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Research on Structural Characteristics and Optimization of Policy Mix for Pollution Reduction and Carbon Abatement in Chengdu-Chongqing Twin-City Economic Circle

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Abstract

Against the background of the carbon peaking and carbon neutrality goals as well as ecological civilization construction, the collaborative governance of pollution reduction and carbon abatement has become an important direction for regional green and low-carbon transition. Taking the Chengdu-Chongqing Twin-City Economic Circle as the research object, this paper constructs a three-dimensional analytical framework of policy objective – policy instrument – policy intensity based on relevant policy texts from 2000 to 2025, and analyzes the evolution process and structural characteristics of the regional policy mix for pollution reduction and carbon abatement. The study finds that policy supply has generally gone through three stages: the initial stage of traditional pollution governance, the expansion stage of green low-carbon development, and the intensified stage of coordinated pollution reduction and carbon abatement. Policy objectives have gradually expanded from single pollution control to compound goals covering carbon emission reduction, energy transition, industrial transformation, ecological protection and regional coordination. Mandatory policy instruments dominate, while market-oriented and guidance-based instruments have been gradually strengthened; nevertheless, voluntary instruments and social participation mechanisms remain insufficient. Policy intensity keeps increasing, whereas joint governance, standard alignment, data sharing and collaborative evaluation mechanisms between Sichuan and Chongqing still need to be improved. On this basis, it is necessary to strengthen overall objective coordination, optimize the structure of policy instruments, enhance regional collaboration and improve the dynamic evaluation mechanism, so as to promote the policy mix to shift from quantitative expansion to structural optimization.

Keywords

Chengdu-Chongqing Twin-City Economic Circle; Pollution Reduction and Carbon Abatement; Policy Mix; Policy Text; Structural Characteristics; Regional Coordination

1. Introduction

Climate change has become a severe global challenge, and the carbon dioxide emissions resulting from the combustion of fossil fuels are an important factor affecting global climate change. [1] China's ecological civilization construction is currently facing two major strategic tasks: a fundamental improvement of the ecological environment and carbon peak and carbon neutrality. Coordinating the reduction of pollution and carbon emissions has become an inevitable choice for the comprehensive green transformation of the economy and society in the new development stage. [2] After the "carbon neutrality" goal was proposed in 2020, China's environmental governance logic further shifted from traditional pollution control to systematic emission reduction and structural transformation. Since environmental pollutants and carbon emissions mainly originate from the combustion of fossil fuels such as coal and oil, there is a strong consistency in emission sources, generation mechanisms, and governance paths. The reduction of pollution and carbon emissions have an inherent connection of the same origin, the same process, and the same driving factors. However, for a long time, carbon emission reduction and pollution prevention and control have been relatively separated, resulting in insufficient coordination between policy goals, governance systems, and policy tools. With the successive introduction of policies such as "Opinions of the Central Committee of the Communist Party of China and the State Council on Deepening the Battle Against Pollution in a Comprehensive Manner" and "The Comprehensive Work Plan for Energy Conservation and Emission Reduction in the '14th Five-Year Plan'", environmental governance has gradually shifted from the reduction of single pollutants to pollution reduction, carbon emission control, energy structure optimization, and industrial green transformation. The complexity of the governance objects of pollution reduction and carbon emission reduction determines that they cannot be accomplished by a single policy or a single tool, but require multi-objective, multi-tool, and multi-level policy arrangements to form a governance synergy. From a theoretical perspective, the key to environmental policy design lies in the scientific selection and reasonable combination of policy tools. Problems such as an overemphasis on the industrial structure, high energy consumption intensity, and excessive resource exploitation are also difficult to be solved solely through market self-regulation and still need to be promoted by the government through institutional arrangements, policy guidance, and the combination of multiple tools. As policy goals become increasingly diverse, traditional single environmental policies have been unable to respond to environmental governance issues in complex situations. [4]

The Chengdu-Chongqing Twin-City Economic Circle is an important object for observing the policy combination of pollution reduction and carbon emission reduction in regional governance. Different regions in China have significant differences in economic development levels, resource endowments, energy

structures, industrial structures, and capital and technology conditions. [5] To achieve the synergy of pollution reduction and carbon emission reduction, all regions need to promote policy, industry, technology, energy, and ecological multi-sectoral collaboration. [6] The Chengdu-Chongqing Twin-City Economic Circle is located at the intersection of the "Belt and Road Initiative" and the Yangtze River Economic Belt, and is a growth pole in the west and an ecological security barrier in the upper reaches of the Yangtze River. This region has a large total energy consumption and a relatively heavy industrial structure. Moreover, the basin terrain leads to frequent calm winds and inversion weather, which makes the atmospheric pollution diffusion conditions relatively unfavorable. [7] Therefore, promoting pollution reduction and carbon emission reduction is not only of immediate urgency but also has regional representativeness. The "Construction Outline for the Chengdu-Chongqing Twin-City Economic Circle" has clearly proposed to take the lead in demonstrating in the field of green and low-carbon development. Sichuan and Chongqing have also successively introduced relevant policies, providing institutional support for regional collaborative governance. In the past five years, the two regions have continuously deepened cooperation in environmental governance coordination and have achieved initial results. [8] However, due to differences in industrial foundation, energy structure, environmental carrying capacity, and policy implementation conditions, there are still inconsistencies in policy advancement rhythm, tool selection, and governance priorities between the two regions. [9]

Based on this, the research focuses on the policy combination of pollution reduction and carbon emission reduction in the Chengdu-Chongqing Twin-City Economic Circle as the object. It does not examine the policy effect from the perspective of causal identification, but rather based on policy text analysis, focuses on three dimensions of policy goals, policy tools, and policy intensity to reveal its structural characteristics, current deficiencies, and optimization paths.

2. Theoretical Basis and Analytical Framework of Pollution Reduction and Carbon Abatement Governance from the Perspective of Policy Mix

2.1. Literature on Policy Mix and Pollution Reduction & Carbon Abatement Governance

Research on policy mix originated initially in the field of macroeconomic policy. Meade early pointed out that a single policy instrument can hardly achieve multiple macroeconomic goals simultaneously, thereby putting forward the idea of the combined application of policy instruments. [10] Tinbergen further proposed the principle of matching policy objectives with the number of policy instruments, emphasizing the necessity of allocating multiple policy instruments under multi-objective scenarios. [11] As public governance issues grow increasingly

complex, policy mix research has gradually extended to environmental policy, innovation policy, sustainable transition policy and other fields. Gunningham and Sinclair noted that different environmental policy instruments have respective advantages and limitations, and their rational combination helps improve governance effectiveness. [12] Rogge and Reichardt argued that a policy mix is not a simple superposition of policy instruments, but a systematic arrangement composed of policy strategy, instrument portfolio, policy process, as well as consistency, coherence, credibility and comprehensiveness. [13] Domestic studies also highlight that the matching relationship between policy objectives and policy instruments is always the core of policy mix research. [14] From the structural dimension, policy objectives, policy instruments and policy intensity constitute key perspectives for understanding policy mix. Policy objectives indicate the governance orientation, while policy instruments are institutionalized means to achieve goals. Hood proposed the "government toolbox" model and classified policy instruments into authoritative, financial, organizational and informational types. [15] From the perspective of policy instrument selection, Howlett and Ramesh contended that different instruments reflect distinct governance approaches and policy preferences. [16]

Nevertheless, policy mix does not necessarily generate synergistic effects. Howlett and del Rio believed that policy mix may face risks such as over-design, under-design and instrument conflict. [17] Studies by Del Río, Yi, Feiock and other scholars also show that different instruments may be complementary, substitutive, offsetting or conflicting with one another. [18][19] Therefore, the focus of policy mix research lies not only in whether the policy quantity is sufficient, but also in the consistency of policy objectives, the compatibility of instruments, and the formation of complementary relationships among policies. Policy intensity is likewise a crucial dimension. Rothwell was among the earliest to divide policy mix into three dimensions: policy objective, policy instrument and policy intensity. [20] Most domestic studies also adopt "policy intensity" to measure the degree of policy constraint, the administrative level of issuing authorities and implementation strength. [21][22][23]

Environmental governance and low-carbon transition are distinctly complex, involving multiple goals including pollution control, energy transition, industrial restructuring, technological innovation, public participation and regional coordination, where a single instrument is insufficient to cope with complex governance scenarios. Existing studies have proven that policy mix can affect governance performance through goal setting, instrument allocation and policy intensity arrangement. Zhang Xiaojie et al. found a complementary relationship between market-based instruments and regulatory instruments. [24] Liu Jianping et al. pointed out that excessively overlapping policy measures may lead to resource waste and inefficient implementation. [25] Liu Haiying and Wang Yu also held that

the effect of policy mix cannot be simply equated to the sum of individual instrument effects. [26]

In terms of pollution reduction and carbon abatement governance, pollutant emission reduction and carbon emission control share the same root and sources. IPCC reports indicate that fossil energy combustion, industrial production and transportation are major sources of both carbon dioxide and air pollutant emissions. [27] Swart et al. also stressed that climate change and air pollution have common emission sources and intertwined environmental impacts. [28] Domestic studies suggest that the key to collaborative governance of pollution reduction and carbon abatement lies in shifting from end-of-pipe treatment to source prevention and control. By optimizing energy structure, upgrading industrial structure and advancing green technological progress, coordinated advancement of pollutant abatement and carbon emission control can be realized. [29][30] However, pollution reduction and carbon abatement are not naturally synergistic. Differences still exist in policy targets, governance paths and assessment mechanisms, which may bring about synergistic benefits, effect offset or even conflicts. [31][32] (Yang Jing et al., 2023; Mao Xianqiang et al., 2021)

Accordingly, the core of formulating the policy mix for pollution reduction and carbon abatement is not merely setting dual goals of pollution control and carbon reduction, but forming systematic governance synergy through overall goal coordination, instrument allocation and policy intensity arrangement.

2.2. Theoretical Explanation of Regional Pollution Reduction and Carbon Abatement Empowered by Policy Mix

With the diversification of governance objectives, the policy system often presents a complex structure featuring superposition of multiple departments, administrative levels and policy instruments. Lack of overall planning among different policy objectives, insufficient coordination among policy instruments, and unclear responsibility boundaries among governance entities may result in policy overlap, departmental segmentation, fragmented implementation and inadequate regional coordination.

Institutional complexity theory provides an important perspective to interpret such problems. The theory holds that organizational behavior is constrained not only by economic rationality, but also by the external institutional environment and internal rule structure. Under the coexistence of multiple institutional logics, institutional arrangements may enhance the adaptability of the governance system; meanwhile, they may also lead to rising coordination costs and implementation deviations due to goal conflicts, means conflicts or ambiguous priority orders. [33]

Introducing institutional complexity theory into the research on pollution reduction and carbon abatement policy mix in the Chengdu-Chongqing Twin-City Economic Circle helps explain the necessity of policy mix optimization. The local policy system

involves multiple sectors such as ecological environment, development and reform, industry and information technology, energy, transportation, finance, as well as governance division among Sichuan, Chongqing and various cities within the region.

A denser policy system does not always mean higher effectiveness, nor does stronger policy intensity guarantee better performance. Ostrom pointed out that institutional complexity is not more effective at a higher level but has an optimal moderate range. Moderate institutional complexity helps enhance institutional flexibility and adaptability, while excessive complexity may trigger rising coordination costs, implementation failure and even governance breakdown. [34]

Therefore, the optimization of pollution reduction and carbon abatement policy mix in the Chengdu-Chongqing Twin-City Economic Circle lies not in simply increasing policy quantity, but in reducing institutional complexity and coordination costs in policy operation through overall goal planning, instrument matching, responsibility division and regional coordination.

2.3. Three-Dimensional Analytical Framework of "Objective-Instrument-Intensity"

Based on the above literature review and theoretical foundation, this paper constructs a three-dimensional analytical framework of policy objective – policy instrument – policy intensity to analyze the structural characteristics of the pollution reduction and carbon abatement policy mix in the Chengdu-Chongqing Twin-City Economic Circle. This framework is not designed for constructing econometric models or identifying policy causal effects, but serves as a tool for policy text analysis and policy structure diagnosis. Among them: policy objectives reflect the value orientation and governance priorities of the policy system; policy instruments embody the specific means adopted by the government to achieve goals; policy intensity reflects the strength of policy supply, the degree of institutional constraints and organizational promotion approaches.

The three dimensions jointly answer three core questions of the policy system: what problems to solve, how to solve them, and at what strength to promote implementation.

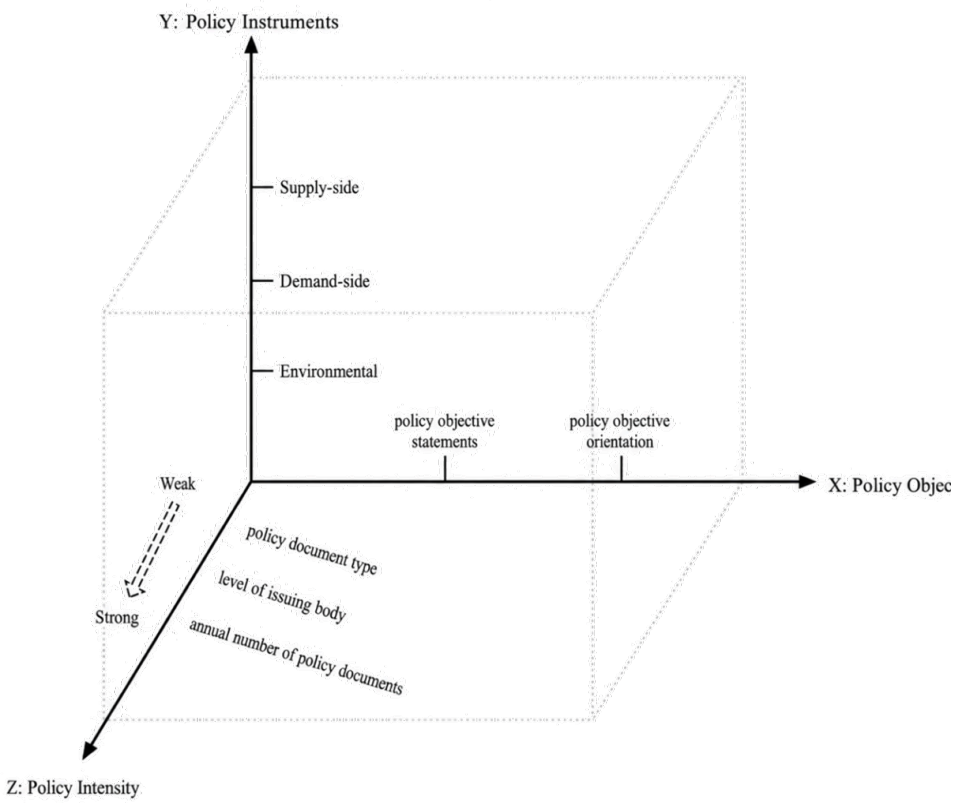


Figure 1. Three-dimensional Analytical Framework of Objective-Instrument-Intensity.

3. Text Sources and Processing of Pollution Reduction and Carbon Emission Reduction Policies for the Chengdu-Chongqing Twin-City Economic Circle

The policy texts mainly come from authoritative policy databases and official websites of all levels of government. Firstly, the professional policy databases such as Beida Baoda are used as the main search platforms. Around the keywords such as "carbon", "pollution", "greenhouse gases", "energy conservation and emission reduction", "low carbon", "carbon peak", "carbon neutrality", "decarbonization and pollution reduction", "synergistic governance", etc., systematic searches are conducted on the policy texts issued by relevant cities in Sichuan Province, Chongqing Municipality, and the Chengdu-Chongqing region. Secondly, to make up for the possible lag or omission in the database collection, additional searches are carried out on the government websites of Chongqing Municipality and its subordinate districts, the relevant prefecture-level cities in Sichuan Province, as well as the websites of departments such as Ecology and Environment, Development and Reform, Economy and Information Technology, Energy, and Finance under the "government affairs disclosure", "policy documents", and "planning and plans"

sections. Subsequently, the policy documents obtained from different channels are integrated, duplicates are removed, and formats are standardized to form a policy text database for reducing pollution and lowering carbon emissions in the Chengdu-Chongqing Twin-City Economic Circle.

The sample range is based on the Chengdu-Chongqing Twin-City Economic Circle, mainly including relevant districts and counties of Chongqing Municipality and cities such as Chengdu, Zigong, Luzhou, Deyang, Mianyang, Suining, Neijiang, Leshan, Nanchong, Meishan, Yibin, Guang'an, Dazhou, Ya'an, Ziyang in Sichuan Province. This region has the dual attributes of an important economic growth pole in the west and an ecological security barrier in the upper reaches of the Yangtze River. The tasks of pollution control, energy transition, green industrial upgrading, and regional collaborative governance are particularly prominent, making it a typical area suitable for observing the structural characteristics of the policy combination for reducing pollution and lowering carbon emissions. The time range is set from 2000 to 2025. This is mainly because since 2000, the industrialization and urbanization process in the Chengdu-Chongqing region has accelerated, and policy demands for pollution prevention and control, energy conservation and reduction, and ecological protection have gradually emerged; in the 2010s, ecological civilization construction, green development, and low-carbon transformation have continuously been integrated into local policy systems; after the "dual carbon" target was proposed in 2020, the synergy of reducing pollution and lowering carbon emissions has further become an important guiding principle for environmental governance. Therefore, the time range of 2000 to 2025 can present the process of policies evolving from traditional pollution control to green and low-carbon transformation, and then to collaborative governance for reducing pollution and lowering carbon emissions in a relatively complete manner.

To ensure the relevance of the samples to the research topic, the policy selection is based on the "Implementation Plan for Synergistic Effect of Reducing Pollution and Lowering Carbon Emissions" issued by seven departments including the Ministry of Ecology and Environment as an important basis for concept identification and keyword system construction. Policies for reducing pollution and lowering carbon emissions are defined as those closely related to pollution prevention and control, energy conservation and emission reduction, green and low-carbon, carbon peak and carbon neutrality, energy structure adjustment, green industrial transformation, ecological protection, and regional collaborative governance, and have policy rules attributes or governance orientations. The specific selection process follows the steps of "title initial screening - content review - standardized screening - organization and storage": first, preliminary screening based on title keywords, then judgment of whether the text contains clear policy goals, tool arrangements, responsibility divisions, or governance mechanisms, and finally determination of whether to include in the analysis based on the general applicability, rule-setting

attributes, and governance orientation of the text. After the selection, the research is conducted based on the framework of "policy goals - policy tools - policy intensity".

4. Evolution and Structural Characteristics of the Pollution Reduction and Carbon Abatement Policy Mix in the Chengdu-Chongqing Twin-City Economic Circle

4.1. The policy mix exhibits a phased evolution characteristic.

From the perspective of the release time of the policies, there were a total of 2,579 policies related to pollution reduction and carbon emission reduction in the Chengdu-Chongqing Twin-City Economic Circle from 2000 to 2025. The policy supply was not evenly distributed; instead, it showed distinct phased evolution characteristics as the national environmental governance strategy, regional development policies, and the "carbon neutrality" goal were implemented. The number of policies underwent a process of starting from a low level, continuously expanding, and then achieving coordinated strengthening.

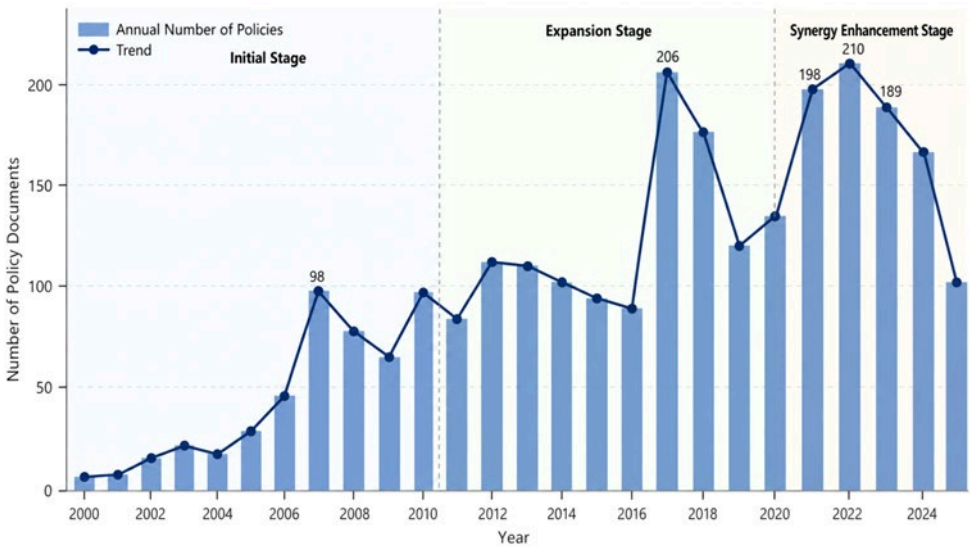


Figure 2. Figure of Annual Issuance Quantity of Pollution Reduction and Carbon Abatement Related Policies in Chengdu-Chongqing Twin-City Economic Circle (2000–2025).

From the perspective of the release time of the policies, there were a total of 2,579 policies related to pollution reduction and carbon emission reduction in the Chengdu-Chongqing Twin-City Economic Circle from 2000 to 2025. The policy supply was not evenly distributed; instead, it showed distinct phased evolution characteristics as the national environmental governance strategy, regional development policies, and the "carbon neutrality" goal were implemented. From 2000 to 2010, it was the initial stage. During this period, the overall scale of policy supply in the Chengdu-Chongqing region was relatively small, and the policy focus mainly concentrated on traditional pollution control,

energy conservation and consumption reduction, sewage treatment, waste management, pollution discharge supervision, and ecological protection. At this time, the policy goals were mainly focused on improving environmental quality and controlling pollutant emissions, and the policy tools were mainly administrative supervision, standard constraints, and special rectification, and a clear coordinated governance orientation for pollution reduction and carbon emission reduction had not yet been formed. Overall, the policy combination in this stage mainly manifested as the accumulation and institutionalization of traditional environmental governance policies. From 2011 to 2020, it was the expansion stage. With the continuous advancement of ecological civilization construction, green development concepts, and the pollution prevention and control battle, the number of policies related to pollution reduction and carbon emission reduction in the Chengdu-Chongqing region significantly increased, and the policy content gradually expanded from single pollution control to ecological protection, resource conservation, industrial restructuring, green development, and low-carbon transformation. Compared with the initial stage, the policy system in this period was significantly more comprehensive, with the goals of pollution prevention and control, energy conservation and emission reduction, ecological construction, and green industrial development beginning to interweave. The policy combination gradually expanded from traditional pollution control policies to a comprehensive policy system covering environmental protection, energy conservation and emission reduction, green low-carbon development. From 2021 to 2025, it was the coordinated strengthening stage. After the "carbon neutrality" goal was proposed in 2020, the policy supply related to pollution reduction and carbon emission reduction in the Chengdu-Chongqing region was further strengthened. The policy texts showed a significant increase in content such as "carbon peak", "carbon neutrality", "green low-carbon", "energy conservation and carbon reduction", and "coordinated governance". Compared with the previous two stages, this period's policy system placed greater emphasis on the coordinated promotion of pollution control and carbon emission reduction, and the contents such as energy structure optimization, industrial green transformation, ecological protection restoration, and regional coordinated governance were further strengthened, indicating that the policy combination began to shift from the parallel promotion of pollution control and low-carbon development to a comprehensive treatment stage of pollution reduction and carbon emission reduction synergy.

4.2. Expansion of Policy Objectives from Single Pollution Control to Compound Goals of Pollution Reduction and Carbon Abatement.

Based on the identification of keywords in the policy titles and combined with manual review, this paper classifies the relevant policy objectives of the

Chengdu-Chongqing Twin-City Economic Circle on pollution reduction and carbon emission reduction into six categories: pollution control, carbon emission reduction, energy transition, industrial transformation, ecological protection, and regional collaboration.

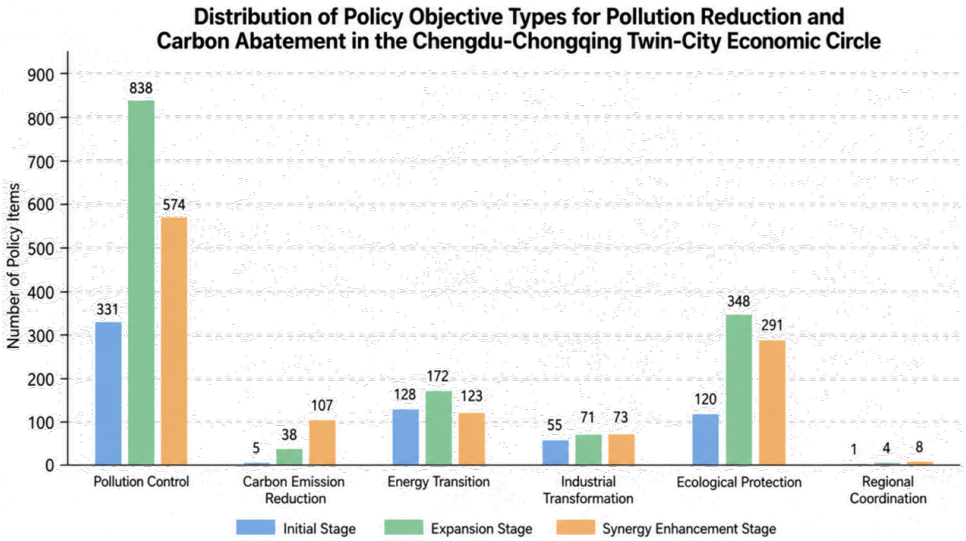


Figure 3. Distribution of Policy Objective Types for Pollution Reduction and Carbon Abatement in the Chengdu-Chongqing Twin-City Economic Circle.

The policy goals for pollution reduction and carbon emission reduction in the Chengdu-Chongqing Twin-City Economic Circle exhibit an evolving characteristic of gradually expanding from traditional pollution control to comprehensive governance goals. Pollution control has always been the fundamental content of the policy goal system and occupies an important position at all stages, indicating that regional policy supply initially focuses on traditional environmental governance tasks such as air pollution, water pollution, solid waste management, and improvement of ecological environment quality. On this basis, the changes in carbon emission reduction goals further reflect the shift of the policy goal system. Early policies mainly focused on energy conservation and emission reduction and pollution control, and low-carbon development and greenhouse gas emission reduction had not yet become independent and clear policy goals; as the concepts of ecological civilization construction, green development, and low-carbon transformation have been continuously strengthened, carbon emission reduction-related contents gradually entered local policy texts. Especially after the "dual carbon" goal was proposed, contents such as carbon peak, carbon neutrality, low-carbon development, and carbon emission control have significantly increased, indicating that regional policy goals have begun to shift from "pollution control as the main focus" to "equal emphasis on pollution reduction and carbon emission reduction". At the same time, the goals of energy

transition and industrial transformation also maintain a relatively stable position in the policy system, and contents such as energy conservation and consumption reduction, optimization of energy structure, clean energy substitution, industrial upgrading, green manufacturing, and circular economy were included in the policy goal system earlier, indicating that the policies in the Chengdu-Chongqing region for pollution reduction and carbon emission reduction do not solely rely on end-of-pipe pollution control, but gradually extend to adjustments in production methods and energy utilization methods. Especially in the collaborative strengthening stage, energy transition and industrial transformation remain important contents in the policy text, reflecting that local policies have recognized that the coordinated promotion of pollution reduction and carbon emission reduction must be systematically adjusted in terms of energy structure, industrial structure, and technical paths. With the continuous expansion of policy goals, the importance of ecological protection goals has also gradually increased. The construction of the ecological security barrier in the upper reaches of the Yangtze River, ecological civilization construction, and regional high-quality development, etc., have led to the continuous entry of contents such as ecological protection restoration, river basin governance, and ecological barrier construction into the policy system, promoting the policy goals to further extend from pollutant emission control to ecosystem protection and ecological function improvement, presenting a "environment - ecology - low-carbon" comprehensive governance orientation. In contrast, the representation of regional collaboration goals in the policy text is still relatively limited. Although the contents of joint prevention and control, cross-regional collaboration, and ecological environment co-governance have gradually increased in recent years, they have not yet become the dominant goals, indicating that the institutionalized linkage of the two regions in the field of pollution reduction and carbon emission reduction still needs to be strengthened. For the Chengdu-Chongqing Twin-City Economic Circle with a cross-administrative region characteristic, further strengthening regional collaboration in areas such as joint governance, standard alignment, joint law enforcement, and information sharing is still necessary.

4.3. Mandatory Instruments Dominate the Policy Mix with Gradually Enhanced Policy Intensity

Policy tools are important carriers for converting policy goals into governance practices. Based on the identification of policy title keywords and combined with manual review, this paper classifies the policy tools for pollution reduction and carbon emission reduction in the Chengdu-Chongqing Twin-City Economic Circle into four types: mandatory tools, market-based tools, guiding tools, and voluntary tools. Since a policy text may contain multiple governance means, this

part statistics the mentions of various policy tools in the text, and the different tool types are not mutually exclusive.

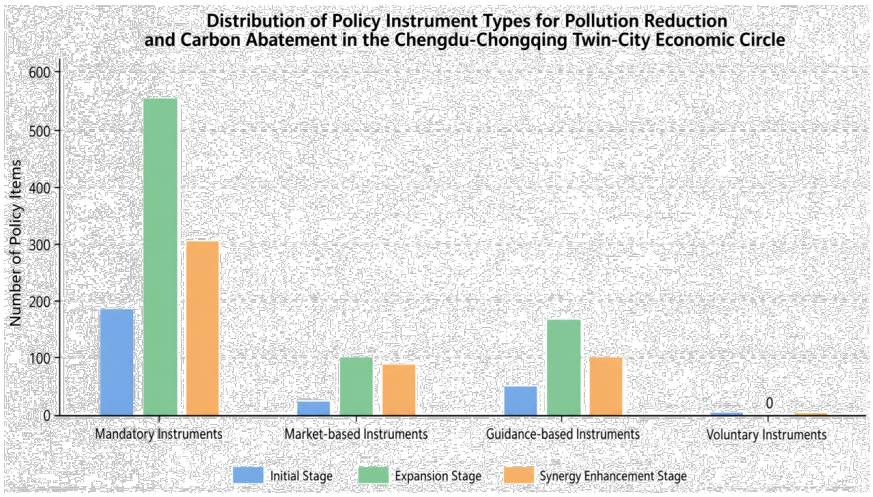


Figure 4. Distribution of Policy Instrument Types for Pollution Reduction and Carbon Abatement in the Chengdu-Chongqing Twin-City Economic Circle.

The pollution reduction and carbon abatement policy instruments in the Chengdu-Chongqing Twin-City Economic Circle are dominated by mandatory tools, with market-oriented and guidance-based ones gradually playing a supporting role, while voluntary instruments and social participation remain inadequate. Policy intensity keeps rising with improved institutional deployment and constraints under the dual-carbon goals. Nevertheless, Sichuan and Chongqing still lack a sound cross-regional coordination mechanism in policy alignment, joint law enforcement and data sharing.

5. Conclusion

The policy instruments of pollution reduction and carbon abatement in the Chengdu-Chongqing Twin-City Economic Circle are mainly mandatory ones, with market-oriented and guidance-based instruments gradually playing a supporting role. Policy intensity has been continuously strengthened, yet voluntary tools and social participation remain insufficient. The existing policy mix suffers from inadequate goal integration, unbalanced tool structure and weak cross-regional coordination between Sichuan and Chongqing. It is necessary to strengthen overall goal coordination, optimize the allocation of policy instruments, improve regional collaborative mechanisms, and establish a dynamic policy evaluation system, so as to promote the policy mix to shift from quantitative expansion to structural optimization and enhance the overall governance efficiency of pollution reduction and carbon abatement.

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