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Original Paper

Constraint Mechanism of Environmental Regulation on Carbon Emission of Heavy Industry in Chengdu-Chongqing Region of China

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Abstract

Regional differences and development heterogeneity lead to an unbalanced distribution of heavy industry in Chengdu-Chongqing region of China. Under the background of low-carbon development, clarifying the constraint mechanism of environmental regulations on carbon emissions of heavy industry becomes more important to solve prominent problems of resources and the environment. In this work, literature analysis, comparative analysis and statistical induction are carried out to illustrate a constraint mechanism of environmental regulation on carbon emission. Based on literature reports and government yearbook data, the impacts of environmental regulations on carbon emissions of heavy industry in Chengdu-Chongqing region are studied. Analysis and demonstration are carried out from four dimensions: corporate identity, technological progress, policy constraints, and government supervision. The predicament of environmental regulation affecting heavy industry carbon emission reduction is expounded and puts forward reasonable policy suggestions. The research results can enrich the theory of environmental regulation, and provide policy suggestions for optimizing the green transformation of heavy industry.

Keywords

environmental regulation, Carbon emission, Constraint mechanism

1. Introduction

Climate warming caused by the rapid development of the global economy has caused significant obstacles to the sustainable development of humanity (X. Li, Cooper, & Plater, 2021; Peng, Wen, Fu, & Yi, 2020; Tsamos et al., 2017; van Vuuren et al., 2017; X. Zhang et al., 2023). In October 2021, the Central Committee of the Communist Party of China and The State Council officially issued the *Opinions on Fully, Accurately, and Comprehensively Implementing the New Development Concepts to Achieve Carbon Peak and Carbon Neutrality*. The document lays out the strategic plan, and defines the overall requirements, working principles, and primary objectives for China efforts to achieve carbon neutrality. Aimed to peak carbon dioxide emissions by 2030 and become carbon neutral by 2060. Clarifying the necessary choice for China to put forward efforts to solve the outstanding problems of resources and the environment. It is also a solemn commitment to building a community with a shared future for humanity. On October 16, 2020, the Political Bureau of the CPC Central Committee put forward goals for constructing the Chengdu-Chongqing region. It formed the *Planning Outline for the Construction of Shuangcheng Economic Circle in Chengdu-Chongqing Region*, which refers to building Chengdu-Chongqing into a critical modern industrial base in China. Chengdu and Chongqing, as the core position, have formed a radiating driving effect, making them the most dynamic region of economic development in western China. However, the rapid development of heavy industry has brought about environmental severe pollution (Gou & Liu, 2022; Qisheng Jiang, Fu, & Zuo, 2019; Tan et al., 2023; Tang, Jiang, & Mi, 2021). Development degree and distribution differences in Chengdu-Chongqing region have different impacts on carbon emission intensity, which makes the carbon emission intensity unbalanced. This has brought great difficulties to the formulation and implementation of environmental regulations. In this work, the basic theory of environmental regulation affecting carbon emissions is investigated on the imbalance of heavy industry structure in Chengdu-Chongqing region. The constraint mechanisms of environmental regulation on carbon emission are clarified. The findings can provide policy suggestions for optimizing environmental regulation and industrial development in Chengdu-Chongqing region.

2. Literature Review

Environmental regulation is a kind of restrictive behavior to regulate various behaviors that pollute the public environment for the purpose of protecting the environment (Du, Cheng, & Yao, 2021; Liu, Xin, & Li, 2022; McManus, 2009; Shang, Tan, Feng, & Zhou, 2022). Meanwhile, environmental regulation and carbon emission reduction are also important ways to achieve green development, which is the policy guidance of the current government. Scholars have studied and confirmed the constraint effects of environmental regulations on carbon emissions. The effects are discussed in three parts: the green paradox effect, the forced emission reduction effect, and the heterogeneous environmental regulation effect (Danish, Ulucak, Khan, Baloch, & Li, 2020; Qichuan Jiang & Ma, 2021; Y. Wang et al., 2019; Wenbo & Yan, 2018).

The first is the green paradox effect. “Green paradox” refers to the strict policies issued by the government to reduce carbon emissions in response to environmental degradation (Bauer, McGlade, Hilaire, & Ekins, 2018; Kollenbach & Schopf, 2022; Lai, Wang, & Cui, 2022). The strict policies have had the opposite effect in the process of implementation, leading to increased carbon emissions and defeating the original intention of green development. The research on the “green paradox” has always been controversial. The “green paradox” was first proposed by Sinn in 2008. He focuses on one specific cause of this contradictory outcome: the impact of climate policy on long-term profits, and the expectation by owners of fossil resources to make profits by selling resources over time (Sinn, 2008). Jensen et al. (Jensen, Mohlin, Pittel, & Sterner, 2015) found that the term “green paradox” is widely used to describe the unintended consequences of climate policies. When carbon emissions are high, enterprises will be forced by environmental protection policies to reduce investment in fixed assets and increase investment in environmental governance. With the increase of investment in environmental governance, it was found that carbon emissions did not decrease, indicating that the regulation effect of carbon reduction policy on carbon emissions is poor. Zhang et al. (K. Zhang, Zhang, & Liang, 2017) found that although implementing environmental policies promoted the reduction of carbon emissions, government fiscal decentralization led to the increase of carbon emissions, which led to the confirmation of the green paradox hypothesis. Arne Steinkraus (Steinkraus, 2019) evaluates the effect of the US Environmental Action Plan policy. The discovery policy announcement led to a significant increase in coal production in the United States, triggering the “green paradox” effect.

The second is the forced emission-reduction effect. “Forced emission-reduction” refers to the problem of high carbon emissions. The government adopts various environmental regulations to force enterprises to strengthen technological innovation and reduce carbon emissions continuously. It should be pay attention to environmental protection in the development of enterprises. Enable enterprises to adapt to the market and promote to achieve high-quality economic development (Q. Wang & Chen, 2010). Li et al. (P. Li et al., 2017) studied the governments controlled industrial carbon emissions through environmental regulations during the 2016 G20 Summit, including forcing the closure of highly polluting industries and limiting emissions from urban transport and buildings. Finally, a significant reduction in pollutant emissions was achieved. Yin et al. (Yin, Liu, & Gu, 2022) explored the direct and indirect impacts of environmental regulations on carbon emissions. They found that relatively loose policies are manifested as the green paradox, and the tightening of policies is manifested as forced emission-reduction. Shapiro et al. (Shapiro & Walker, 2018) found that between 1990 and 2008, while manufacturing output rose sharply in the US, emissions of air pollutants from manufacturing declined by nearly 60%. The gradual tightening of environmental regulations is the main reason for the decline in manufacturing pollution. The effect of government forced emission-reduction is obvious. Guan et al. (Guan, He, & Zhu, 2022) used a difference-in-differences specification to examine whether the policy reformation facilitates pollution reductions. They found that environmental regulation can be enhanced across industries, and large-scale firms are regulated.

The third is the heterogeneous environmental regulation effect. “Heterogeneous environmental regulation” means that environmental regulation has category heterogeneity and different types of environmental regulation have phased synergistic effects (Huang & Yi, 2023; Sun, Zhai, Miao, Mu, & Li, 2023; X. Wang, Chu, Ding, & Chiu, 2023; Y. Zhang, Song, & Zou, 2022). In order to give play to the synergy of environmental regulations, it is necessary to design the combination and intensity of environmental regulations reasonably. To ensure that different types of environmental regulations cooperate and complement each other, achieve the flexibility of policy implementation, and play the synergistic effect at different stages. Wang et al. (L. Wang, Long, & Li, 2022) divided heterogeneous environmental regulation into three categories, namely, command-based environmental regulation, market-oriented environmental regulation, and voluntary environmental regulation. Their research found that implementing the policy was conducive to the rapid improvement of enterprise GTI. Lu et al. (Lu, Wu, & Geng, 2021) analyzed the heterogeneity and threshold effect of environmental regulations on health expenditure based on panel data from 30 provinces in China from 2007 to 2017. They found that the single threshold effect of environmental regulation on health expenditure was significantly different in the eastern, central and western regions. Xie et al. (Xie, Yuan, & Huang, 2017) examined the impact of different regulatory instruments and relative stringency on “green” productivity. The results support the “strong” Porter Hypothesis, which is reasonable stringency of environmental regulations may enhance rather than lower industrial competitiveness. Shen et al. (Shen, Liao, Deng, & Wang, 2019) used the Metafrontier Malmquist-Luenberger method to analyze the impact of pollution emissions and the technology gap on China’s total industrial factor productivity from 2000 to 2016. The threshold model was adopted to investigate the nonlinear dynamic effects of different types of environmental regulation on the total environmental factor productivity of industrial sectors. They found that the impact of different types of environmental regulations on total factor productivity in different industries is heterogeneous due to industry heterogeneity.

3. The Impacts of Environmental Regulations on Carbon Emissions

This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation, as well as the experimental conclusions that can be drawn.

3.1 Carbon Emission Status of Heavy Industry in Chengdu-Chongqing Region

The carbon emission of heavy industry in Chengdu-Chongqing region is mainly concentrated in ten industries, including petroleum processing coke and nuclear fuel (PPCNF); production and supply of electric power and heat power (PSEPHP); non-ferrous metal smelting and extended pressing (NFMSEP); ferrous metal smelting and extended pressing (FMSEP); non-metallic mineral products industry (NMMPI); chemical raw materials and chemical products manufacturing (CRMCPM); coal mining and washing industry (CMWI); chemical fiber manufacturing (CFM), medical manufacturing (MM); and special equipment manufacturing (SEM), etc. The total CO2 emissions from heavy industry in different regions were calculated using the formula:

$$E_i = \sum_{i=1}^{n} X_{ij} C_j \quad (1)$$

where E_i is the total CO_2 emissions of the number *i* heavy industry, X_{ij} is the number *j* heavy industry energy consumption above scale in the number *i* heavy industry, C_j is the CO_2 emission coefficient of the number *j* energy source.

The primary energy types of these industries are raw coal, coke, gasoline, kerosene, diesel, fuel oil, and electricity. Different energy sources have different carbon emission coefficients. To get the total carbon emission, it is necessary to compare the carbon emission coefficients of different energy sources. According to the calculation method mentioned in the 2006 IPCC Guide to National Greenhouse Gas Inventories (Bastianoni, Marchi, Caro, Casprini, & Pulselli, 2014; Velychko & Gordiyenko, 2009), the carbon emission coefficients of different energy sources in China can be obtained, as shown in Figure 1. From the carbon emission coefficient distribution, the energy coefficient of electric power is the highest, while that of raw coal is the lowest.

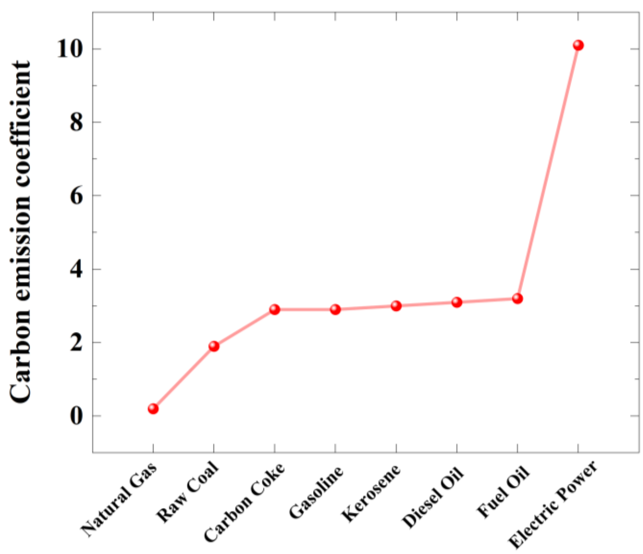

Figure 1. Carbon Emission Coefficients of Different Energy Sources in China

The calculation method of carbon emission intensity is referred to Liu et al., who analyze the carbon emission of industrial industries in heavy industry cities in Northwest China. Based on the carbon emission coefficient of different energy sources and the energy consumption of heavy industry above the designated size in government yearbook data, this paper calculates the carbon emissions of heavy industry in Chengdu and Chongqing from 2016 to 2020. The results are shown in Figure 2 and Figure 3. Figure 2 shows the carbon emissions of heavy industry in Chengdu from 2016 to 2020, and Figure 3 shows the carbon emissions of heavy industry in Chongqing from 2016 to 2020.

The results show that the production and supply of electricity and heat have the highest carbon emission in Chengdu heavy industry, followed by non-metallic mineral products, accounting for more than 20%. The carbon emissions of petroleum processing, coking and nuclear fuel, ferrous metal smelting and pressing, chemical raw materials, and chemical products manufacturing exceed 10%. From Figure 2, the carbon emissions of all industries in Chengdu from 2016 to 2020 show a slightly rising trend year by year, in which the production and supply of electricity and heat increased significantly in 2020.

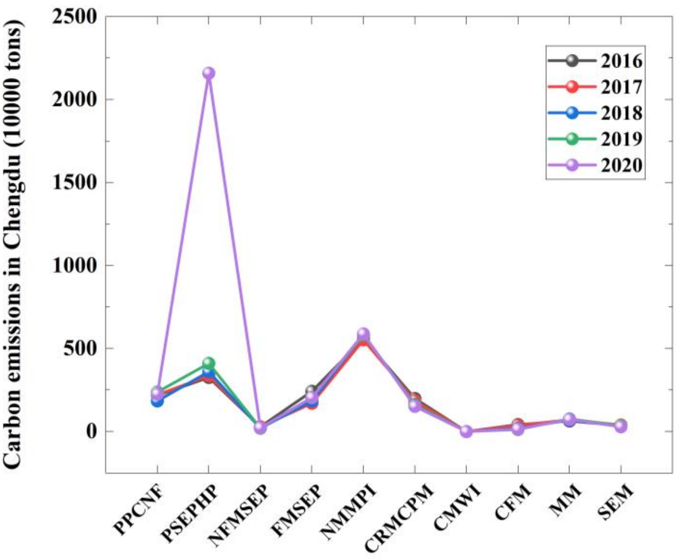

Figure 2. Carbon Emissions in Chengdu from 2016 to 2020 (10,000 tons)

In Chongqing, the highest carbon emission is the production and supply of electricity and heat, accounting for more than 30%. Five industries, namely non-ferrous metal smelting and pressing, ferrous metal smelting and pressing, non-metallic mineral products industry, chemical raw materials and chemical products manufacturing, coal mining, and washing industry, accounted for more than 10%. According to Figure 3, energy types in some fields of Chongqing show a steadily rising trend year by year from 2016 to 2020. The carbon emissions of electricity and heat production and supply, non-ferrous metal smelting and extended pressure, ferrous metal smelting and extended pressure, and other industries reached the peak in 2019, while decreasing slightly in 2020. For coal mining and washing industries, carbon emissions show a trend of decreasing year by year.

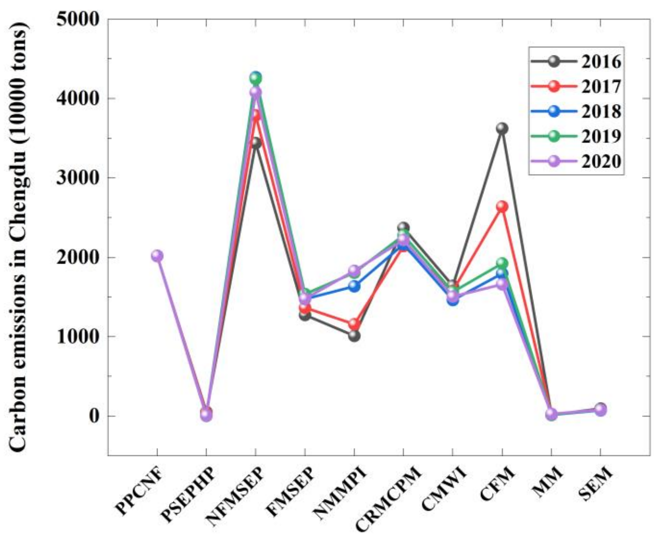

Figure 3. Carbon Emissions in Chongqing from 2016 to 2020 (10,000 tons)

According to the actual annual carbon emissions of heavy industry in Chengdu and Chongqing, the carbon emissions of heavy industry in Chengdu and Chongqing in different years can be clearly compared. The related results are list in Figure 4. Carbon emissions from enterprises above the designated size in Chengdu increased from 17.16 million tons in 2016 to 34.69 million tons in 2020. In Chongqing, carbon emissions dropped from 135.73 million tons in 2016 to 129.22 million tons in 2020. Total carbon emissions in Chengdu are lower than that in Chongqing. Carbon emissions in Chongqing are mainly concentrated in the production and supply of electricity and heat, which is exceeded the total carbon emissions in Chengdu. This is mainly due to there is more high-energy industry in Chongqing, including steel industry, thermal power industry and the automobile industry. These industries contribute most of the carbon emissions. The carbon emissions from 2016-2020 in Chongqing are relatively stable. The overall trend shows a slight downward, which may be related to the implementation of environmental regulations.

The low industrial carbon emission in Chengdu is mainly attributed to the industrial structure of the light industry, science and technology, and the new generation of information technology. However, due to the rapid increase in carbon emissions from the production and supply of electricity and heat, carbon emissions in Chengdu also showed an upward trend from 2016 to 2020. The electricity consumption in Chengdu increased by 8.7% year-on-year in 2020.

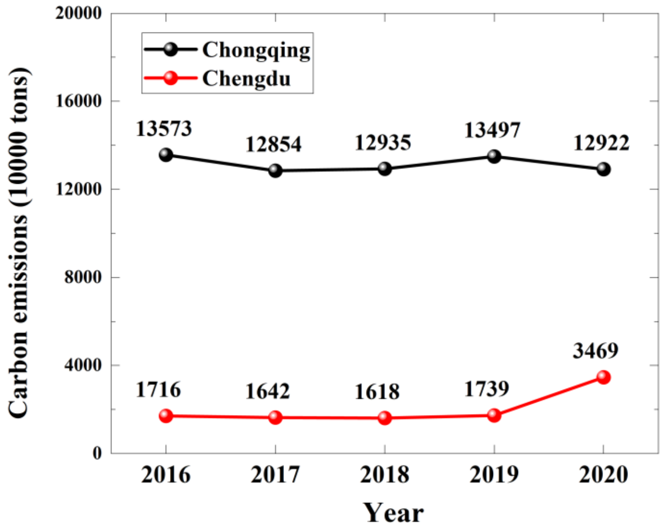

Figure 4. Comparison of Annual Carbon Emissions between Chengdu and Chongqing

3.2 The Current Situation of Environmental Regulations on Carbon Emission Constraints

In order to achieve the dual carbon goal and reduce carbon emissions, Chengdu and Chongqing have promulgated a series of environmental protection policies to regulate environmental pollution. From the perspective of the environmental policies of Chengdu, Chengdu promulgated the *2016 Annual Implementation Plan of Chengdu Air Pollution Prevention and Control Action Plan*. The plan calls for improving environmental pollution and air quality in Chengdu. In addition, urge key enterprises to complete energy audit and energy utilization in a timely manner. Since implementing the environmental protection policy, the carbon emissions of enterprises in the chemical raw materials and chemical products manufacturing industry have decreased year by year. This indicates that the introduction of the environmental policy has played a restraining role in reducing carbon emissions.

The carbon emissions of some ferrous metal smelting and pressing industries decreased significantly in 2017 after the implementation of the policy, but gradually rebounded in 2018 and beyond. The “green paradox” effect of environmental regulation was presented. The effect of the policy was evident in the early stage. However, the carbon emissions gradually rebounded due to the lack of policy supervision, which did not achieve the expected effect. *Regulations of Sichuan Province on Prevention and Control of Radiation Pollution (2017 Revision)* promulgated by Sichuan Province. The policy requires to strengthen the prevention and control of radioactive pollution to achieve the purpose of protecting the environment, especially the nuclear fuel pollution of large enterprises and ionizing radiation pollution of hospitals. Chengdu, the capital city of Sichuan Province, is the core area of the implementation. Since the promulgation of the policy, the carbon emissions generated by petroleum processing coke-making and nuclear fuel enterprises have decreased yearly. It shows that the implementation of the policy is effective. However, for the pharmaceutical manufacturing industry, its carbon emissions showed a trend of first decreasing and then increasing, with inevitable volatility. In general, implementing environmental policies in Chengdu has played a particular restraining role in environmental pollution problems, but it also reflects the heterogeneity of industrial development. That is, the same environmental policy has different degrees of restraint on different industries.

From the perspective of the environmental policy of Chongqing, the carbon emission reduction mode of Chongqing is not only constrained by environmental regulations, but also a pilot of carbon trading has been established. Regarding environmental regulations, the Chongqing Ecological Environmental Protection Bureau issued a notice on the management of coal-fired boilers in 2016. Coal-fired boilers are required to be phased out in the main urban areas and new boilers are prohibited. After the announcement, carbon emissions from coal mining and washing industries in Chongqing fell sharply, from 36.228 million tons in 2016 to 16.599 million tons in 2020. Carbon emissions have fallen by more than half, indicating that the formulation and implementation of environmental policies can promote rapid emission reduction.

In 2017, Chongqing Ecological Environmental Protection Bureau issued a notice on strengthening the supervision and management of oil and gas recovery devices in oil storage depots, gas stations, and tanker trucks. The policy mandates that gas stations, storage depots, and tanker trucks strictly control carbon emissions from oil and gas pollution and strengthen environmental governance. After the implementation of the policy, the carbon emissions of the petroleum processing coke-making and nuclear fuel industries in Chongqing showed a downward trend year by year, with carbon emissions reduced from 355,000 tons in 2017 to 67,000 tons in 2018. Carbon emissions declined significantly in the first year after the policy was promulgated, and then tended to be stable. It shows that the promulgating of the policy has played a crucial role in limiting the carbon emissions of enterprises.

Regarding carbon trading pilot, Chongqing carbon pilot policy, as a command-and-control environmental regulation tool, requires all regions to clearly put forward essential tasks, specific targets, and specific measures for greenhouse gas emissions. In 2014, Chongqing Municipal Government issued the *Interim Measures for the Management of Carbon Emission Rights Trading of Chongqing Municipality* (No. 17, Chongqing Municipal Government issued (2014)). After implementing the policy, the third-party verification agency will verify the emission control enterprises included in the carbon emission trading every year. It is hoped that this can achieve the constraint effect of environmental regulation. Meanwhile, the policy system of “1+3+N” carbon emission trading system has been established to control the carbon emissions of industries above the scale through the carbon emission trading system. Since 2016, through the pilot of low-carbon cities and the implementation of relevant policies and regulations, carbon emissions have been relatively stable from 2016 to 2020, showing a slight downward trend. However, after the opening of carbon trading pilot market in Chongqing, it was found that the implementation of environmental policies had an inhibitory effect on carbon emissions in Chongqing.

Environmental policies implemented in Chengdu and Chongqing were analyzed. The environmental policy of Chengdu shows the effect of “green paradox”. On the other hand, the constraint effect of environmental policies on carbon emissions in Chongqing fluctuates over time, indicating that there is certain heterogeneity in the implementation of environmental policies. There are four main reasons:

First, some enterprises do not recognize specific environmental regulations, ignore environmental policies, take profits as the goal, and do not care about environmental pollution. Part of enterprises also has the problem of poor implementation. Only to deal with the inspection of government departments, but not to actually reduce carbon emissions.

Second, technological innovation is challenging. For the industry, especially the old large heavy industry in Chongqing, the carbon emissions are generally high. It is quite difficult for such enterprises to carry out technological innovation and green transformation in the short term. In addition, green technology innovation often requires high green subsidies from the government to effectively achieve carbon emission reduction. At present, the financial pressure on local government is great, and it is difficult to help all enterprises achieve technological innovation in a short time.

Third, the effect of policy constraints is poor. Some environmental policies only guide the general direction, prompting some enterprises to take advantage of loopholes. There are no specific environmental regulations, resulting in insufficient policy constraints. Environmental regulations promulgated at the same time may not be applicable to every enterprise, which makes some enterprises not subject to environmental regulations. These problems have led to difficulties in reducing carbon emissions.

Fourth, the supervision of local government is weak. After the implementation of the policy, the government failed to pay attention to the improvement of environmental pollution in the region and the implementation of enterprises. The lack of supervision leads to the lack of timely feedback on the implementation of policies. Some enterprises only have to deal with the inspection in the early implementation stage, and continue to use the previous way when the government is not in place. The restraining effect of environmental regulations is ignored.

4. Policy Recommendations for Environmental Regulation to Promote Carbon Emission Reduction

4.1 Enhance Corporate Identity and Follow the Low-carbon Concept

Define the path of high-quality and low-carbon development. Environmental regulation in Chengdu and Chongqing has inevitable heterogeneity. Under the condition of environmental regulation, according to the development of heavy industry and carbon emission in the two areas, environmental regulation suitable for the region shall be formulated. The government of the jurisdiction should guide correctly, organize experts to discuss, and implement opening to the outside world, technological reform, and transformation of industrial structure. Improving the low-carbon competitiveness among enterprises and strengthening the management of carbon assets within enterprises. Promoting the exemplary role of low-carbon enterprises, and actively contributing to carbon emission reduction and high-quality economic development.

Foster the concept of green and low-carbon development. Chengdu-Chongqing region should actively build a green low-carbon circular development economic system. Environmental protection gives priority to the concept of sustainable development. It is conducive to promoting green transformation in each region. By strengthening the publicity and education of low-carbon and environmental protection concepts, enterprises with high carbon emissions can transform into green enterprises. Strengthen the demonstration role of green and low-carbon enterprises in the industry, and create the concept of green and low-carbon development of enterprises. Meanwhile, promote Chengdu-Chongqing cooperation in energy conservation and emission reduction. Jointly build and share green technology and carbon emission reduction technology, and build a community of shared future in Chengdu-Chongqing region.

4.2 Achieve Technological Breakthroughs, Reduce Carbon Emissions at Low-cost

Optimize the energy structure and promote the successful transformation of enterprises. Encourage enterprises to upgrade existing equipment and achieve technological innovation. Transforming high-carbon energy into low-carbon energy by accelerating research and development of advanced low-carbon technologies. Promote technological innovation to become the main driving force of low-carbon development. Actively promote the implementation of a carbon trading pilot in Chengdu-Chongqing region, and make the carbon trading market a mainstream carbon emission reduction tool. Find a balance between enterprise development and energy conservation and emission reduction. The government sets the intensity of environmental regulation according to local conditions. Optimize the energy structure with technological reform, and guide the transformation of enterprises with environmental policies.

Developing efficient carbon capture and carbon conversion technologies. Heavy industry has serious environmental pollution, and some enterprises with high energy consumption have difficulty in energy transition. Using carbon capture technology to collect and transform carbon emissions, which can effectively reduce environmental pollution caused by CO_2. The captured CO_2 can also be effectively used as resources, such as industrial additives, quality stabilizers, and fire extinguishing materials. In addition, more advanced capture technologies need to be developed to improve the efficiency of carbon capture and reduce the cost of carbon capture. Carbon conversion can be carried out in multiple channels to transform pollutants into usable resources.

4.3 Policy reform, reasonable planning and constraint policies

A virtuous cycle mechanism can be formed through the improvement of governance policies. The existing environmental regulation can promote the reduction of carbon emissions to a certain extent, but it will inevitably lead to the opposite effect in the long run. Local government departments need to formulate reasonable laws and regulations through the level of enterprise development and carbon emission reduction technology. The existing environmental policies should be improved. To serve as a warning, enterprises that do not meet environmental standards should give strict penalties. Set up a green enterprise model room and give corresponding incentive policies. Finally, the heavy industry with extensive pollution will be cleaned up, forming a virtuous cycle mechanism.

Formulate multiple environmental regulations to form reasonable restraint schemes. There were regional differences in carbon emissions and heavy industry distribution. As the intensity of environmental regulation gradually changes, the “green paradox” and “forced emission-reduction” change each other. The government should give full play to the effectiveness of heterogeneous environmental regulation, strengthen the promotion role of environmental regulation on carbon emission reduction, and form a reasonable constraint scheme. In addition, it actively responded to the national “release, regulation, and service” reform system to improve government efficiency. Formulate multiple environmental regulations, and improve the environmental protection legal system. Enhance the willingness of enterprises to participate in environmental governance, and promote the transformation from “policy promotion” to “legal guidance”.

4.4 Effective Supervision to Activate the Drivers of Green Development

Optimize the management system. The government should optimize the investment strategy, reduce the introduction of heavy industry with high carbon emissions, and support enterprises with green environmental protection technology. Encourage enterprises to develop green innovative technologies and activate green growth drivers. The government needs to control the energy consumption of heavy industry. To favor such enterprises through financial assistance, to help enterprises with higher carbon emissions to transform technology. The government can provide subsidies for green transformation by increasing support for resources and the environment. And implement tax incentives for green enterprises, so as to quickly and effectively achieve carbon emission reduction.

Establish a comprehensive coordinated supervision mechanism. The carbon emissions of neighboring regions are complementary and interact with each other. In order to establish the collaborative supervision mechanism of environmental pollutants in the treatment process, the governments of Chengdu and Chongqing should carry out policy coordination, improve the cross-domain collaborative supervision mechanism, and effectively control the carbon emissions of heavy industry. In addition, the policy should actively expand the public participation mechanism. Build a cross-domain ecological environment collaborative supervision platform. As a result, the governments, enterprises, and the public of the two places participated in the control of environmental pollution to reduce the overall carbon emissions.

5. Conclusions

In this work, the constraint mechanism of environmental regulation on carbon emission was investigated by literature analysis, comparative analysis and statistical induction. The main conclusions were listed as follows:

(1) The carbon emissions of the heavy industries in Chengdu showed a slight increase from 2016 to 2020. Implementing environmental policies in Chengdu has played a particular restraining role in environmental pollution problems, but it also shows the green paradox effect. In other words, policies

can reduce carbon emissions in the short term, but lead to an increase in carbon emissions in the long term.

(2) The carbon emissions of Chongqing showed a fluctuation, with a trend of first decreasing, then increasing, and then decreasing. Carbon emissions value reached peak in 2019. Environmental policy in Chongqing consists of various forms, including environmental regulations and carbon trading markets. Although Chongqing has many heavy industries, these emission reduction tools can promote the reduction of carbon emissions to a certain extent.

(3) Comparing the constraint effects of environmental regulations on carbon emissions in Chengdu and Chongqing, there was a specific heterogeneity in implementing environmental policies. There are mainly the following four dilemmas: firstly, part of enterprises is hard to accept specific environmental regulations; secondly, the innovation of emission reduction technology is difficult; thirdly, the effect of environmental policies on carbon emissions is limited; fourthly, the government's supervision is weak.

(4) According to the current dilemma, policy recommendations are put forward from four aspects, including corporate identity, technological progress, policy constraints and government supervision. The findings are beneficial to improve the theory of environmental regulation, which can provide policy proposals for optimizing the green transformation of heavy industry.

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