Article

The Dual Effects of Environmental Regulation on Water Resources Utilization Performance

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Abstract: Environmental regulation has dual effects on water resource utilization performance through various channels such as the "three-red lines" and the "Porter hypothesis". In accordance with a detailed examination of the influence path of environmental regulation on the performance of water resource utilization, the double effects of environmental regulation on water resource utilization performance were examined using panel statistics from 30 provinces and cities from 2004 to 2020 using the two-step system GMM approach. The results demonstrate that: (1) Environmental regulation has a direct effect on water resource utilization performance which is currently in the stage of the positive relationship of an inverted u-shaped relationship. (2) The influence of environmental regulation on water resource utilization performance through government intervention and industrial structure adjustment is indirect, among which government intervention can significantly improve water resource utilization performance, while the growth of the tertiary industry as a percentage can lower water resource utilization performance. (3) Both direct and indirect impacts indicate that enhancing the efficiency of the use of water resources is sustainable, and the water resource utilization performance of the preceding period had a major positive impact over the present phase. Therefore, the paper sets out a few policy suggestions, such as choosing reasonable environmental regulation tools, actively guiding the market-oriented reform with constraints, and upgrading the industrial structure in a green way.

Keywords: environmental regulation; water resource utilization performance; dual effects; two-step system GMM

1. Introduction

As industrialization and urbanization have progressed in China, the problems of insufficient water resources, serious damage to the water environment and unequal allocation of water resources over time and space are increasingly severe. These problems restrict sustainability of the economy and society in China. Based on the China Water Resources Bulletin in 2018, China's total water supply in 2018 reached 2,746.25 billion cubic meters, while the overall amount of water supply in the six northern areas was only 580.72 billion cubic meters, accounting for only 21.15%. In view of these problems, the Party Central Committee clearly put forward a 16-word water control policy, requiring local governments to use a variety of regulatory means to effectively deal with complex water resources issues. To pursue the implementation of the guideline, the Ministry of Water Conservancy and the National Development and Reform Commission jointly issued the "national water-saving action plan" in April 2019, which clearly requires to comprehensively enhance the effectiveness with which water resources are used and hasten the alteration of water usage patterns from extensive to cost-effective and intensive, so as to construct a water-efficient society in a comprehensive manner.

Environmental regulation is a measure, policy, regulation and execution proceeding that restricts economic action to enhance ecological and economic efficiency[i]. For one thing, environmental regulation directly affects the demand and supply of water resources through effective means like "overall control" and "pollutant control", then affects the utilization performance of water resources; for another, through "Porter Hypothesis", companies are required to undertake industrial upgrading innovation so as to obtain good market competitive advantages[ii,iii,iv], thus indirectly affecting water resources utilization performance. But the problem is, considering complex water resource utilization problems in China, whether the dual effects of the environmental ordinance on the usage of water resource performance exists? If so, are they acting in the same direction? How much does it work? In order to strengthen the implementation effect of major national policies such as water control policies and water-saving programs of the Ministry of Water Conservancy, we must theoretically clarify the mechanism of direct and indirect impacts, and explore the direction and extent of these two effects. This paper studies this issue, hoping to provide the drafting of environmental regulatory guidelines for water resources with theoretical guidance, so as to provide a new research perspective for the efficient usage of water supply and the construction of China's ecological civilization.

2. Related Literature

Water is "the source of life, the essence of the output and the groundwork of ecology". The measurement of water resource utilization performance catches the eyes of academics. At present, three main measurement approaches are as followed: data envelopment analysis (DEA), index system evaluation method and stochastic frontier analysis (SFA)[v]. In terms of index system investigation, Simon T P et al. (2010)[vi], Lei Mengting (2017)[vii] and others used the index system approach to grade the efficiency of water resources usage in different regions. Through their research, it can be found Different provinces and cities, as well as various regions of the equal province, have large distinctions in water use Therefore, to strengthen water resource utilization performance, targeted methods are needed. DEA can clearly measure the relationship between multiple inputs and outputs among different DMUs, especially the efficiency of unexpected outputs. Therefore, many academics adopted this way to measure efficiency of water resource usage, such as Ma H et al. (2016)[viii], Rodric M et al. (2019)[ix], Sun Caizhi et al. (2017)[x], Yang Gaosheng et al. (2019)[xi]. As a representative of Frontier parameter analysis, SFA method is more served as analysis of the influencing factors on the efficiency of water resource usage because it can consider the influence of random factors. Scholars such as Fang S et al. (2010)[xii], Abdulrasoul M et al. (2018)[xiii], Lei Yutao et al. (2017)[xiv] used SFA method to find that economic development level, pollution control investment, scientific research investment, industrial structure and other factors may have an important impact on the effectiveness of water resources utilization.

Similarly, environmental regulation, as an important means of ecological civilization construction, has attracted great focus from scholars. The investigation primarily concentrates on two points: environmental regulation tools and the effectiveness of its policies. Considering the premier problem, scholars define environmental regulation tools from different angles. Zhao Yumin et al. (2009)[xv] separated environmental regulation into explicit environmental regulation (command control environmental regulation, market-based incentive environmental regulation and voluntary environmental regulation) and implicit environmental governance in accordance with the degree of policy intervention. Zhang Ping Ping (2016)[xvi] divided environmental regulation into cost-based environmental regulation and investment-based environmental regulation from the perspective of economic benefits. Aiming at the second problem, some academics assumed environmental regulation took a crucial role in both economic and ecological fields. Natalie Stoeckl (2004)[xvii] and Li Bin et al. (2017)[xviii] concluded that performance in the circular economy has a 'U' relationship with environmental regulations. Nonetheless, many academics have doubts about the efficiency of environmental regulation strategies. For example, Chen Ming et al. (2018)[xix] carried out research on specific water environment regulation efficiency. Through SE-DEA method, they found that the increase of China's water environment regulation investment did not significantly improve the efficiency of water environment regulation. Tu Zhengge et al. (2019)[xx] took the reform of the industrial sulfur dioxide emission fee collection standard as an example, and found that the adjustment of emission charge standard did not achieve significant emission reduction effect through multi-period dual difference method.

Through literature review, it is found the specific effects of environmental regulation in the field of water resources have not been focused on. Although a small number of literature have studied the relationship between environmental regulation and water resource utilization performance, such as Feng Junhua (2017)[xxi], Ding Xuhui (2019)[xxii], etc. However, their water resources utilization performance indicators are not comprehensive enough and fail to take into account the situation of ecological water use. In addition, its environmental regulation indicators only reflect the absolute situation of environmental pollution in the industrial field and they did not specifically analyze the dual effects of water resources utilization performance. Therefore, this paper constructs an index structure appraising the performance of water resource utilization from three aspects of economy, society and ecology, and designs comprehensive environmental regulation indicators. On this basis, the direct effect on water resources utilization performance is empirically analyzed by using the two-stage System GMM method. Simultaneously, considering that improving the performance of the usage of water resources is a process of multiple factors, a market-oriented reform, industrial structure and technical level can influence the performance of water resources utilization under the constraints of environmental regulation as well. Therefore, we analyze indirect effect of environmental regulation on water resources utilization performance by establishing an interaction between environmental regulation and the three, and then put forward policy suggestions.

3. Mechanism Analysis of the Impact of Environmental Regulation on Water Resources Utilization Performance

Two points show how environmental regulation affects water resource utilization performance: direct impact and indirect impact. Direct impact refers to that environmental regulation directly affects the total amount and output performance of water resource usage by influencing the relevant decisions of water supply and water users. Indirect impact means the indirect effect of environmental ordinance on the utilization performance of water resources through market-oriented reform, industrial structure upgrading and technical level improvement. The mechanism of the dual effects is analyzed as follows.

3.1. Direct Impact of Environmental Regulation on Water Resources Utilization Performance

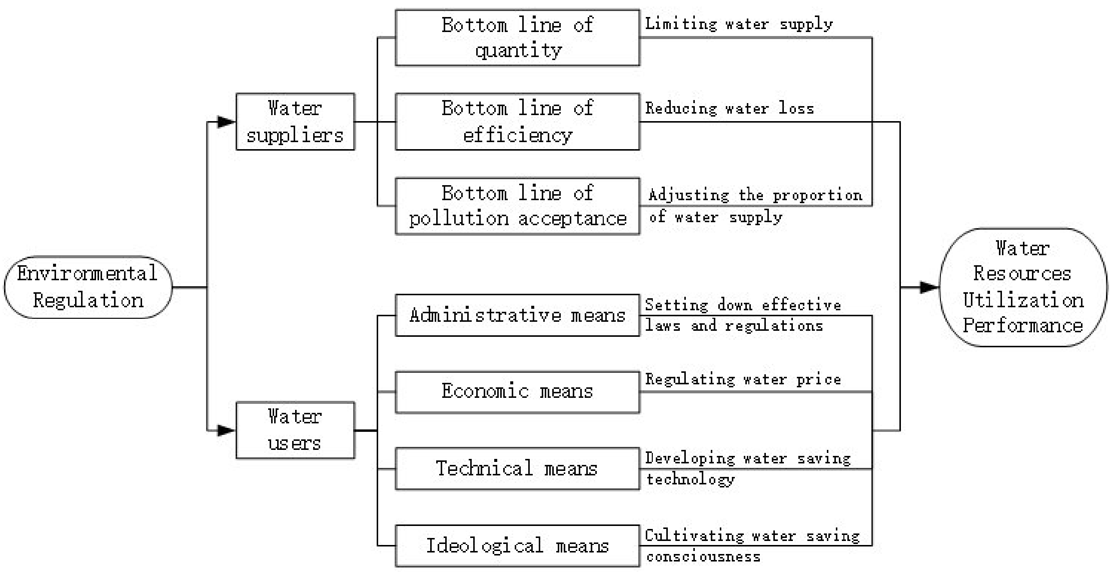

Figure 1. Direct effect of environmental regulations on water resource utilization performance.

The direct impact can be understood from the point of view of water suppliers and water users.

(1) Water Suppliers: By means of the most rigorous water management structure and dual control scheme, the state strengthens the binding effect of the "three red lines", which directly influences how water resources are utilized from the source of water. First of all, the government should ensure the control of whole water ingestion and strictly guard against the excessive development of water resources. Under the restriction of industry water allocation standards and policy files, the water quantity is limited from the source by limiting the water supply. Secondly, target control is carried out to strengthen effectiveness of water utilization in agricultural and industrial fields. In agriculture, the government pays attention to the problem of water supply loss to avoid wasting water resources such as flooding; in industry, the government implements water monitoring and industrial approval to force enterprises to achieve intensive development and increase water utilization performance in the industrial field. Thirdly, through the planning of the water function area to restrict the sewage disposal from the source and appropriately increase the proportion of water supply for the ecological environment by using the water quality standard assessment system of water function zone.

(2) Water Users: The restriction of environmental regulation on water users is mainly realized by administrative means, economic means, technical means and ideological means. Administrative means that the government through the introduction of laws and regulations to clarify the bottom line of sewage discharge and water resources use norms, and regularly takes specific measures to assess the water users to restrain their bad behavior. Economic means refers to the use of market forces, mainly through the adjustment of water prices, water resources tax reform and other measures. They encourage water users to take measures to improve water use performance in order to seek economic benefits. Technical means are realized by strengthening the national scientific research investment as regard of water resources protection and water contamination prevention and green R & D ability of enterprises, and the power of science and technology is used to promote water-saving technology. Ideological means are to cultivate the water-saving consciousness of water users by means of publicity and education, so that they can internalize the water conservation standards and norms into their own ideas, which is an invisible means of environmental regulation[15].

3.2. Indirect Impact of Environmental Regulation on Water Resources Utilization Performance

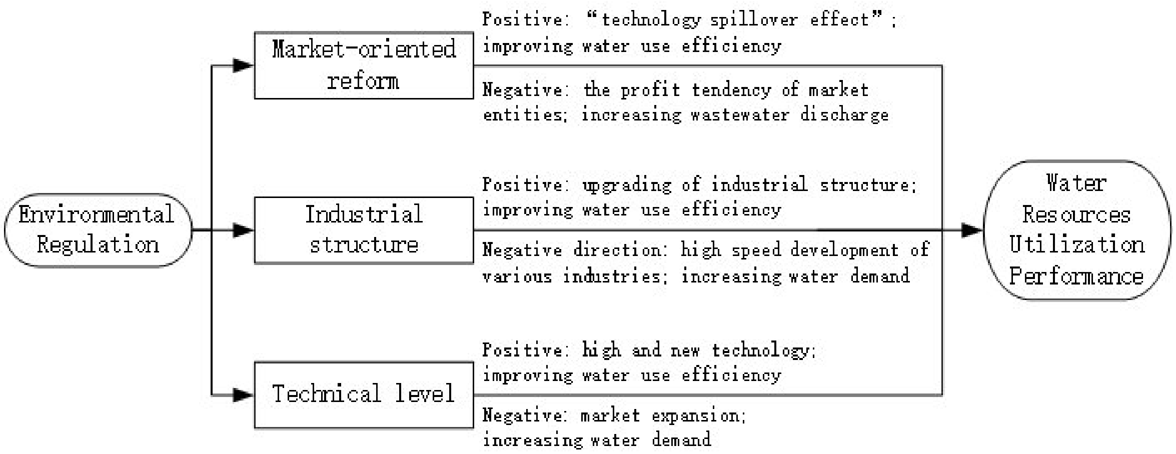

Figure 2. Indirect effect of environmental regulations on water resource utilization performance.

Besides directly influencing water resources utilization performance, environmental regulation also indirectly affect water resources utilization performance through market-oriented reform, industrial structure and technical level.

(1) Environmental regulation indirectly affects the performance of water resources utilization through market-oriented reform. For one thing, we should use environmental regulation to promote foreign direct investment and other market means to guide enterprises to reduce water pollution emissions and actively improve the green development of the market. Simultaneously, the market-oriented reform is conducive to the "technology spillover effect", which can make the market participants actively pursue more advanced clean technology, higher environmental protection standards and more efficient pollution prevention and regulation measures, so as to improve the utilization rate of water resources. Research by Han Jing et al. (2017)[xxiii] concludes that the improvement of marketization can substantially improve the level of regional green development. For another, because of the unbalanced development of the market and the inequality of regulation in China, environmental regulation affects the investment location choice of some high pollution enterprises. Considering the cost and regulation results, some pollution intensive enterprises will gather in areas with low degree of environmental regulation, resulting in increasing water demand and water contamination degree. So, water resource utilization performance may be seriously reduced.

(2) Environmental regulation indirectly affects water resources utilization performance through industrial structure adjustment. Environmental governance plays its part in improving the adjustment of industrial structure[xxiv]. Environmental regulation can inhibit the growth of pollution intensive industries by setting up green barriers and other measures. It facilitates the green transformation of corporations and the promotion and adjustment of industrial configuration, in order to indirectly improve the performance of water resources utilization. However, with the fast growth of various industries, the rise of water demand and the destruction of water ecology cannot be ignored. The research of Ma Hailiang et al. (2012)[xxv] shows that in the industrial restructuring of the pursuit of industrialization in eastern China, on account of the growth of undesirable output, the efficiency of green water resource usage is reduced.

(3) Environmental governance not only affects the level of technology, it also influences the performance of the utilization of water resources in an indirect way. The effect of environmental regulation on technology level is the outcome of the balance between "compensation effect" and "offset effect"[2,xxvi]. Under "compensation effect", appropriate environmental ordinance will stimulate technological innovation; under the "offset effect", the cost rise caused by environmental regulation will restrain technological innovation. For example, Zhang Xiaoying et al. (2014)[xxvii] found that the technical level of various regions in China has been improved with the reinforcement of environmental regulation; however, Jiang Ke et al. (2011)[xxviii] proved environmental regulation could not support China's technological innovation, and it needs to be combined with certain human capital. Through technological innovation, enterprises will help to reduce the investment in basic production elements like water resources. At the same time, in the production process, the usage of various water-efficient technologies and environmental protection equipment will also reduce the dissipation of water resources and water environmental contamination, so as to enhance the effectiveness of water resources employment. However, by virtue of the "rebound effect" of technological progress, there are many uncertainties in the usage of water resources over the long turn.

4. Model Construction and Index Selection

4.1. The Model

Considering the sustainability and long-term incentive of existing water resources utilization performance, we construct the dynamic regression model with one period lag of explained variables. At the same time, considering the direct effect of environmental regulation on water resources usage performance may not be simple linear connection, quadratic and cubic terminologies of environmental ordinance are introduced to investigate the potential nonlinear impact. Here's a description of the model.

$$WE_{i,t} = \alpha_0 + \alpha_1 WE_{i,t-1} + \alpha_2 ER_{i,t} + \alpha_3 ER_{i,t}^2 + \alpha_4 ER_{i,t}^3 + \alpha_5 X_{i,t} + \varepsilon_{i.t} \quad (1)$$

i represents province and t represents the year. $WE_{i,t}$ is the explained variable, indicating the performance of water resources utilization. α_1 represents the lag multiplier, indicating the effect of water resources utilization performance in the previous period. $ER_{i,t}$ represents the intensity index of environmental ordinance. $X_{i,t}$ represents the control variable, including market-oriented reform, industrial structure and technical level. $\varepsilon_{i,t}$ is the random error item.

Additionally, for the purpose of analyzing the indirect impact of environmental regulation on water resources utilization performance, this paper introduces the interaction between environmental regulation and market-oriented reform, industrial structure and technical level. This paper constructs the following model to measure the indirect effect of environmental regulation on water resources utilization performance.

$$WE_{i,t} = \beta_0 + \beta_1 WE_{i,t-1} + \beta_2 ER \times MR_{i,t} + \beta_3 ER \times INDU_{i,t} + \beta_4 ER \times TECH_{i,t} + \varepsilon_{i,t} \quad (2)$$

where i represents province and t represents the year. $ER \times MR_{i,t}$represents the interaction between environmental regulation and market-oriented reform. $ER \times INDU_{i,t}$represents the interaction between environmental regulation and industrial structure. $ER \times TECH_{i,t}$represents the interaction between environmental regulation and technical level. $\varepsilon_{i,t}$ is the random error item.

4.2. Data Description

This paper picks out the panel data of 30 provinces and cities in China from 2004 to 2020 (in view of the availability of data, and the article excludes the Tibet Autonomous Region) for empirical test. The data are from China Environmental Statistical Yearbook, China Environmental Yearbook, China Science and technology statistical yearbook and China Statistical Yearbook over the years, and are obtained through calculation.

(1) Water Resources Utilization Performance ($WE_{i,t}$): As an important economic resource and basic living resource, the utilization performance of water directly affects economic growth and life well-being. In order to comprehensively consider the utilization degree of water resources, we systematically construct the index system of water resource usage performance evaluation from three aspects of economy, society and ecology, as shown in Table 1. Water resources utilization performance of per year in the study phase can be calculated by the entropy method.

Table 1. Evaluation Index System of Water Resources Utilization Performance.

Target strata	Criterion layer	Index layer	Meaning of indicators	Direction of action
Water Resources Utilization Performance	Economics	GDP output per cubic meter of water	GDP / total water consumption	Positive
		Industrial added value water consumption	Industrial water consumption / industrial added value	Negative
		Grain yield per cubic meter of water	Grain production / total agricultural water consumption	Positive
	Sociology	Daily domestic water consumption per capita	Average daily domestic water consumption per water user	Negative
		Total domestic water supply	Total domestic water supply in urban area	Negative

Ecology	COD emission of 10000 yuan GDP	COD emissions in wastewater / GDP	Negative
	Waste water discharge of 10000 yuan GDP	Total wastewater discharge / GDP	Negative
	Per capita park green space area	Average area of park green space per person in urban area	Positive

(2) Environmental Regulation ($ER_{i,t}$): In view of the facts that absolute indicators are easily interfered by other factors[xxix] and cannot fully reflect the strength and effect of environmental regulation, this thesis adopts the idea of Wang Yong et al. (2015)[xxx]. We uses the relative index of required treatment input per unit pollutant to express the intensity index of environmental regulation, in a bid to comprehensively reflect the effects of "governance input" and "pollution output". The specific formula is shown in formula (3).

$$ER_{i,t} = \frac{TITEP_{i,t}}{E_{i,t}} \quad (3)$$

where is the province or city and what is the year. $TITEP_{i,t}$ is the total amount of environmental pollution control investment containing urban environmental infrastructure construction investment, industrial pollution source control investment and construction project "Three Simultaneity" environmental protection investment. $E_{i,t}$ is the comprehensive pollution emission level obtained after dimensionless treatment of industrial solid waste production, total wastewater discharge and sulfur dioxide emission. If the index is larger, the environmental regulation will be stronger accordingly.

(3) Other Variables: The market-oriented reform ($MR_{i,t}$) is commonly measured by the proportion of local general budget expenditure in GDP. The larger the index is, the more significant the role of the "visible hand" of the local government in the distribution of social resources, and the weaker the degree of market-oriented reform. Industrial structure ($INDU_{i,t}$) is the expression of the proportion of the added value of the tertiary industry in the GDP of each region. The larger the index is, the better the industrial structure of the region tends to be. Technology level ($TECH_{i,t}$) is measured by the proportion of R & D expenditure of Industrial Enterprises above designated scale in the paid-in capital of Industrial Enterprises above designated scale in each region. The larger the index is, the stronger the technical level of enterprises in the region is. To enhance the comparability of data, the data is standardized in the course of its use.

5. Empirical Results

In this paper, stata11.0 is used to regress the direct impact model and indirect impact model. Since the first-order lag term of the explained variable is added, it is easy to produce endogenous problems. However, the fixed effect method in panel data cannot tackle the endogenous issue of the model and cannot control the non-observed factors that change with time, so the dynamic panel model should be adopted. Considering the heteroscedasticity problem, two-stage System GMM method is used to estimate formula (1) and formula (2). In an effort to effectively avoid multicollinearity between variables, this paper introduced variables to carry out regression analysis on the two models in a gradual manner.

5.1. Analysis of Direct Impact of Environmental Regulation on Water Resources Utilization Performance

On the basis of formula (1), the direct impact of environmental regulation on water resources utilization performance is calculated, as is shown in Table 2. Models 1-3 are the estimation results of the first, second and third power terms of environmental regulation and water resources utilization performance.

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Table 2. Direct impact of environmental regulation on water resource utilization performance.

	Model 1	Model 2	Model 3
L.WE	0.7467***	0.7289***	0.7090***
	(0.0683)	(0.0642)	(0.0785)
MR	0.1325***	0.1084***	0.0983**
	(0.0400)	(0.0388)	(0.0396)
INDU	-0.0667	-0.0728*	-0.0740*
	(0.0407)	(0.0372)	(0.0367)
TECH	-0.0106	0.0415	0.0643
	(0.0992)	(0.0933)	(0.0911)
ER	0.1126***	0.2338***	0.6250**
	(0.0327)	(0.0546)	(0.2489)
ER2		-0.1466***	-1.2575
		(0.0515)	(0.7434)
ER3			0.7625
			(0.5131)
Constant term	0.0780***	0.0778***	0.0634**
	(0.0252)	(0.0235)	(0.0279)
Sample size	390	390	390
AR(1)	-4.3657	-4.3344	-4.3043
	[0.0000]	[0.0000]	[0.0000]
AR(2)	0.0660	0.3639	0.3054
	[0.9474]	[0.7159]	[0.7601]
Hansen test	21.0633	21.5255	22.8866
	[0.5168]	[0.4273]	[0.2944]

Notes. ① ***, **, * denote statistical significance at 1%, 5% and 10% levels respectively, the values in brackets below the coefficients are the standard errors, and the values in square brackets are the corresponding P values of statistics; ② AR (1) and AR (2) are Arellano-Bond autocorrelation tests of first-order and second-order difference residual sequences, and Hansen test is over recognition test.

Based on this paper, Arellano-Bond autocorrelation test's purpose is to verify the stationarity of the data and Hansen test is used to verify the validity of the tool variables. What can be seen from table 2 is that the residuals obtained by the difference equation follow the process of AR (1) and AR (2). The P values of AR (1) are all 0, showing that the original hypothesis that there is no autocorrelation of the first order sequence is rejected. The P values of AR (2) are all above 0.7, indicating that the original hypothesis of no autocorrelation of second-order sequence is accepted. The P values of Hansen test are between 0.29 and 0.52, indicating that the tool variables introduced in the model are reasonable and reliable. Therefore, the results of Arellano-Bond autocorrelation test and Hansen test in Table 2 show that the model setting is reasonable and the estimation results are reliable as well. The following are the results of direct impact regression that are analyzed.

(1) In Model 1-3, the coefficient of lag period of water resource utilization performance is significantly positive correlation at the level of 1%, which means that the lag period of water resource utilization performance exerts a strong positive effect on the current period. This is mainly owing to the continuous improvement of water resources utilization performance, indicating that the improvement of water resources utilization performance is a long-term dynamic adjustment process. Only by increasing the continuous

investment of the government, enterprises and residents, can the long-term utilization of water resources be improved.

(2) Under the current level of economic development, the impact of environmental regulation on water resources utilization performance presents an inverted "U" curve. As can be seen from table 2, the first power term of environmental regulation is in the confidence interval of 99% and 95% in Model 1, 2 and 3, respectively, indicating that environmental regulation can strikingly better the performance of water resources utilization. As is shown in Model 2, the quadratic term of environmental regulation is significantly negative at the level of 1%, indicating that the impact of environmental regulation on water resources utilization performance presents an inverted "U" curve. According to Model 2, the inflection point of the inverted "U" curve is about 0.7974, while the average value of environmental regulation variables is about 0.1094, which is far less than the threshold, which means that China's environmental regulation can effectively promote the improvement of water resources utilization performance. In Model 3, the cubic term of environmental regulation is further introduced. The results reveal that the quadratic and cubic coefficients of environmental regulation are not significant, so there is no obvious "n" type or inverted "n" type curve.

(3) Analysis of the influence of other control variables. The market-oriented reform coefficient is significantly positive at the level of 1% and 5% in Model 1-3, showing that government intervention can strikingly better the performance of water resources utilization in the current development stage. The reason is that the governments at all levels in our country have strong control power, which plays an indispensable role in resource allocation and market activities. Especially in the production of public goods like water resources allocation and water resources utilization, our government plays a leading role. The coefficient of industrial structure is significantly negative at the level of 10% in Model 2-3, which indicates that the proportion of tertiary industry is higher, the performance of water resource utilization is worse accordingly. This is mainly because the tertiary industry in China is generally in the extensive growth stage, and many specific service industries are in the stage of rapid expansion and disorder, thus directly leading to the much waste of water resources and serious water pollution. For instance, the development of tourism and catering industry has seriously affected the sustainable utilization of lake resources. What's worse, the coefficient of technology level is not significant, implying that the current R & D investment of enterprises may focus more on economic benefits, while the promotion of ecological benefits is not obvious.

5.2. Analysis of Indirect Impact of Environmental Regulation on Water Resources Utilization Performance

The above analysis shows that the performance of water resources utilization will be affected by market-oriented reform, industrial structure and technical level to a certain degree. In a gesture to better analyze whether the impact of these factors on water resource utilization performance will change under the constraint of environmental regulation, the interaction items of environmental regulation and market-oriented reform, industrial structure and technical level are introduced in Model 4-6 to observe the indirect impact of environmental regulation on water resource utilization performance through three ways. The indirect impact of environmental regulation on water resources utilization performance is shown in Table 3.

Table 3. Indirect impact of environmental regulation on water resource utilization performance.

	Model 4	Model 5	Model 6
L.WE	0.7774***	0.7955***	0.7925***
	(0.0870)	(0.0623)	(0.0569)
ER×MR	0.6085**	1.1426***	1.1932***
	(0.2718)	(0.3099)	(0.2884)
ER×INDU		-0.4812*	-0.4536
		(0.2529)	(0.3896)
ER×TECH			-0.1343
			(0.5425)
Constant term	0.0741**	0.0681**	0.0666**
	(0.0359)	(0.0255)	(0.0257)
Sample size	390	390	390
AR(1)	-4.2303	-4.3548	-4.4235
	[0.0000]	[0.0000]	[0.0000]
AR(2)	0.4561	0.7548	0.6984
	[0.6483]	[0.4504]	[0.4849]
Hansen test	17.4076	11.9608	10.8951
	[0.0964]	[0.2877]	[0.2830]

Notes. ① ***, **, * denote statistical significance at 1%, 5% and 10% levels respectively, the values in brackets below the coefficients are the standard errors, and the values in square brackets are the corresponding P values of statistics; ② AR (1) and AR (2) are Arellano-Bond autocorrelation tests of first-order and second-order difference residual sequences, and Hansen test is over recognition test.

The P values of AR (1) in Table 4 are all zero, which indicate that the original hypothesis that there is no first-order sequence autocorrelation is rejected. The P values of AR (2) are above 0.4, indicating that the original hypothesis of no second-order sequence autocorrelation is accepted; the P values of Hansen test of Model 5 and Model 6 is above 0.28, indicating that the original hypothesis is accepted, that is, the tool variable introduced in the model is reasonable and reliable. Although the Hansen test in Model 1 fails to accept the original hypothesis, its P value is close to 0.1. Therefore, according to the results of Arellano bond autocorrelation test and Hansen test in Table 4, the residual error obtained by the difference equation follows the process of AR (1) and AR (2), and the tool variable selection is reasonable. Thus, the model setting is effective, and the estimation results are reliable as well. The results of indirect impact regression are analyzed as follows.

(1) The performance of water resources utilization through government regulation is influenced by environmental regulation positively and indirectly. Although Model 4, Model 5 and Model 6 are significant in different confidence intervals, the coefficients of interaction between environmental regulation and market-oriented reform are all positive, that is, the greater the government power, the greater the indirect impact of environmental regulation on improving water resources utilization performance. The reason is that in our country, the government is the maker and main promoter of environmental regulation policies, and its coercive force can effectively guide and constrain the market players, so as to effectively improve the performance of water resources utilization. This is in line with the empirical results of Guo Qing (2014)[xxxi]. He pointed out that in different types of environmental regulation tools, the role of command and control policy is greater than that of economic incentive policy and public participation policy.

(2) Environmental regulation has a significant negative indirect impact on water resources utilization performance through industrial structure adjustment. The coefficient

of the interaction between environmental regulation and industrial structure is significantly negative at 10% level in model 5, which indicates that the development of tertiary industry will have a negative impact on water resource utilization performance under the constraint of environmental regulation. This result doesn't correspond to what we have expected. The reason is as follows: the performance indicators of water resources utilization include economic, social and ecological aspects. As mentioned above, the tertiary industry is in an extensive growth stage. Many service-oriented industries, such as catering and car washing, have serious water resource waste and water pollution problems. Compared with the secondary industry, the economic added value of the tertiary industry is relatively low. Additionally, the current water environment regulation policies mainly focus on non-point source pollution and industrial pollution, while the government's constraints on the tertiary industry are weak and lack of targeted water resources management measures. The research of Hong Siyang (2016)[xxxii] also verified this judgment. After analyzing the water use situation of Beijing's tertiary industry, he believed that the boom of Beijing's tertiary industry, to some degree, inhibited the improvement of water resource utilization performance.

(3) The coefficient of interaction between environmental regulation and technology level is not significant, but its negative trend shows that the role of environmental regulation on technological level is mainly "offset effect". This shows that the focus of R & D investment of enterprises is still on how to seek more economic profits, and less attention is paid to the social responsibility and ecological performance of enterprises. Therefore, the government should focus on guiding enterprises to enhance the research and development of internal green environmental protection technology in the next stage.

(4) In common with the results of direct effect analysis, the water resource utilization performance of the previous period has a significant positive driving effect on the current water resource utilization performance in the indirect effect analysis, at the 1% level, which further proves the improvement of water resources utilization performance is sustainable.

5.3. Robustness Test

To get the robustness of the research results verified, the ratio of the investment of wastewater treatment project to cod and ammonia nitrogen emissions in wastewater was used to measure the intensity of environmental regulation, and the direct and indirect effects of environmental regulation on water resources utilization performance were analyzed. The data processing method is in Formula (3). The empirical results reveal the fact that the symbol of the key coefficient does not change, and the significance level does not show significant difference. The direct effect is still a significant inverted "U" curve. The average value of environmental regulation variables remains much less than the inflection point, that is, China's environmental regulation can effectively facilitate the performance improvement of water resources utilization. The specific regression results are not shown on account of the space.

6. Conclusions and Suggestions

Under the constraint of unbalanced demand and supply of water resources, decreasing the intensity of industrial sewage discharge and promoting the accurate use of water in ecological environment is urgent for the purpose of accelerating the enhancement of water resources usage performance. However, strict environmental regulation measures will not only have a direct impact on water resources utilization performance, but also have indirect effects on water resources utilization performance through market-oriented reform, industrial structure and other factors. An inverted "U" curve is revealed by the panel data regression results of 30 provinces and cities from 2004 to 2020 when examining the direct effect of environmental regulation on the usage of water resource performance. Under the constraint of environmental ordinance, the enhancement of government intervention can significantly improve the usage performance of water resources.

Simultaneously, the rapid improvement of the tertiary industry will reduce the usage performance of water resources. Therefore, we suggest that the government should take the following measures.

(1) It is significant to enhance water environmental regulation and select reasonable environmental regulation tools. The results show that environmental ordinance takes positive impact on water resources utilization performance, and the efficiency of environmental regulation is contingent not only on the degree of implementation of relevant policies, but also by different environmental regulation tools. Therefore, it is very important to formulate appropriate environmental regulation measures. Governments at all levels should strengthen the "double control" rigid behavior of water resources through policy documents, and vigorously facilitate the innovation of water resources tax. Meanwhile, the government should enhance the propaganda and education of individuals and organizations to cultivate their "green" living and production needs, for the purpose of improving the performance of water resources utilization.

(2) The government should formulate effective water-saving plans for different industries with the purpose of promoting the green upgrading of industrial configuration. Although the industrial structure is undergoing rapid transformation and upgrading, water contamination has not been effectively controlled. Consequently, it is necessary for the government to further strengthen the governance, take different water-saving measures for different industries, and take "green" as the core to promote the common improvement of economy and ecology. In agriculture, new irrigation technology and crop selection should be taken to promote water use efficiency; in industry, the pollutant content in wastewater should be decreased and the reuse rate of water resources should be improved through industrial upgrading and the transformation of old and new kinetic energy; in the third industry, the regulation of high water consumption and high pollution industries such as catering and car washing should be strengthened, and the water efficiency should be improved through industrial innovation.

(3) The government should reinforce the role of environmental adjustment in promoting the development of science and technology, and guide enterprises to pursue a win-win situation of economic and environmental efficiency. In empirical results, the technical level does not have a significant impact on the performance of water resources utilization, indicating that the "compensation effect" of environmental regulation has not been clearly reflected. Therefore, first, the government should formulate environmental science and technology policies through top-level design, and encourage R &D institutions to make major innovations in environmental science and technology, especially in water pollution control and water recycling. Second, the government is supposed to guide corporations to strengthen research and improvement of green technology, and encourage enterprises to actively pay attention to ecological benefits while pursuing economic benefits through tax incentives or industrial support policies.

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References

1. Tan Juan, Chen Xiaochun. Analysis on the impact of government environmental regulation on low carbon economy from the perspective of industrial structure [J]. Economist, **2011** *(10):* 91-97
2. Jiang Fuxin, Wang Zhujun, Bai Junhong. Dual effects of environmental regulation on Technological Innovation: An Empirical Study Based on dynamic panel data of Jiangsu manufacturing industry [J]. *China industrial economy*, **2013** (07): 44-55
3. Zhang Hua, Wei Xiaoping. Green paradox or forced emission reduction: double effects of environmental regulation on carbon emissions [J]. *China population, resources and environment*, **2014**,*24 (09)*: 21-29
4. Cai Wuji, Zhou Xiaoliang. Dual effects of environmental regulation on green total factor productivity in China [J]. *Economist*, **2017** (09): 27-35
5. Shen Manhong, Chen qingneng. Water resources economics [M]. *Beijing: China Environmental Science Press*, **2008**:98-125
6. Simon T P, Emery E B. Modification and assessment of an index of biotic integrity to quantify water resource quality in great rivers[J]. **2010**, *11(3-4)*:283-298.
7. Lei Mengting. Application of sfla-pp model in comprehensive evaluation of regional water resources utilization efficiency [J]. *Journal of Yangtze River academy of Sciences*, **2017**,*34 (11)*: 27-32
8. Ma H, Shi C, Chou N T. China's Water Utilization Efficiency: An Analysis with Environmental Considerations[J]. *Sustainability*, **2016**, *8(6)*:516-522.
9. Rodric M. Nonki, André Lenouo, Christopher J. Lennard. Assessing climate change impacts on water resources in the Benue River Basin, Northern Cameroon[J]. *Environmental Earth Sciences*, **2019**, *78(20)*： 59-65.
10. Sun Caizhi, Jiang Kun, Zhao Liangshi. Measurement and spatial pattern of green efficiency of water resources in China [J]. *Journal of natural resources*, **2017**,*32 (12)*: 1999-2011
11. Yang Gaosheng, Xie qiuhao. Spatiotemporal differentiation of green water resources efficiency in Yangtze River Economic Belt: Based on se-sbm and ml index method [J]. *Resources and environment of Yangtze River Basin*, **2019**,*28 (02)*: 349-358
12. Fang S, Pei H, Liu Z, et al. Water Resources Assessment and Regional Virtual Water Potential in the Turpan Basin, China[J]. *Water Resources Management*, **2010**, *24(13)*:3321-3332.
13. Al-Omran A M , Mousa M A , Alharbi M M , et al. Hydrogeochemical characterization and groundwater quality assessment in Al-Hasa, Saudi Arabia[J]. *Arabian Journal of Geoences*, **2018**, *11(4)*:79.
14. Lei Yutao, Huang Liping, Zhang Heng. Dynamic evolution and driving factors of industrial water use efficiency in China [J]. *Resources and environment of the Yangtze River Basin*, **2017**,*26 (02)*: 159-170
15. Zhao Yumin, Zhu Fangming, he Lilong. Definition, classification and evolution of environmental regulation [J]. *China population, resources and environment*, **2009**,*19 (06)*: 85-90
16. Zhang Ping, Zhang pengpeng, Cai Guoqing. Comparative study on the impact of different types of environmental regulations on enterprise technological innovation [J]. *China population, resources and environment*, **2016**,*26 (04)*: 8-13
17. Natalie Stoeckl. The Private Costs and Benefits of Environmental Self-Regulation: Which Firms Have Most to Gain? [J]. *Business Strategy & the Environment*, **2004**, *13(3)*:135-155.
18. Li Bin, Cao Wanlin. Research on the impact of environmental regulation on the performance of circular economy in China -- Based on the perspective of Ecological Innovation [J]. *China soft science*, **2017** (06): 140-154
19. Chen Ming, Qiu Junqin. Research on water environment regulation based on Environmental Kuznets curve [J]. *Journal of Jiangxi University of Finance and economics*, **2018** (04): 53-59
20. Tu Zhengge, Zhou Tao, Chen Renjun, Gan Tianqi. Environmental regulation reform and high quality economic development: evidence based on the adjustment of industrial sewage charges [J]. *Economic and management research*: **2019**, *40 (12)*: 1-19
21. Feng Junhua, Cheng Yao, Zhang Lili. Study on industrial water use efficiency and influencing factors under environmental regulation -- Taking Shaanxi Province as an example [J]. *Price theory and practice*, **2017** (07): 141-144
22. Ding Xuhui, Gao Suhui, Wu Fengping. Spatial spillover effects of environmental regulation, FDI agglomeration and water use efficiency in the Yangtze River economic belt [J]. *China population, resources and environment*, **2019**, *29 (08)*: 148-155
23. Han Jing, Liu Yuan, Zhang Xinwen. Marketization, environmental regulation and green economic growth in China [J]. *Comparison of economic and social systems*, **2017** (05): 105-115
24. Zheng Jiamei. Analysis on the effect and mechanism of industrial structure adjustment of environmental regulation [J]. *Finance and trade research*, **2018**,*29 (03)*: 21-29
25. Ma Hailiang, Huang Dechun, Zhang Jiguo. Study on water resource utilization efficiency and influencing factors considering undesirable output [J]. *China population, resources and environment*, **2012**,*22 (10)*: 35-42
26. Zhang Qian. Reexamination of the relationship between environmental regulation, foreign direct investment and enterprise technological innovation [J]. *Statistics and decision making*, **2018**,*34 (08)*: 177-181
27. Zhang Xiaoying, Zhang Hongfeng. Study on the mechanism of the impact of environmental regulation on China's technical efficiency [J]. *Research on financial issues*, **2014** (05): 124-129

28. Jiang Ke, Lu Xianxiang. Environmental regulation and technological innovation: Based on the provincial panel data analysis of China from 1997 to 2007 [J]. *Scientific research management*, **2011**,*32 (07)*: 60-66
29. Cheng Du, Li Gang. Current situation and trend of environmental regulation intensity measurement [J]. *Economic and management research*, **2017**,*38 (08)*: 75-85
30. Wang Yong, Li Jianmin. Main methods, potential problems and correction of environmental regulation intensity measurement [J]. *Finance and economics*, **2015** (05): 98-106
31. Guo Qing. Evaluation of the relative role of environmental regulation policy tools —taking water pollution control as an example [J]. *Economic and management review*, **2014**,*30 (05)*: 26-30
32. Hong Siyang, Wang Hongrui, Cheng Tao, Lai Wenli, Jiao Zhiqian. Water use characteristics and development strategies of tertiary industry in Beijing [J]. *China population, resources and environment*, **2016**,*26 (05)*: 108-116