environment in the country. In order to reduce absolute differences between the data and avoid the influence of individual outliers, we applied logarithms to all values.
(b) LER—In terms of market competition index, we draw on the research results of Peress [51] and measure market power using the Lerner index. The value of the Lerner index reflects the level of competitive market pressure faced by the company.
(c) RDI—R&D intensity is the strength of investment by an enterprise in innovation, measured by the ratio of R&D input to operating revenue.
(d) GRA—This is the ratio of the number of people with an undergraduate degree or higher to the total number of employees in a company. It is an indicator of the number of R&D staff in a company.

(4) Control variable: Regions where companies are registered (AREA)

In addition to the above variables, regional distribution (AREA) is likely to have an impact on the findings of the study and therefore it is selected as a control variable in this paper. There are differences in the level of economic development and government policies in different regions of China. As such, we will divide the regions where the companies are registered into the three strategic areas (Beijing-Tianjin-Hebei, Yangtze River Delta, Greater Bay Area) and other regions. This is to study the development of different urban clusters and the values of regional variables are indicated using coded values.

All of the above information has been summarized in the Table 1 below:

Table 1. System of indicators for variables.

Variable Type	Variable Name	Symbolic	Description
Dependent variable	Company operating income	OPE	OPE = Ln (the operating income)
Independent variables	Company R&D input	RD	RD = Ln (Research and Development input)
	Patent performance	PTF	PTF = Ln (numbers of patent applications + 1)
	Number of patent applications for a region	PAP	PAP = Ln (regional patent applications numbers in province-level division where companies are registered)
	Market competition index	LER	LER = (operating income-operating costs-sales expenses-management expenses)/operating income
	Research and development investment intensity	RDI	RDI = the strength of an enterprise's investment in innovation
	Ratio of employees with undergraduate degrees and above	GRA	GRA = (employees with bachelor's degree or above)/(total number of employees) × 100%
Control variable	Regions where companies are registered	AREA	The three strategic areas = 1, Other regions = 0

3.3. Analysis of the Role of Intermediaries

First, we investigate the direct impact of company R&D input on company operating income and the mediating role of the number of patents on company performance. Model 1 is to test the influence of company R&D input on the operating income of wastewater treatment companies, as shown in Equation (1). The model OPE denotes the operating income of the wastewater treatment industry, RD denotes the company R&D input and ε denotes the random error term, including the total effect term for explanatory variables not included in the model and several random factors influencing the explained variables.

Model 2 is the regression model of company R&D input on the patent performance of wastewater treatment companies. The variable PTF denotes the patent performance of wastewater treatment companies as shown in Equation (2). Based on model 1, model 3 adds the variable patent performance of wastewater treatment companies. It then determines the influence of company R&D input and patent performance on the operating income of wastewater treatment companies as shown in Equation (3).

$$\ln(\mathrm{OPE}) = \beta_0 + \beta_1 lnRD + \beta_2 lnPAP + \beta_3 LER + \beta_4 RDI + \beta_5 GRA + \beta_6 AREA + \varepsilon \quad (1)$$

$$\ln(\mathrm{PTF} + 1) = \beta_0 + \beta_1 lnRD + \beta_2 lnPAP + \beta_3 LER + \beta_4 RDI + \beta_5 GRA + \beta_6 AREA + \varepsilon \quad (2)$$

$$\ln(\mathrm{OPE}) = \beta_0 + \beta_1 lnRD + \beta_2 \ln(PTF + 1) + \beta_3 lnPAP + \beta_4 LER + \beta_5 RDI + \beta_6 GRA + \beta_7 AREA + \varepsilon \quad (3)$$

Subsequently, we introduce two variables, the internal regulation and external regulation, corresponding to three impact factors, to examine the mechanism of the impact of company R&D input, company patent performance and company operating income for different levels of internal and external regulation.

We simplify the internal environment as R&D intensity and the external environment as market competition and then divide the total sample by the median size of internal and external regulation. This yields a high external regulation-high internal regulation group (Group 1), a low external regulation-high internal regulation group (Group 2), a high external regulation-low internal regulation group (Group 3), and a low external regulation-

low internal regulation group (Group 4). Following this, the four sub-samples are brought into Equations (1)–(3).

4. Empirical Results and Analysis

4.1. Descriptive Statistics

From descriptive statistics for the variables in Table 2, there is a large gap between the maximum and minimum values of RD, which indicates that the innovation capabilities of different companies differ greatly. At the same time, the maximum and minimum values of RDI and LER also have a large gap and low mean values. This indicates that the internal and external environments faced by different companies vary greatly, which also matches the logic of this paper in distinguishing between internal and external environments for research. The other indicators have normal values and lie within a reasonable range.

Table 2. Descriptions.

Variable	Obs	Mean	Std.Dev.	Min	Max
OPE	518	20.724	1.194	17.782	23.386
RD	429	16.892	1.386	12.676	19.597
PTF	518	1.85	1.766	0	5.252
LER	513	0.177	0.24	−0.923	0.793
PAP	518	11.167	0.967	8.984	13.364
RDI	518	2.362	1.907	0	7.116
GRA	518	30.429	21.264	0	86.27

4.2. Regression Analysis of Company R&D Input, Patent Applications and Company Operating Income

4.2.1. The Relationship between Company R&D Input and Their Operating Income

The following three regressions are used to test the correlation between patent performance, company R&D input and company operating income. Model 1 tests the influence of company R&D input on company operating income and model 2 tests the influence of company R&D input on patent performance. Model 3 integrates these results to verify whether company R&D input can promote company operating income by influencing patent performance. The regression results are as follows (Table 3).

As we can see in Table 3, in model 1, the coefficient of company R&D input RD is 0.690, which passes the significance test at 1% level. This indicates that company R&D input has a significant positive impact on company operating income. Company R&D input can promote the level of company operating income for companies.

In model 2, the coefficient of company R&D input RD is 0.856, which also passes the significance test at 1% level. This shows that company R&D input has a significant positive impact on patent performance and company R&D input can significantly contribute to patent performance.

In model 3, the coefficients of company R&D input RD and patent performance PTF are 0.561 and 0.151 respectively, which are both significantly greater than 0. It is evident that both company R&D input and patent applications can have a significant positive impact on company operating income.

The above three models show that there is a partial mediating effect of patent performance between company R&D input and company operating income. On one hand, company R&D input can directly promote the influence of company operating income. On the other hand, company R&D input can promote patent performance which subsequently improves company operating income.

Hypotheses 1 and 2 are verified.

Table 3. Regression results of RD, PTF and OPE.

Variables	β Coefficients (Above Parentheses)		
	Model 1	**Model 2**	**Model 3**
RD	0.690 ***	0.856 ***	0.561 ***
	(33.88)	(18.21)	(21.96)
PTF			0.151 ***
			(7.61)
LER	−0.206 *	−0.674 **	−0.105
	(−1.68)	(−2.38)	(−0.90)
PAP	−0.009	−0.057	−0.001
	(−0.34)	(−0.89)	(−0.03)
RDI	−0.485 ***	−0.415 ***	−0.423 ***
	(−30.58)	(−11.33)	(−24.85)
GRA	0.006 ***	0.012 ***	0.004 ***
	(4.51)	(4.06)	(3.24)
AREA	−0.132 **	0.251 **	−0.170 ***
	(−2.38)	(1.97)	(−3.25)
Constant	10.608 ***	−10.897 ***	12.251 ***
	(26.26)	(−11.69)	(28.08)
Observations	429	429	429
R-squared	0.814	0.531	0.836

β Coefficients above parentheses; t-statistics in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$ (the same below).

4.2.2. Relationship between Company R&D Input and Operating Income under Internal and External Regulations

The following table tests the relationship between the differing intensities of internal and external regulations in the R&D input of companies and the company operating income. The level of regulation can be divided into four categories according to the internal and external intensities: high external regulation-high internal regulation (Group 1), low external regulation-high internal regulation (Group 2), high external regulation-low internal regulation (Group 3) and low external regulation-low internal regulation (Group 4).

The regression results obtained are as follows.

Table 4 shows that the coefficients of RD in the four groups are 1.011, 0.998, 0.766 and 0.677. All of them pass the significance test, which shows that corporate R&D input can have a significant positive impact on operating income of these four types of enterprises. The enhancement is the strongest in the high external regulation-high internal regulation group and the weakest in the low external regulation-low internal regulation group.

Table 4. Regression results of sub-groups for different regulations (Model 1).

Variables	β Coefficients (Above Parentheses)			
	Group 1	**Group 2**	**Group 3**	**Group 4**
RD	1.011 ***	0.998 ***	0.766 ***	0.677 ***
	(211.82)	(275.75)	(12.73)	(14.70)
LER	−0.009	−0.103 ***	−0.416	0.441 **
	(−0.16)	(−3.44)	(−0.92)	(2.11)
PAP	0.002	−0.001	−0.125 **	−0.011
	(0.33)	(−0.23)	(−2.03)	(−0.13)
RDI	−0.230 ***	−0.237 ***	−0.948 ***	−1.197 ***
	(−57.25)	(−67.18)	(−7.15)	(−13.41)
GRA	−0.000	−0.000	0.013 ***	−0.003
	(−0.96)	(−0.86)	(2.78)	(−0.69)
AREA	0.006	−0.002	−0.258 **	0.070
	(0.52)	(−0.31)	(−2.02)	(0.52)
Constant	3.985 ***	4.256 ***	11.091 ***	11.974 ***
	(38.43)	(69.23)	(11.48)	(9.86)
Observations	138	121	85	85
R-squared	0.998	0.999	0.781	0.781

β Coefficients above parentheses; t-statistics in parentheses; *** $p < 0.01$, ** $p < 0.05$.

The following regression test evaluates the relationship between different intensities of internal and external regulation and patent performance.

Table 5 shows that the coefficients of RD in the four groups are 1.222, 1.189, 0.673 and 0.676. All of them pass the significance test, which shows that corporate R&D input can have a significant positive impact on the patent performance of these four types of enterprises. This impact is the strongest in the high external regulation-high internal regulation group and the weakest in the low external regulation-low internal regulation group.

Table 5. Regression results of sub-groups for different regulations (Model 2).

Variables	β Coefficients (Above Parentheses)			
	Group 1	**Group 2**	**Group 3**	**Group 4**
RD	1.222 ***	1.189 ***	0.673 ***	0.676 ***
	(11.87)	(9.83)	(5.01)	(6.76)
LER	−1.609	−0.836	−0.821	0.522
	(−1.27)	(−0.84)	(−0.81)	(1.15)
PAP	−0.016	−0.098	−0.143	−0.167
	(−0.14)	(−0.79)	(−1.04)	(−0.93)
RDI	−0.190 **	−0.193	−0.465	−0.589 ***
	(−2.19)	(−1.64)	(−1.57)	(−3.04)
GRA	0.006	0.000	0.031 ***	−0.004
	(1.42)	(0.08)	(2.94)	(−0.49)
AREA	0.235	0.361	0.708 **	0.228
	(0.94)	(1.52)	(2.49)	(0.78)
Constant	−18.312 ***	−16.483 ***	−7.591 ***	−5.902 **
	(−8.18)	(−8.03)	(−3.52)	(−2.24)
Observations	138	121	85	85
R-squared	0.607	0.576	0.574	0.429

β Coefficients above parentheses; t-statistics in parentheses; *** $p < 0.01$, ** $p < 0.05$.

Finally, the model was run simultaneously using company R&D input and patent performance. This is to verify whether the mediating effect of patent performance on company R&D input and company operating income differs under different levels of environmental regulation. The following results were obtained.

Table 6 shows that for Group 3 and Group 4, the coefficients of RD and PTF are both significantly greater than 0, indicating that both company R&D input and patent performance have a significant positive effect on company operating income.

Table 6. Regression results of sub-groups for different regulations (Model 3).

Variables	β Coefficients (Above Parentheses)			
	Group 1	**Group 2**	**Group 3**	**Group 4**
RD	1.010 ***	0.994 ***	0.648 ***	0.551 ***
	(146.42)	(202.31)	(10.11)	(10.32)
PTF	0.000	0.003	0.175 ***	0.186 ***
	(0.08)	(1.13)	(3.71)	(3.88)
LER	−0.009	−0.100 ***	−0.272	0.344 *
	(−0.15)	(−3.35)	(−0.64)	(1.77)
PAP	0.002	−0.001	−0.100 *	0.020
	(0.33)	(−0.15)	(−1.74)	(0.27)
RDI	−0.230 ***	−0.236 ***	−0.867 ***	−1.087 ***
	(−56.00)	(−66.31)	(−6.94)	(−12.51)
GRA	−0.000	−0.000	0.008 *	−0.002
	(−0.95)	(−0.87)	(1.67)	(−0.54)
AREA	0.006	−0.003	−0.382 ***	0.027
	(0.51)	(−0.47)	(−3.11)	(0.22)
Constant	3.991 ***	4.308 ***	12.417 ***	13.074 ***
	(31.19)	(56.08)	(12.88)	(11.33)
Observations	138	121	85	85
R-squared	0.998	0.999	0.814	0.817

β Coefficients above parentheses; t-statistics in parentheses; *** $p < 0.01$, * $p < 0.1$.

This means that in the high external regulation-low internal regulation group and the low external regulation-low internal regulation group, there is a partial mediating effect of patent performance between enterprise R&D input and enterprise operating income. The R&D input of a company also has a significant positive influence on its operating income. In the two leftmost regulations, company R&D input has a direct significant positive effect on operating income, while patent performance does not have a mediating effect at all.

Hypothesis 3 is verified.

4.2.3. Sub-Regional Regression Analysis

The following table tests the relationship between company R&D input, patent performance and company operating income for enterprises in different regions. These regions are the Yangtze River Delta, Beijing-Tianjin-Hebei, the Greater Bay Area and other regions. As there are only two companies in the Greater Bay Area region, it is only the remaining three regions that can be verified and the results are as follows.

As shown in Table 7, Model 1 shows that RD in Area 1 and Area 0 has a significant positive effect on company operating income (Area 1 > Area 0). Model 2 shows a significant positive effect of RD on patent performance in Area 1 and Area 0 (Area 1 > Area 0). In Model 3, there is a significant positive relationship between RD in Area1 and Area0 and company operating income, while PTF has a significant positive effect on company operating income for Area1 and Area0 (Area 1 > Area 0).

Table 7. Regression results for different areas.

Variables	β Coefficients (Above Parentheses)					
	Model 1		Model 2		Model 3	
	Area 1	Area 0	Area 1	Area 0	Area 1	Area 0
RD	0.790 ***	0.621 ***	0.910 ***	0.823 ***	0.743 ***	0.384 ***
	(41.34)	(15.52)	(13.85)	(11.63)	(30.11)	(8.06)
PTF					0.051 ***	0.287 ***
					(2.92)	(7.18)
LER	−0.510 ***	0.217	−1.073 ***	−0.153	−0.455 ***	0.261
	(−4.49)	(0.93)	(−2.74)	(−0.37)	(−4.01)	(1.29)
PAP	0.035	−0.060	0.105	−0.192 **	0.030	−0.005
	(1.25)	(−1.25)	(1.08)	(−2.26)	(1.07)	(−0.11)
RDI	−0.449 ***	−0.513 ***	−0.381 ***	−0.442 ***	−0.430 ***	−0.387 ***
	(−33.75)	(−14.52)	(−8.33)	(−7.06)	(−29.17)	(−10.96)
GRA	0.002 **	0.013 ***	0.012 ***	0.012 **	0.002	0.010 ***
	(2.18)	(4.29)	(3.46)	(2.28)	(1.56)	(3.56)
Constant	8.331 ***	12.064 ***	−13.449 ***	−8.920 ***	9.019 ***	14.626 ***
	(19.99)	(16.62)	(−9.38)	(−6.94)	(19.04)	(20.27)
Observations	274	155	274	155	274	155
R-squared	0.917	0.692	0.553	0.513	0.920	0.772

β Coefficients above parentheses; t-statistics in parentheses; *** $p < 0.01$, ** $p < 0.05$.

To sum up, regardless of the region in which the company is registered, there is a partial mediating effect of patent performance between company R&D input and company operating income. This means that company R&D input can directly promote increased company operating income and can further encourage increased company operating income by raising the level of patent performance.

Hypothesis 4 is verified.

5. Conclusions

5.1. Main Findings

We take listed companies in the wastewater treatment category listed on the Shanghai and Shenzhen Stock Exchanges in China as the focus of our research and select balanced panel data for these companies from 2013–2020 for analysis. We use logistic regression and

multiple linear regression methods to study the impact of the R&D input of wastewater treatment companies on company operating income and come to the following conclusions.

First, there is a partial mediating effect of patent performance between company R&D input and company operating income. On the one hand, company R&D input can directly strengthen the influence of company operating income. On the other hand, company R&D input can boost patent performance which improves company operating income.

Second, the utility of company R&D input varies, with differing intensities for internal and external regulations. In the high external regulation-low internal regulation group and low external regulation-low internal regulation group, there is a partial mediating effect of patent performance between enterprise R&D input and operating income. At the same time, company R&D input has a significant positive influence on its operating income. In the high external regulation-high internal regulation group and the low external regulation-high internal regulation group, company R&D input has a direct significant positive effect on operating income, while patent performance does not have a mediating effect.

Third, regardless of the region in which a company is registered, there is a partial mediating effect of patent performance between company R&D input and operating income. Specifically, in the three strategic regions, the direct contribution of enterprise R&D input to enterprise operating income is more significant. In other regions, the contribution of enterprise R&D input to enterprise operating income is more closely related to the mediating variable of patent performance.

5.2. Research Insights

First, the wastewater treatment industry should increase investment in the R&D system to improve its own R&D input. The wastewater treatment industry is one of the strategic emerging industries in China and is also a key development industry in China. In the wastewater treatment market, technological advantages have gradually become a key competitive element, so companies should continue to strengthen the construction of R&D systems to improve their level of technology. Wastewater treatment companies that intend to increase investment in R&D need a certain system to ensure that, for example, companies can allocate a certain percentage of net profit to annual investment in R&D. Second, we should pay attention to the R&D department of a company. Although the R&D department is not able to yield a direct income for the company, it is an important factor in determining the ability of the company to continue to operate. The R&D department should have a suitable number of R&D personnel that will account for a minimum percentage of the total number of employees. In addition, companies can cooperate with universities and research institutes to set up joint R&D centers for R&D into cutting-edge technology, technology introduction integration and collaborations. They can also cooperate with companies in the same industry to solve technology and talent problems and reduce risks associated with technology R&D.

Second, companies should focus on the training of R&D personnel to increase their talent advantages. The water treatment industry is under the umbrella of environmental protection and the goal of its innovation policy is to promote the development of technology. This is so that it can improve the efficiency of wastewater treatment, reduce its cost, improve water quality and protect water resources. R&D personnel are the core of technological innovation, so the company can attract excellent technical R&D personnel through equity incentives and other measures. It can also focus on environmental protection equipment engineering, water recycling and other businesses. This will enhance the business integration advantages of the company, expand the scope of domestic and international markets, and enhance the company operating income [52].

Third, companies in the three major national strategic areas should play an exemplary leading role. These three regions are the most important economic centers in China, which account for nearly half of Chinese GDP. In 2020, several major policies were piloted in the three major national strategic areas. This has generated new power on regional innovative development. Therefore, the wastewater treatment companies in these three strategic areas

should take the lead in technological innovation and play an exemplary leading role in fulfilling their social responsibilities. The economy and financial industry in these regions is more developed, so companies can try to cooperate with financial institutions, introduce strategic investors and broaden financing channels. These include the issuance of green bonds and other financing products and the opening of PPP asset securitization projects to raise funds for research and development to reduce the risk involved with R&D funding.

Fourth, the government should fully take on a policy-oriented role to create a good ecosystem for the development of the wastewater treatment industry. The water pollution management industry is a fundamental industry of economic and social development and a pillar for key industries. It is one of the implementation approaches to attain the "carbon peak, carbon neutral" goal and one of its key focus areas. After unremitting efforts in recent years, China has achieved remarkable results in its management of wastewater [53]. On this basis, the "double carbon" target will reshape the wastewater management industrial ecosystem, which is conducive to the emergence of several new processes and products in the field of pollution management. This will reduce energy consumption and also promote greater use of recycled water and more comprehensive use of residual sludge after wastewater treatment. Therefore, the Government should formulate and improve the industrial policy of green development and persevere on the road of safe, green and high-quality development. This is also an important step in promoting the strategic goal of "double carbon" and industrial innovation and development.

Fifth, the government should promote the "chain chief system" for the industry by promoting the development of industry around the principles of "saving water", "source control", "emission reduction" and "carbon reduction" for the entire process of green technology development. For example, "saving water" revolves around the efficient use of recycled water equipment, pharmaceuticals and descaling technology, as well as unconventional water utilization technology. "Source control" would involve the extraction and recovery of highly concentrated organic wastewater components as well as the enrichment and extraction of heavy metals in wastewater, sludge and kettle residual waste. "Emission reduction" requires a two-pronged approach. On one hand, enrichment of advantageous strains, filler improvement and process multi-parameter regulation can be used to improve the effect of conventional pollutant co-processing. On the other hand, biological, chemical and physical methods can be used to further improve the removal efficiency of organic pollutants that are difficult to degrade.

The awareness and protection of intellectual property in the field of wastewater treatment is far behind IT, electronic communication and other technology-intensive fields. In the future, wastewater treatment enterprises should further improve the intellectual property protection system. Enterprises can establish a domestic and foreign patent tracking and retrieval mechanism for the process of technology research and development, and should conduct regular searches of domestic and foreign technological progress and patent application of R&D projects to avoid duplication of R&D. Second, the legislature should speed up the amendment of outdated laws and actively connect with relevant international treaties to ensure timely and effective regulation and adjustment of new issues arising in the field of IPR. The patent application procedures should be further streamlined [54]. The transparency of relevant legislation should be enhanced. Actively expanding the channels for enterprises, industry associations and the public to participate in legislation is also essential.

Lastly, wastewater treatment enterprises bear a heavy responsibility for environmental protection. Therefore, from the perspective of environmental protection, enterprises should carry out solid legal risk prevention work for environmental protection. Enterprises should combine the actual production and operation process to identify the legal risk points of environmental protection that cause or may cause environmental pollution and ecological damage. In addition, they should take effective measures to strengthen prevention and control beforehand, and refine the responsibility of the whole staff for environmental protection. At the same time, enterprises can regularly summarize the environmental

protection legal dispute cases occurring in the field of sewage treatment. Enterprises can seriously carry out case analysis and look deeply into the causes of occurrence and sources of risk to inform about the legal risks of environmental protection in a timely manner.

5.3. Contributions and Limitations

In the wastewater treatment industry, there are still only a few studies on the R&D input of enterprises and company operating income. Therefore, combined with the above-mentioned studies, we find that, for wastewater treatment enterprises, it is crucial to improve their R&D input and patent performance. This will help improve their competitiveness in the market. Furthermore, studies on the three strategic development areas have not yet appeared for the wastewater treatment industry. In addition, in order to reduce carbon emissions, reducing energy and material consumption of wastewater treatment is the inevitable goal of industrial upgrading. Reducing water pollution is still the top priority for ecological environmental protection and this study provides relevant suggestions for how wastewater treatment enterprises can improve their core competitiveness and embark on the path of green and low-carbon development.

Despite the contribution of our study, there are still limitations. First, we have no way of considering every variable related to enterprise development. For example, the degree of internal control of enterprises may be closely related to their management structure. In addition, the wastewater treatment industry is more dependent on national industrial policy and the scale of investment in environmental protection. As such, enterprises with perfect internal control systems are better able to strictly implement relevant laws and regulations, fulfill their social responsibilities and obtain a greater competitive advantage through their development. Second, government subsidies may also influence the development of the industry. Third, government subsidies may also affect the level of R&D input of enterprises, due to the higher risk and longer profit cycle of their R&D activities. Enterprises that receive more government subsidies are often willing to increase their R&D input to improve their R&D input and thus their operating income. Considering the influence of the above factors can increase the value of this study.

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