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Influence of Environmental Regulation and Resource Utilization on Research and Development Towards Sustainability: A Perspective of China's Coal Mining Industry

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Abstract. The multi-directional variation of results among environmental regulation, resource utilization, and Research and Development (R&D) investments continue to gain more popularity but few studies have examined the nexus among these variables in an open economy. To analyze the individual and combined effects of environmental regulation and resource utilization on industrial R&D investments, a panel data of 30 provinces in China from 2008 to 2018 was used. We also examined the mechanism underlying the magnitude of pollution inducement on R&D investment. The results show that environmental regulation significantly and positively promotes R&D investment while resource utilization has an inverse effect. Environmental regulation does not interfere with efficiency and neither does the quest for efficiency in resource utilization weaken the impact of environmental regulation on R&D investment. Only a few provinces are within the rising stages of the inverted n-shaped curve indicating environmental regulation level is still low. Even though there are tighter laws, government needs to continue to put in more stringent environmental policies towards achieving sustainable development.

Keywords. Environmental regulation, resource utilization, R&D investment, sustainable development

1. Introduction

China's economy has seen significant development since the 1970s from its reforms and opening ups. Coal extraction and its utilization for energy production worldwide has also

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improved significantly from 1973 to date. China had a world coal production percentage share of 13.6% and 44.5% in 1973 and 2016 respectively and is therefore described as the Coal Giant. It is on record that about 40% of the world's electricity production is from coal. The gush of production included steam coal, lignite and recovered coal. Predictably, the global dependence and increase in production and consumption reflected in relative CO_2 emissions between the same periods. Consequently, there is a cleaning up agenda for which China is attracting global attention [1, 2] by catching up with multiple investments, strategies in resource utilization and stringent environmental regulations. Environmental regulation could stimulate research and development (R&D) investment mechanisms [3] and as a condition of an open economy, the technological progress of a region could impact its R&D spillover effects.

Coal mining industries regard strict environmental regulations as an extra load on the process of production. However, this helps mitigate pollution through traditional productive resource utilization. Ning, Van and Lo [4] argued that, the shrinking expectation of stringent environmental regulations and the quest for profit would put extra burden and pressure on industries to promote R&D investments as well as compelling them to enhance efficiency in resource utilization and minimizing pollution towards environmental sustainability. Nonetheless, the legitimate question is; to what extent does both environmental regulation and resource utilization stimulate R&D? In an attempt to provide a hypothetically tested analysis in responding to the posed question, this study would, first of all, analyze the independent and collective effects of these variables on R&D. We would also adopt the causal mediator model to investigate the influence of environmental regulation and resource utilization on R&D towards sustainability of China. The remainder of this paper is segmented and follows orderly as; Literature Review, Data and Methodology, Results, and Conclusion.

2. Literature Review

Governments all over the world have attached increasing significance to tackling environmental regulation since the 1970s [5] and the impact of the environmental regulations on R&D has generated variant assertions among researchers. Environmental regulation refers to the policies and initiatives that ensures rehabilitation of the ecosystem to minimize damages. Pedersen [6] and Tosun [7] argued that, coercing market players implementing environmental policies by administrative inspections and reducing violations of environmental standards constitute environmental regulation. For the purposes of this study, policies regarding; Unharmful domestic waste treatment, Industrial solid waste treatment and Sewage treatment were considered as the standard definition of environmental regulations. Environmental regulators supervise and inspects the biosphere and initiates sanctions as well as recommendation to violators [6]. Chinese government have persistently encouraged R&D initiatives, drafted and enforce environmental laws which has yielded great positive outcomes in managing natural resource utilization. This has contributed in mitigating environmental pollution towards sustainable development of China to an extent. Industries do not necessarily and willingly implement environmental policies towards managing pollutant emissions [8] and so therefore, environmental policies are carried out and enforced to safeguard efficiency and effectiveness in resource utilization [9, 10] and reduce pollution. The categorization of economic growth theory; classical, neoclassical and modern, all affirm the influencing role of stringent environmental regulations. Liu, Wang and Guo [5] found that environmental protection level, and emissions could be improved while technological innovation increase through strict environmental regulations. Wanlley [11] further asserted that industrial production cost and technological innovation would increase to promote crowd out industrial innovation while investment in pollution reduction initiatives and industrial quality enhancement induce efficiency in resource utilization.

Coal mining cities poses wide range of challenges which are related to the safety of the ecosystem [12] hence the need for stringent environmental regulations. The study of Ning, Van and Lo [4] found internal financing to be the only way through which environmental regulation affect R&D investment. Similarly, the findings of Chakraborty and Chatterjee [13] in analyzing the indirect impact of environmental regulation on technological innovation in India concluded that, from case to case, environmental regulation could significantly increase technological innovation. Han, Hui and Song [14] projected an inverted n-shaped nexus between environmental regulation and technological progress in their study. This implied, strict environmental regulation could increase R&D investment initially, reduce at a point then turn to rise again. Stringent environmental regulation could help rehabilitate industrial pollution through innovative innitiatives towards promoting green development [15, 16]. Flexible environmental policy enhances efficiency in resource utilization [17] and what becomes of the direct influence of both environmental regulation and resource utilization on R&D? Generally, industrial sweage discharge, unharmful domestic waste discharge, and industrial solid waste discharge are minimized through strict enforcement of environmental regulation and industrial capacity could be enhanced by constantly finding solutions through R&D innovation. The sector of R&D creates technological innovation using human capital and the stock of existing knowledge which generates mechanism to achieve structural changes in innovation [18, 19]. R&D implementation is an objective towards achieving efficiency in production and environmental responsibility in mining [20]. Mining industries' improvement in R&D intensity could have a spillover effect by lessening environmental pollution and enhancing sustainability [21]. The most prominent ways to achieve green development and persistent economic growth include balancing environmental regulation in resource utilization and rehabilitation with sustainable development through R&D. This promotes the restructuring and upgrade of coal mining cities that are contributing agents of environmental pollution. The presumption of a stringent environmental regulation and the quest for profit will compel firms to adobt efficient approach in utilization of resource and find innovative ways to reduce pollutant discharges through R&D investment. The attention of R&D to lead to innovation is focused on technology with increased profitability as their main drivers. However other studies [22-23] hold mining (including coal) from sustainable driven perspective which focuses on posed challenges resulting from mining. They includes supply security, input to global climate change, and high inhabitant and customer demand for accountability. These various challenges emanating from coal mining industries for now and the future are strongly linked to better approaches towards sustainability and transformation with the proposed way forward being all-round change caused by innovation and industrial structure upgrade. R&D is a major source for novelty and technological advancement while enhancement in technological capabilities positively affect production [24] and efficiency, crating a link between R&D and resource utilization. Most literature affirm the significant impact of environmental regulation on technological innovation. However, it is unconclusive whether the most effective method of encouraging technological innovation which is R&D spillover effect is influenced by the individual and combined effect of environmental regulation and resource utilization. This study therefore seek to find the extent of the influence of environmental regulation and resource utilization on R&D investment.

3. Data and Methodology

3.1. Variable Selection

With the newly implemented accounting disclosure system of China since 2007, listed firms and industries are obliged to make public their R&D information in their annual reports. In this study, R&D is measured by the proxy of R&D investment. Considering the availability of the data, we chose 2008-2018 as the sample period. The research objective was to examine if environmental regulation and resource utilization influence the rate of R&D investments and to what extent is the level. For consistencies and the avoidance of errors in data curation due to the history of China, the data for four administrative units; Hong Kong, Taiwan, Macau and Tibet, out of the 34 provincial units in China were excluded from the analysis. All the observations were obtained after data formating for each variable in coal mining cities of the 30 provinces of China mainland.

3.1.1. Data Source

For the purposes of the analysis, data on R&D, environmental regulation , resource utilization and social development were compiled from China statistical year book. Economic growth, Human capital and Enterprise scale data were accertained from local statistical year book of all provinces under study. Finally, values for pollution was amassed from world indicators. To analyse the impact of environmental regulation and resource utilization on R&D using a panel data, we grouped China's 30 provinces into three major economic regions (Bohai Rim, Pan-Pearl region, and Pan-Yangtze River region) for convenience profiling as similarly classified by Liu, Wang and Guo [5]. The various components under the three classifications are (i) **Bohai Rim**; Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia, Liaoning, Jilin, Heilongjiang and Shandong (ii)**Pan-Pearl region**; Fujiang, Jiangxi, Hubei, Hunan,Guangdong, Guangxi, Hainan, Sichuan, Guizhou, Yunnan and Chongqing (iii) **Pan-Yangtze River region**; Shanghai, Jiangsu, Zhejiang, Anhui, Henan, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang.

3.1.2. R&D Investment Index (RD)

From the proxy of R&D investment, we used the perpetual inventory method to measure R&D stock of province *j* as similarly used by Berlemann and Wesselhöft [25];

$$DR = (1 - \nabla)DR_{t-1} \;\; + RD_t \tag{1}$$

where DR_{t-1} represents the depreciation rate of R&D investment of a province at year *t* of time *t-1* years while ∇ denotes the depreciation rate of R&D investment. We used a 5% rate as adopted in other studies [5, 26]. $R\&D_t$ is the actual R&D expenditure index in 2008.

3.1.3. Environmental Regulation (ER)

Environmental regulations are policies and initiatives that ensure the rehabilitation of the ecosystem to minimize damages. ER according to Chengliang, Tao and Qingbin [5] can be categorized into voluntary environmental regulation, command-controlled environmental regulation and incentive-type environmental regulation. The latter only occurs from the government side by treating the market as a carrier. They coerce market players to implement environmental policies through administrative inspections [6, 7]. The common practices under this type are the guidance of industry players' behavior on sewage treatment, supporting emissions and other discharge trading and granting subsidies from the government's administrative arm. The incentive-typed is more operational and results-oriented, hence its implementation in our studies. Environmental regulations would equate the relationship among resource utilization, quantum pollutant discharge and related treatment rate from industries through their R&D to promote green development [15, 16] Following the measurement method of other researchers [4, 5], we measured environmental regulation by the high intensity to clean environment which includes sewage treatment rate, unharmful domestic waste treatment rate and industrial solid waste treatment rate.

3.1.4. Resource Utilization (RU)

Persistent economic advancement put excessive pressure on resource utilization for economic growth. Quality environmental protection is considered as a scarce resource and so therefore other studies [27] suggested the need for it to be considered as a resource that needs to be conserved and protected. To maintain the pattern of economic growth as well as preserving the natural environment, R&D should be encouraged for sustainable solutions to be meted out. Mehdiloozad and Roshdi [28] studied the development capabilities of China from the viewpoint of resource base city and found that the developmental process requires much attention in environmental pollution and resource utilization efficiency. The debate of resource utilization and its influence on R&D and vice versa keep intensifying hence the choice of this variable. Scholars [29, 30] have estimated resource utilization using coal cyclic utilization rate, coal industrial labor productivity, industrial coal output rate, coal mining rate and total coal industrial output. This study therefore measures resource utilization using per capita land area occupied by coal mining industries, per capita used water resources of coal mining industries and total industrial coal output.

3.1.5. Pollution

Vance, Eason and Cabezas [31] emphasized that, to reduce environmental impact, critical strategies such as increasing efficiency and incorporating environmentally friendly energy generation process and regulated industrial activities could be implemented, although this does not limit the benefits of economic development. Mining problems differ due to different compositions of natural resources and mining process and so the various geochemical properties for mining which include low pH, toxic concentration and liquid discharge could increase environmental pollution. There is therefore the need to rehabilitate through innovative and improved techniques such as R&D. Differences in the country's comparative advantage affect the relationship between economic growth, social development and environmental pollution. To meet the objective of this study, we estimate pollution by the three waste of coal mining industries, namely; per capita industrial wastewater discharged, Per capita SO_2 emission and per capita CO_2 emission.

3.1.6. Control Variables Measurement

The level of economic growth (Y) is measured by the GDP per capita and calculated using the GDP deflator of each province over the period. Social Development (SD) is measured by the per capita green space, that is the total green space of each province. Human capital (HC) is the total average educational level of each province. Scholars have expressed the influencing role of human capital on environmental regulation and R&D. For instance, Chengliang, Tao and Qingbin [5] and Graff and Neidell [32] indicated that for environmental regulation to promote technological innovation, they must rely on a certain level of human capital. Holding other things constant, a higher level of provincial economic growth would mean there is a greater influence of R&D investment on industrial activity for social development. To assess the size of the industry, we introduce enterprise-scale (ES) as an indicator and it is measured by the average assets of industries above the designated threshold size.

3.2. Methodology

Stepwise regression as used by Ning, Van and Lo [4] and Ma, Qu and Zhang [33] is modified to suit our objective of examining both the independent and combined effects of environmental regulation and resource utilization on R&D as shown in equation (2) below:

$$RD_{i,t} = \beta_0 + \beta_1 ER_{i,t} + \beta_2 R_{i,t} + \beta_3 (ER_{i,t} * R_{i,t}) + \sum_{j=1}^{m} \emptyset_j \lambda_{j,i,t} + \mu_{i,j} + \gamma_{i,t} + \tau_{i,t} + \varepsilon_{i,t} \tag{2}$$

where RD represents R&D investments, ER indicates environmental regulations, R represents resource utilization, λ is the control variable while μ,γ, τ and ε respectively stand for fixed effect, year fixed effect, provincial fixed effect and error term. We would again follow the three bootstrapping steps by Imai, Keele and Yamamoto [34] to test the mediation effect of environmental regulation and resource utilization indicators as shown in equations (3)-(5) below:

$$RD_{i,t} = \beta_0 + \beta_1 X_{i,t} + \sum_{j=1}^{m} \emptyset_j \lambda_{j,i,t} + \mu_{i,j} + \gamma_{i,t} + \tau_{i,t} + \varepsilon_{i,t} \tag{3}$$

where X represents both ER and R, with β_1 representing be the total effect. All other variables remain the same as (2).

$$P_{i,t} = \beta_0 + \alpha_1 X_{i,t} + \sum_{j=1}^{m} \emptyset_j \lambda_{j,i,t} + \mu_{i,j} + \gamma_{i,t} + \tau_{i,t} + \varepsilon_{i,t} \tag{4}$$

P in equation (4) represents pollution while α_1 signifies the effect of both ER and R on pollution.

$$RD_{i,t} = \beta_0 + \beta_1 X_{i,t} + \delta_1 P_{i,t} + \sum_{j=1}^{m} \emptyset_j \lambda_{j,i,t} + \mu_{i,j} + \gamma_{i,t} + \tau_{i,t} + \varepsilon_{i,t} \tag{5}$$

δ_1 represents the effect of other influencing indicators on R&D, β_1 is the direct effect of ER and R on R&D towards sustainability.

A significant α_1 and δ_1 in equations (4) and (5) would imply the existence of mediation [4] but if otherwise, we will use bootstrapping and the significant product term of α_1 and δ_1 would imply the presence of mediation. The summary statistics are shown in table 1 with pollution recording the highest mean followed by R&D while enterprise scale has the lowest mean.

Table 1. Descriptive statistics (Source: Authors' estimation).

Variable	Mean	Variance	Minimum Value	Maximum Value
RD	2.1418	1.6422	0.4402	10.5281
ER	1.0184	1.0829	0.0044	5.5974
RU	1.0921	1.0521	0.0344	5.4957
P	2.1581	1.6585	0.4907	10.6983
Y	0.1735	0.1396	0.0067	0.9919
SD	0.6249	0.6337	−0.9939	2.1408
HC	0.0906	0.0594	0.0183	0.4121
ES	0.0534	0.0470	0.0016	0.4831

4. Results

4.1. Interactional Effect of Environmental Regulation, Resource Utilization and R&D Spending

Model 1 and 2 in table 2 show the individual (independent) effect of environmental regulation and resource utilization on R&D spending of coal mining industries of China. Model 3 explains the combined effect of environmental regulation and resource utilization on R&D spending. The coefficient of environmental regulation in model 1 is positive at 0.185 with a significance level of 0.084.

Table 2. Interactional effect of ER, R and R&D.

	(1) RD	**(2) RD**	**(3) RD**
ER	0.185*		0.187*
	(0.084)		(0.089)
RU		-0.211**	0.186**
		(0.023)	(0.041)
ER*RU			-0.003***
			(0.002)
P	-2.471**	-3.481**	-3.821*
	(0.033)	(0.042)	(0.061)
Y	0.647**	1.061*	1.307**
	(0.039)	(0.054)	(0.044)
SD	1.174**	1.092**	1.085*
	(0.021)	(0.048)	(0.078)
HC	0.014***	0.895***	0.019***
	(0.000)	(0.001)	(0.005)
ES	0.219***	0.533***	0.019***
	(0.002)	(0.001)	(0.006)
CON	-141.193***	-79.523***	-82.955**
	(0.008)	(0.005)	(0.033)
R-square	0.5848	0.5970	0.7572

[a]Note: *,** and *** express significance level of 10%,5% and 1% respectively; the value inside parentheses is the p value.

This implies that environmental regulation can positively and significantly increase R&D investment which affirms the finding of Ning, Van and Lo [4]. This is due to the continuous toughening of environmental regulations to induce industries to increase their R&D investments. Industries redesign and upgrade production processes and again adopt pollution treatment initiatives in accordance with regulatory requirements towards sustainable development to avoid sanctions. Model 1 also explains about 58% variations among the variables. In model 2, the independent effect of resource utilization is significant but negative. The finding suggests that R&D investment and resource utilization have an inverse relationship. This is to say that, for a percentage increase in R&D, would result in about a 21% reduction in inefficiency in resource utilization as a results of improved methods from R&D investment towards achieving industrial returns. When confronted with effective resource utilization decisions, industries would prefer to allocate R&D investment even at a higher cost initially to achieve long term returns through effective and efficient resource utilization. Industries need to justify their sustainable development capabilities through effective use of resources, and recovery and treatment of pollutants. Model 3 shows that both environmental regulation and resource utilization affect R&D investment. The combined effects shows a significance of 0.002 which is stronger than the individual effects. The negative interaction effect indicates that environmental regulation does not necessarily enhance the efficiency of resource utilization on R&D investment and resource utilization does not also weaken the positive impact of environmental regulation on R&D investment. All the control variables for model 1,2 and 3 were significant and positive which indicate that R&D investment promotes steady economic growth, improve social development, and empower human capital. This conforms with the results from Chengliang, Tao and Qingbin [5].

4.2. Transformational Mechanism of Environmental Regulations and Pollution

Table 3 below shows the mediation effect of environmental regulation on R&D investment. Column 1 presents the first step in the mediation test (equation (3)), column 2 represents equation (4) as the second step while the final step (equation (5)) in the mediation analysis is shown in column 3. The coefficient for pollution and environmental regulation in equations (4) and (5), represented by α_1 and δ_1 respectively are positive and significant at 5% level with a value of 1.014 and 0.100. The coefficient of determination could explain about 62%, 50% and 63% of variations among the variables respectively for models 1, 2 and 3.

Table 3. Mediation analysis of environmental regulation.

	(1) RD	(2) P	(3) RD
ER	0.175**	1.014**	0.100**
	(0.044)	(0.037)	(0.040)
P			0.071***
			(0.003)
Y	0.007***	45.710***	3.451**
	(0.001)	(0.000)	(0.041)
SD	0.054***	-15.984*	0.227**
	(0.000)	(0.068)	(0.047)
HC	4.416**	2.045*	4.420*
	(0.039)	(0.095)	(0.098)
ES	-0.097***	-0.157**	-0.227**
	(0.008)	(0.030)	(0.036)

CONS	-0.115**	-730.339*	-72.350*
	(0.031)	(0.089)	(0.069)
R-square	0.621	0.503	0.626

[a]Note: *,** and *** express significance level of 10%,5% and 1% respectively; the value inside parentheses is the p value.

This indicates that environmental regulation mediates the relationship between pollution and R&D investments. It is worth noting that the coefficient of pollution is significantly higher in (absolute figure) as compared to the other values. This implies that pollution affects R&D investment mainly through spending on pollutant treatments and enhancement in the production process. A slight improvement in environmental regulation initiative could induce R&D investment reterns of about 7.1% towards pollution reduction for sustainable development. Environmental regulation recorded positive significannce on R&D at 5% level in model 1, 2 and 3 as exhibited in table 3. This implies that, a slight tightening of environmental regulation could push the probability of industrial R&D investment by 17% and 10% for model 1 and 3 respectively towards mitigating quantum plutant discharged for environmental sustainability. At the same time, pollution related discharges could be reduced by 1.4% considering a constatant return to scale on efficiency of ER without focusing on the absolute coefficient value of 1.014. Judging from the descriptive statistics, pollutant discharge which accounted for regional GDP was 1.0184% indicating better but low level of ER. Social Development (SD) is significant at all levels but positive for model 1 and 3, and negative for model 2. This implies that R&D investmentment posivetively induce SD while pollution shows a negative influence. When pollutant discharge levels seem to increase, conditions for social development turns to detororate at a faster rate due to the higher magnitude of the agents of pollution to the society. The findings equally show the influencing role of the control variables. The coefficients of economic growth (Y) for model 1 and 3 are significant and positive. This suggests that economic growth is higher when there are stiffer environmental regulations and R&D investment by industries. Similarly, pollution has a positive correlation with economic growth. From a fair point of the analysis, the higher the pollutant discharged the greater the economic growth and R&D investments. Enterprise-scale (ES) is found to have a significant negative influence on R&D investments, indicating a relative negative productivity effect.

Table 4. Povincial profiling analysis.

	Model A R&D	**Model B R&D**	**Model C R&D**
ER	30.778***	792.767**	308.384***
	(0.019)	(0.038)	(0.082)
RU	4.419***	5.476	5.382***
	(0.004)	(0.151)	(0.010)
P	-3.097***	-5.865***	-5.994**
	(0.001)	(0.000)	(0.018)
Y	4.336*	25.17	24.099**
	(0.148)	(0.013)	(0.151)
SD	0.324*	0.521*	0.529***
	(0.147)	(0.104)	(0.053)
HC	4.420***	0.834**	0.751**
	(0.022)	(0.050)	(0.002)
ES	-0.101**	-0.135**	-0.135***
	(0.022)	(0.074)	(0.029)

CONS	-9.750*** (0.010)	0.746** (0.041)	-5.362*** (0.007)
R-square	0.758	0.626	0.767

[a]Note: *,** and *** express significance level of 10%,5% and 1% respectively; the value inside parentheses is the p value.

Table 4 depicts the analysis of the three major classifications of the various provinces. Bohai Rim, Pan-Pearl region, and Pan-Yangtze River region are represented by model A, B and C respectively in table 4. The observations of the analysis exhibited a variation from negative to positive for all the three major classifications in table 4. Environmental regulation recorded a reasonable range of confidence interval from the results and promotes industrial innovation towards regional sustainability from the constant rehabilitation of pollutant discharge. Again, 75% variation among the variables in model A (Bohai Rim region) could be explained. While model B and C could explain 63% and 77% of variation among the variables correspondingly. Both environmental regulation and resource utilization are all significant in the three clusters. This reaffirms the influencing role of ER and RU on R&D. A slight change in R&D investment could influence the reduction in pollutant discharge in absolute values by 3.097, 5.865 and 5.994 for Bohai Rim, Pan-Pearl region, and Pan-Yangtze River region in model A, B and C respectively. The provincial profiling analysis shows differences among model A, B and C. Therefore when developing regulation regarding environmental policies, considerations of local coditions and the tolerance capacity of the province could be looked at to design appropriate environmental regulation in resource utilization base on the distinctiveness of each province towards improving the regional sustainability level.

5. Conclusion

Analyzing the provincial level data of 30 provinces of China from 2008 to 2018, a panel data appraisal modeling was constructed to examine both the independent and combined influence of environmental regulation and resource utilization on R&D investment towards sustainable development. We applied the mediation model to examine the influencial mechanism of environmental regulations and resource utilization no R&D investment towards sustainable development. The empirical results conclude that;

(1) Environmental regulation can positively and significantly increase R&D investment and the combine effect of environmental regulation and resource utilization is stronger than the individual effect. The conclusive remarks for table 2 indigates a positive relationship between environmental regulation and R&D investment while that of resource utilization and R&D investment is negative. This suggested that the growing intensity of environmental regulations and efficiency in resource utilization impact the tendency of R&D investment to decreases, increase and later decrease in the long run towards achieving sustainable development.

(2) The level of environmental regulation in the provinces under study proved to be significant but low. To achieve amutual benefit among environmental protection, efficiency in resource utilization and research and development results, a high level of environmental regulation is required. Strict environmental regulation also appears to be a good approach towards inducing industrial R&D investments in mitigating environmental pollution. The variation from positive to negative among the three major classifications potrayed the different tolerance level towards improving the regional

sustainability level. Eventhough the environmental regulation and industrial level of efficiency is significant and positive, there is still capacity for improvement since the industrial pollution treatment rate does not offset discharges to achieve sustainable development. The government should intensify environmental regulation to push industries to adopt more cleaner and safer technologies through R&D towards reducing pollution for sustainable development.

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