Digital technology enablement and policy synergy: Strategic evolution of digital transformation for climate governance in China (2015-2024)

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ARTICLE INFO	ABSTRACT
	Climate change governance has become a systemic global challenge involving justice, security, and sustainable development, with digital technologies increasingly reshaping governance strategies. Against this backdrop, China, as the world's largest developing country and carbon emitter, has actively embedded digital technologies into its climate policy framework since the Paris Agreement (2015). Drawing on 48 core policy documents issued by the State Council and related ministries, the research employs textual and discourse analysis combined with word frequency extraction, semantic clustering, and thematic module analysis. The findings reveal six interlinked thematic domains, policy framework and institutional design, energy transition, sectoral and regional governance, ecological conservation, market mechanisms, and capacity-building, through which digital technology functions not only as a technical instrument but also as a discursive and institutional driver. The study identifies a dynamic evolution of policy tool portfolios, shaped by path dependency, pilot-driven mechanisms, and institutional synergy between administrative authority and digital intermediaries. This research contributes both theoretically and practically by developing a "technology discourse tool" framework that explains how digital technologies are discursively embedded and translated into institutional practices. Empirically, it shows that China's governance model has generated replicable digital governance templates, offering strategic lessons for other developing countries seeking to integrate digitalization with climate governance. The study concludes that digital technologies, when embedded in policy discourse and institutional tools, can significantly enhance governance efficiency, accountability, and international discourse power in climate policymaking.

1. Introduction

Against the backdrop of profound adjustments in global climate governance, the issue of climate change has long since broken through the realm of environmental issues to become a systemic challenge involving global justice, national security and the sustainable development of human civilization. According to the State of the Global Climate 2024 released by the World Meteorological Organization (WMO), 2024 will be the warmest year on record about 1.55 degrees Celsius above pre-industrial levels (Cerveny, 2023; Croitoru, 2024). This data confirms the warning of the

Intergovernmental Panel on Climate Change (IPCC) that anthropogenic greenhouse gas emissions are changing the Earth's climate system at an unprecedented rate (Rogers et al., 2023).

However, the core complexity of the climate change issue lies in the fact that, while there is a high degree of consensus on its natural science basis, the path to governance is still characterized by significant uncertainty and high levels of controversy (Ergashovich, 2023; Joslin, 2019). Although the physical facts of climate change are generally recognized in the academic community, the divergence in the positions of countries on issues such as the sharing of responsibility for emissions reduction, the design of governance mechanisms and the trade-off between the right to development and environmental obligations has become more prominent (Minnerop, 2024; Otrashevskaya et al., 2024). Developed countries are trying to reshape the global governance order with the help of carbon tariffs, climate clubs and other mechanisms, while developing countries insist on the principle of "common but differentiated responsibilities", which has pushed the climate issue further into a new world. The climate issue has further evolved into a new geopolitical game platform (J. E. Yuan & Zhang, 2025; Zhang & Shang, 2025).

Compared with highly ideological issues such as human rights and democracy, climate change is often regarded as a "technology-neutral" international issue because of its measurable and verifiable natural science basis (S. Yuan, 2025). However, it is this apparent neutrality that makes the competition for discourse power behind the scenes more insidious and strategic. Objective indicators, such as carbon emission data and temperature rise curves, are in fact deeply embedded in specific institutional logics and policy tool configurations, and have become an important fulcrum for shaping national competitive advantages and intervening in the rules of global governance (Beisheim et al., 2022; Elfert & Ydesen, 2023).

As the world's largest developing country and a carbon emitter, China's policy trends in climate governance continue to receive extensive attention from the international community. Since signing the Paris Agreement in 2015, China has successively put forward the "dual-carbon" strategic goal of "peaking carbon emissions by 2030 and realizing carbon neutrality by 2060", and has continued to promote the institutional upgrading of its climate governance system. In this process, digital technologies represented by big data, artificial intelligence and blockchain have been systematically introduced into the governance framework, which not only enhance the efficiency and traceability of policy implementation, but also profoundly affect the combination of policy tools, the evolution of governance logic and the reconfiguration mechanism of institutional authority.

By addressing this gap, the present study contributes theoretically by constructing a "technology discourse tool" framework that explains the interplay between digital technologies and climate governance instruments. Empirically, it provides a systematic policy text analysis of China's climate governance over nearly a decade, revealing the evolutionary path of digital transformation and its institutional mechanisms. Practically, the study offers a paradigmatic reference for developing countries seeking to balance technological innovation with institutional design in addressing climate challenges.

This study focuses on 48 core climate policy documents issued by China's State Council and its related ministries and commissions during the period of 2015-2024, aiming to systematically sort out the evolutionary trends of digital technology-related discourses in the policy texts and reveal their governance embedding mechanisms in the process of climate governance transformation through text mining and discourse analysis methods. Based on the iterative perspective of policy tools, the study focuses on how digital technologies are transformed from the semantic level into an important fulcrum of institutional practices (Abdullayeva & Maxmudova, 2024; Li et al., 2024).

The choice of time period for this study is triply justified: (1) The node of institutional transformation is clear: the 2015 Paris Agreement opened a new phase of global climate governance, after which China accelerated the construction of a "dual-carbon" policy system, providing a good starting point and observation window for the study; (2) Complete policy evolution cycle: The study period covers both the 13th and 14th Five-Year Plan cycles, which helps to identify the transition trajectory of policy instruments from administrative order-based to data-driven; (3) High availability of practical data: The intensive introduction of policies after the 2020 "dual carbon" target, coupled with the accelerated advancement of digital governance during the New Crown Epidemic, has provided rich material for analyzing the coupling of policy content and technical practice.

Despite the increasing integration of digital technologies into climate governance, existing studies have predominantly emphasized either technological effectiveness or policy outcomes, while insufficient attention has been given to the discursive construction of digital technology in policy texts and its role in reshaping governance mechanisms. Moreover, the dynamic interaction between discourse, institutional tools, and policy evolution remains underexplored, particularly in the context of developing countries. This gap underscores the urgency of systematically examining how China, as a leading developing country, embeds digital technologies within its climate governance framework to generate institutional synergy, enhance governance efficiency, and provide replicable models for other nations.

Based on the above background and conditions, the specific objectives of this study include: (1) Quantitatively analyze the evolutionary features and structural distribution of digital technology discourse in policy texts through word frequency statistics and thematic clustering; (2) To reveal the evolution path and internal logic of the digital transformation of climate governance, and to reveal the main features of the digital transformation of China's climate governance from the perspective of iterative policy tools; (3) Constructing a theoretical framework of "technology-institution" synergy, and providing experience and replicable models for developing countries to explore the path of digital climate governance.

2. Theoretical Framework

This study complements and deepens the theory of climate governance from the path of "technological discourse-policy tools-institutional synergy". Existing studies have mostly focused on the specific effectiveness of digital technologies or the setting of policy goals, but have seldom systematically explored how technological discourse is constructed and evolved in policy texts, and how it reconfigures the governance mechanism. Through an in-depth textual analysis of 48 policies, this paper reveals that technological discourse not only assumes the function of information transmission in policymaking, but also participates in defining the power structure and the path of strategy optimization by embedding itself in the combination of governance systems and tools. This perspective not only enriches the theory of public policy tools, but also provides new theoretical coordinates for understanding how technology intervenes in national governance, and thus proposes new interpretive space for the political economy structure and institutional evolution of climate governance.

Practical implications, Over the past decades, there have been numerous cases of institutional change and practical innovation through digital technology in China's climate governance, such as the Smart Carbon Monitoring Platform, the Blockchain Monitoring Mechanism, Ant Forest and other digital application models. However, these cases often focus on technology introduction or effect assessment, and lack the analysis of their policy formation mechanism and institutional

support path. In this study, we embed these practices in the macro policy structure, analyze their institutional embeddedness in terms of the policy embeddedness of digital discourse, and reveal how the practices are solidified into "replicable governance templates" through policy texts. This will not only help other developing countries to learn from China's experience in implementing the digital transformation of climate governance, but also provide an operational path for the implementation of policies, which will effectively enhance the efficiency of governance and the implementation of the system (Varriale et al., 2024).

Policy Implications, Climate governance policy is not only a declaration of goals, but also the result of institutional and instrumental choices, and the effect of its institutional design is often determined by the linguistic structure in the policy text. By analyzing the discourse forms, frequency distribution, discourse transition nodes, and tool combination strategies of digital technologies in policy texts, this study provides a new policy analysis tool and decision-making path for policy makers to show the implicit governance mechanisms in climate policies. Based on this, when designing the governance system, policymakers can more consciously embed digital standards, monitoring systems and accountability mechanisms into the policy text, so as to enhance the scientific nature, operability and long-term driving force of the policy. This "endogenous embedding of digital technology" also helps to optimize the structure of the governance system and increase the efficiency of its implementation (Gleditsch, 2023; Gurr & Goldstone, 2019).

International significance, As a practical vehicle for reforming China's climate governance system, the institutionalization of digital technology has an important international demonstration effect. By systematically demonstrating how China builds digital governance mechanisms through policy tools, it can provide an "Eastern-style" paradigm for global climate policymaking. Especially in the context of developing countries facing similar dual challenges of digitalization and climate governance, this study can serve as a sample of institutional innovation, which can help to enhance China's discourse and rule output in global governance. In addition, this study provides a real-life example for international governance organizations to recognize the potential role of digital technology in driving institutional change, which is of positive significance (S. Wang et al., 2018).

Literature review, In order to gain a deeper understanding of the mechanisms and paths of the digital transformation of China's climate governance, this paper launches a literature review from three interrelated research dimensions: first, the mechanism of climate policy acceptance and institutional drive; second, the application and mechanisms of digital technology in climate governance; and third, the holistic construction of the climate governance model and international comparison. Each dimension covers both macro-institutional analysis and details of technological interventions, and assesses and locates research gaps.

Institutional development and public acceptance mechanisms for climate policy, Existing studies point out that there is a strong link between ideology and public acceptance of climate policy, both directly and indirectly. Guo et al., (2025) emphasizes that behavioral climate policy research not only emphasizes individual behavior change, but also discusses in depth how ideology and social trust influence public response to climate action. In the Chinese context, climate policies are often embedded in macro-strategies such as national development, ecological civilization construction, and modernization of social governance to enhance their public acceptance and implementation (Guo & Lu, 2024).

Analyst Zhao et al., (2021) points out that the development of China's climate policy is driven firstly by economic interests, secondly by energy security considerations, and again by a combination of political and international pressures. This superposition of multiple factors is

shaping the institutional framework of climate governance in China, and provides the institutional premise and social foundation for the embedding of digital technologies (Dremann et al., 2025).

In addition, social advocacy and public trust are also seen as central drivers of climate policy strategies. Guo Shihong et al. point out that "the dimension of policy environment emphasizes the importance of trust, ideology, and other factors for public behavior in response to climate change"; they also suggest that the influence of social advocacy in behavioral public policy cannot be ignored. These conclusions emphasize that understanding the synergy between technologies and institutions must be placed in the social context of policy acceptance and behavioural response.

Digital transformation in urban ecosystem governance, through case studies, Chen & Guo (2023) show how digital technologies such as big data, satellite remote sensing, and the Internet of Things (IoT) can improve the efficiency of urban air quality, water environment, and solid waste governance (Zhao et al., 2021). This study provides a micro-mechanism reference for this thesis i.e., how technology translates into governance behaviors behind policy texts and influences institutional choices.

Technology pathways for artificial intelligence in climate governance, From Ronggang et al., (2025), a comprehensive assessment of the current status and prospects of the application of artificial intelligence (AI) in climate intelligence, monitoring, and early warning, it is argued that AI large model and multimodal technology can significantly improve the efficiency of policy evaluation and decision-making response speed. This study provides important support for the "technical discourse" of this paper, and helps to understand the policy intent of AI embedded in the carbon monitoring system in the Digital Government Guidance (Fan et al., 2025).

Digitization and overall urban climate governance, Global experience shows that digital platforms are often used in governance arenas such as energy management, carbon footprint monitoring, and transportation emissions. While these applications have significantly improved governance efficiency, they have also exposed the challenges of data privacy and the harmonization of technical standards. This logic echoes the frequency with which Chinese policy texts emphasize "standards," "mechanisms," and "systems," raising red flags about the institutionalization of digital pathways.

Climate holistic governance models, Ye et al., (2025) proposed a framework for "China's holistic climate governance", which covers emission reduction, ecological protection, carbon sinks, market mechanisms and other dimensions, emphasizing the systemic nature of policies and government leadership. This provides a holistic perspective for analyzing the synergy between China's policy tools and digital technologies, and lays the theoretical foundation for analyzing the correlation between the various thematic modules (Wang et al., 2025).

Guiding and contrasting international experience, although foreign literature deals with the role of digital pathways in climate governance, the Chinese model possesses scale advantages and administrative efficiency. Comparison of the German smart energy system and the EU carbon market mechanism can reveal differences in the Chinese model's reliance on institutional integration and the way in which technology penetrates, but cross-country comparative studies based on textual analysis are still lacking.

Research space and literature gaps, the above sorting shows that the existing literature generally focuses on the dimensions of institutional acceptance (ideology and economic drive) and technology application mechanisms (AI, digital platforms and urban governance), but there are obvious shortcomings (Fadillah & Huiquan, 2024).

The systematic path of digital technology discourse in the design of policy instruments is not sufficiently established: despite the large number of cases describing the effectiveness of

technology, there is a lack of structured analysis of the synergistic path of "technology-discourse-institutional instruments" based on policy texts. Inter-module correlations are not yet well understood: for example, how technologies diffuse from energy transition to synergistic regional governance, and related mechanisms have not yet developed a harmonized analytical framework. Lack of policy text-based comparisons of Chinese-international digital programs: cross-country comparisons based on policy discourse and tool design have not yet formed a research paradigm.

Through quantitative word frequency analysis and artificial semantic clustering of 48 core policy texts, this study will systematically construct the interpretation paths of technological discourse in policy tools and explore the inter-module linkage mechanisms, thus attempting to fill the gaps in current research in terms of discourse mechanisms, institutional coupling and international comparison.

3. Method

This study selects 48 core climate governance policy documents issued by China's State Council and related ministries and commissions between 2015 and 2024 as the research sample. These policy documents cover multiple aspects of climate governance, including energy transition, low-carbon technologies, ecological protection, market mechanisms, etc., and can comprehensively reflect China's strategic deployment of digital transformation of climate governance. Specific documents include, but are not limited to, the Overall Program for the Reform of the Ecological Civilization System, the Guiding Opinions on Building a Modern Environmental Governance System, and the Opinions on Comprehensively Promoting the Construction of a Beautiful China, etc. These documents are authoritative in terms of policy, comprehensive in coverage, and standardized in text, which provide a solid foundation for the subsequent analyses (Fadillah et al., 2023).

Word frequency extraction and term cleaning, in the text pre-processing stage, this paper adopts KHCoder software to analyze 48 policy documents by automatic word classification and word frequency statistics. In order to improve the effectiveness of terminology analysis, the TF-IDF algorithm was used to initially screen out the first 150 high-frequency words, and manually checked to exclude the more generic administrative verbs such as "advance", "study", "strengthen", etc. The first 150 high-frequency words were initially screened by the DDF algorithm, and after manual checking, the more generalized administrative verbs such as "promote", "research" and "strengthen" were removed. In the end, 120 keywords with professional orientation are retained to provide a vocabulary base for subsequent semantic clustering. Artificial semantic clustering, implementing artificial semantic clustering based on the theoretical framework of policy tools, a two-stage clustering strategy is adopted, resulting in six thematic modules (Fadillah, 2025a).

Stage 1: Association identification, apply the word co-occurrence matrix and word frequency comparison technology to identify keyword combinations with correlation (e.g. "monitoring-data-platform", "standard-mechanism", "carbon emission") to form preliminary word clusters. -Carbon Emission") to form a preliminary word cluster. Stage 2: Thematic categorization, combining the contextual logic of the original policy text and the types of policy tools, the above word clusters are further categorized into six thematic modules, corresponding to the six core dimensions of institutional design, energy transformation, industry synergy, ecological protection, market mechanism and capacity building in China's climate governance. Such clustering methods can reveal the distributional characteristics of digital technology discourse in the semantic structure of policy more accurately and provide structural support for the analysis of the modular evolution of policy tools (Fadillah, 2025b).

Analysis of thematic modules, On the basis of semantic clustering, this paper carries out an in-depth analysis of the six thematic modules, respectively combing the content of keywords, institutional functions and linkages with other modules. The dimensions of the analysis cover the proportion of word frequency, keyword combination characteristics, types of policy tools, institutional embedded logic and other aspects . By comparing and integrating the modules, the internal mechanism of how digital technology discourse is embedded in different policy scenarios and how it promotes the evolution of governance logic is further refined. This methodological framework combines the advantages of quantitative calculation and manual identification to ensure that the analysis results are scientific and retain the contextual features of the policy language. It ultimately realizes the logic of deduction from "keywords-thematic modules-institutional tools" and lays the methodological foundation for the subsequent analysis of conclusions and theoretical refinement (Aripin et al., 2025).

4. Result and Discussion

Policy framework and institutional design

In the module of "policy framework and institutional design", the word frequency analysis shows that the frequency of words such as policy (51), mechanism (53), system (39), planning (37), standard (33), demonstration (33), promotion (27), implementation (37), improvement (41), program (15), measure (19), target (23), formulation (27), strengthening (21), etc. is high, accounting for about 17.4% of all words in China's climate policy. The high frequency of terms such as "development" (27) and "enhancement" (21), accounting for about 17.4% of the total, suggests that the trend of hierarchical and standardized institution building and policy architecture is particularly prominent in China's climate policy. This result shows that the trend of hierarchization and standardization of institutional construction and policy structure is particularly prominent in China's climate policy:

Table 1. Policy framework and institutional design

Policy dimension	High-frequency subject words (word frequency)	word frequency ratio
Policy framework and institutional design	Policies (51), Mechanisms (53), Systems (39), Planning (37), Standards (33), Demonstration (33), Promotion (27), Implementation (37), Improvement (41), Programs (15), Measures (19), Targets (23), Development (27), Strengthening (21)	17.4%
Energy transition and low-carbon technologies	Energy (77), Low Carbon (203), Green (24), Energy Efficiency (47), Technology (150), High Efficiency (20), Retrofit (19), Application (32), R&D (22), Facility (44), Model (16), Solar (20)	25.7%
Synergistic sectoral and regional governance	Industry (32), Agriculture (33), Transportation (35), Buildings (47), Parks (21),	15.0%

Policy dimension	High-frequency subject words (word frequency)	word frequency ratio
	Cities (59), Districts (55), Regions (22), Communities (18), Functional Areas (16), Production (21), Consumption (20), Transportation (15)	
Ecological conservation and climate adaptation	Climate (248), low carbon (203), ecology (67), forests (18), oceans (18), biology (19), water resources (25), nature (19), disasters (30), adaptation (38), conservation (24), species (14)	27.6%
Market mechanisms and international cooperation	Markets (17), Trading (28), Economy (32), Global (20), Finance (15), Guidance (18), International cooperation (40), Carbon trading (53)	8.5%
Monitoring, assessment and capacity-building	Monitoring (18), systems (38), capacity (63), institutions (30)	5.7%

As seen in Table 1, The recurrence of high-frequency words such as "planning", "standards" and "system" shows that the governance system relies on the five-year plan and technical standards to build a closed loop of the system, from the national to the local level, from the top-level design to the concrete implementation of the system. From national to local, from top-level design to concrete implementation. This type of governance structure reflects the inertia of the mechanism of coordinated central-local governance, emphasizing the enforceability and traceability of policies from top-level design to grass-roots implementation.

The high frequency of terms such as "demonstration" and "implementation" suggests a circular logic of "pilot-evaluate-scale". This not only reflects a robust administratively-led model, but also provides a mechanism for technological innovation. This not only reflects a robust administratively-led model, but also provides an experimental stage for technological innovation and reduces the cost of trial and error, and is the main driving mechanism for China's exploration of carbon trading and the construction of smart carbon monitoring platforms.

Strong verbs such as "strengthen" and "promote" appear frequently in the text, reflecting the government's leading role in digital climate governance. The parallel use of incentivizing words suggests that the government is balancing coercive and incentivizing tools in the design of the system. This approach strengthens institutional enforcement while preserving room for market participation, reflecting the delicate balance between authority and flexibility in China's governance model.

The high-frequency words "standards" coexist with "mechanisms" and "targets", suggesting that digital technology has been integrated into the core of institutional design. The policy emphasizes the construction of institutions such as technical interface specifications, carbon emission monitoring standards and data-sharing mechanisms. This not only provides institutional safeguards for the digitalization of governance, but also reflects a technology-based governance path dependency, which is consistent with standardized governance research findings.

Energy transition and low-carbon technologies

The high frequency words in the module "energy transition and low carbon technologies" include: energy (77), low carbon (203), green (24), energy efficiency (47), technology (150), high efficiency (20), retrofit (19), application (32), research and development (22), facilities (44), model (16), solar (20). The percentage of word frequency is 25.7%, which is the module with higher percentage. The specific mechanisms and characteristics are as follows:

First, At the same time, traditional energy technologies such as HF "solar" and "energy efficiency" coexist with technical terms such as "facilities" and "retrofit". The coexistence of traditional energy technologies such as "solar" and "energy efficiency" with technical terms such as "facilities" and "retrofit" reflects China's use of digital technologies as an incremental driver of energy transformation, in tandem with the upgrading of existing technologies. Second, multi-body synergistic governance structure, High-frequency words such as "research and development" and "application" form the technology transformation chain, highlighting enterprises as the main body of technological innovation and the government as the infrastructure investor. This division of labor is in line with the theory of policy instruments and promotes public-private synergy.

Third, Inter-module technology diffusion impacts, the application of digital technology in the energy module also provides a technical basis for regional collaborative governance, such as smart grids and big data-driven regional energy coordination mechanisms, which provide technical support and path extension for subsequent modules.

Sectoral and regional synergistic governance

This module has a word frequency of 15.0% and includes the keywords: industry (32), agriculture (33), transportation (35), architecture (47), parks (21), cities (59), districts (55), regions (22), communities (18), functional zones (16), production (21), consumption (20), and transportation (15), which present the following governance logic:

First, Multi-level spatial governance understanding, keywords such as "park", "city" and "region" appear frequently in the text, forming a nested governance structure to support precise emission reduction and cross-regional collaborative governance. Second, Industry differentiation strategy layout, the keywords corresponding to each industry illustrate the customized governance path of the module's policies: "Industry" represents smart grid transformation, "Agriculture" focuses on climate-smart technology applications, and "Transportation " focuses on connected vehicles and new energy systems. Third, Incorporation of personal behavior into monitoring mechanisms, the vocabulary of "consumption" and "community" reflects the entry of individual carbon behaviors into the digital monitoring system, bringing individual behaviors into the governance landscape. Fourth, technology linkage mechanisms within and outside the module, Intelligent systems introduced from the energy module provide technological conditions for regional synergy; at the same time, regional governance in turn promotes the localized adaptation of energy technologies, forming a closed loop feedback between technology and governance.

Ecological conservation and climate adaptation

This word frequency accounts for the largest proportion of 27.6%, indicating that the state attaches great importance to ecology and climate, including: climate (248), low carbon (203), ecology (67), forest (18), ocean (18), biology (19), water resources (25), nature (19), disaster (30), adaptation (38), protection (24), varieties (14), and other core vocabulary words, showing that the ecological digital governance features:

First, Mechanisms for constructing crisis narratives, terms such as "disaster", "protection" and "adaptation" frame ecological risks, reinforce the legitimacy of digital governance and provide a public opinion base for investing in technical resources. Second, Ecological contradiction adjustment path, the intertwining of "biology" and "variety" reflects the tension between ecological conservation and technological applications (e.g. genetic improvement). Policy attempts to maintain a strategic balance between ecology and technology through discursive negotiation. Third, Cross-module eco-service links, the monitoring mechanisms generated by the technology in the eco-module provide basic environmental information for industry synergies, while supporting the closed loop of ecological feedback for energy and regional governance.

Market mechanisms and international cooperation

The module has a word frequency of only 8.5%, including: market (17), trading (28), economy (32), global (20), finance (15), guidance (18), international cooperation (40), and carbon trading (53), but has a significant impact on institutional pathways and global governance:

First, carbon Market Digital Enablement Pathway, the high-frequency words "trading", "platform" and "market" are linked to "monitoring" and "data", indicating that the policy emphasizes the digitalization of the MRV system to enhance the transparency and efficiency of the carbon market. data", indicating that the policy emphasizes the digitalization of the MRV system to enhance the transparency and efficiency of the carbon market.

Second, dual discourse positioning at home and abroad, foreign relations emphasize "green investment along the Belt and Road" and international cooperation, reflecting China's use of digital technology to export its national governance discourse and realize the expansion of institutional soft power. Third, capital factor integration mechanism, the high-frequency words "finance" and "carbon trading" reflect the intent of market instruments embedded in digital governance, both to serve climate goals and to underpin economic incentives. Fourth, institutional interaction pathways, Digital technology is integrated in carbon market pathways to achieve institutional linkages between mechanism interfaces and standardized processes, but it also places higher demands on local pilot mechanisms.

Monitoring, evaluation and capacity-building

Modules have the smallest percentage of word frequency at 5.7%, including: monitoring (18), systems (38), capacity (63), and institutions (30), yet their role cannot be ignored:

First, sustainable pathways for technology governance, the high-frequency words "monitoring" and "system" highlight the fact that digital governance relies on the construction of technological systems to support capacity-building and to realize synergies between digital governance in the ecological and economic fields. Second, mechanisms for the reconfiguration of intellectual power, "The high frequency of terms such as "capacity" and "institution" suggests that research institutions and universities are enhancing their voice and reshaping their decision-making flows and governance structures through the Big Climate Data Model.

Third, system feedback drive closed loop, the continuous interaction between the monitoring system and the institutional mechanism forms a set of feedback mechanisms that can provide real-time data support for subsequent modules and promote the optimization of closed-loop governance of the system, the industry and the ecology.

Theoretical dimension: strengthening the "technology-discourse-institutional tool" pathway

Taking policy discourse as the entry point, this study integrates digital technologies into the theoretical structure of policy tools, realizing a logical chain analysis from linguistic representation to institutional design. In the module of "policy framework", high-frequency "standard", "pilot" and "monitoring" show the institutional path of digital technology embedded in the governance structure, reflecting the way technology shapes the governance system. In the "Policy Framework" module, the high-frequency "standards," "pilots," and "monitoring" demonstrate the institutional paths through which digital technologies are embedded in the governance structure, reflecting the logic of "path-dependency" in which technologies shape the governance system. This mechanism fills the gap in the description of the mechanism of technological discourse in the current literature, forming a systematic analysis path from "semantics - institutional tools - institutional closed loop".

In addition, the inter-module analysis reveals the diffusion of digital technologies: smart technologies in the energy module promote synergistic regional governance, and the ecological monitoring mechanism enters the energy and carbon markets, suggesting that the digital discourse serves as a mediator linking the modules, promoting the connectivity of institutional pathways and synergization of institutional mechanisms. This internal correlation demonstrates the central role of digital technology discourse in promoting the synthesis of policy structures and enriches the extension of the theory of public policy tools in the new field of climate governance.

Practical dimension: digital governance for governance synergy and pilot mechanisms

Through the mechanism of policy pilots, China's climate governance has accumulated a number of digital governance models, such as smart carbon platforms, climate-smart agriculture and ecological monitoring. These pilots have significant policy feedback and optimization effects at the institutional design level: the policy text shows a closed-loop path of "experimentation-evaluation-expansion" through the word frequencies of "demonstration" and "promotion". The policy text shows a closed-loop path of "experiment - evaluation - expansion" through the words "demonstration" and "replication", forming the institutional replication mechanism of the digital governance platform. This governance path, which is directly embedded in the pilot mechanism through policy discourse, effectively connects policy objectives and technical practices, and provides a model path for other developing countries to follow.

Meanwhile, the module on "market mechanism and international cooperation" shows that digital technology has become the core support for international cooperation and carbon market transparency. This not only shows that digital governance paths have become part of the institutional output structure, but also promotes the competitiveness of the discourse at the institutional output level, which is of strategic significance for enhancing the discourse of national governance.

Evolution of policy instruments: executive-led versus digital intermediaries

The study finds that China's climate governance adopts a combination of "authority-incentive-digital intermediary" policy tools: on the one hand, the authority of policy implementation is established through high-frequency administrative terms such as "regulation", "supervision", "reinforcement", and "promotion"; on the other hand, the authority of policy implementation is established through "demonstration", and the authority of policy implementation is established through "demonstration". On the one hand, high-frequency administrative terms such as "regulation", "supervision", "enhancement", and "promotion" are used to establish the authority of

policy implementation; on the other hand, "demonstration" and "encouragement" are used to build the authority of policy implementation; and "incentives" are used to build the authority of policy implementation. On the other hand, "demonstration" and "encouragement" are used to construct a policy incentive mechanism; and digital technology is used as an intermediary tool for monitoring, evaluating, and operating to support the closed-loop mechanism of policy implementation and evaluation feedback. This combination of tools not only inherits the institutional advantages of the executive-led approach, but also acquires the modern governance capabilities of assessment efficiency and institutional feedback mechanisms through digital technology (Ramadhan et al., 2025).

In addition, the evolutionary path of policy tools has shown a "quantitative-qualitative" trend: from the early reliance on administrative documents and planning indicators, there has been a rapid shift towards data governance mechanisms driven by carbon monitoring platforms, data models and intelligent systems. This change demonstrates the dynamic path of the gradual integration of digital technologies as an integral part of institutional tools in national governance structures.

Implications for developing countries

The study reveals that China has scaled up and replicated its digital governance system in the climate sector through a five-year plan overlaid with a policy pilot mechanism. This path is highly informative, especially for developing countries with similar economic systems and political structures:

First, spatial pilot mechanisms: rapid spillover of mechanisms, experiences and standards through provincial and municipal pilots. Second, institutional path dependency: Embedding technology in institutional governance frameworks using existing political institutional structures. Third, parallelism between top-level institutional design and bottom-level technical practice: synchronizing the construction of policy intentions and practice paths to reduce the disconnect between the system and reality. Therefore, this Chinese model can serve as a paradigm for institutional synergy among developing countries in the digital transformation of climate governance, and promote the broader co-construction of global climate governance.

International perspectives: technology-driven and expanding the influence of discourse

At the international level, China's climate governance practices have been actively disseminated to the outside world through discourse output paths such as the "Belt and Road Green Investment" and the Carbon Market Digital Transparency Mechanism. At the same time, this framework and discourse strategy constitutes an institutional export capacity, which helps to enhance the discourse power in the international rule-making and governance framework. This strategy not only expands the scope of application of policy tools, but also shapes the institutional paradigm of "digital governance" in the competition for discourse power in global governance, which is in line with the trend of global digital governance and has important strategic value.

Challenges and future prospects

Although the study presents pathways and mechanisms for digital technology intervention in governance, it still faces practical challenges: First, (c) timeliness of policy implementation and capacity for implementation: there is a "capacity paradox" between the lack of digital capacity of grass-roots governments and the expectations of centralized policies, which requires increased technical training and resource support. Second, standardization and compatibility issues, the lack

of nationwide standards for big data mechanisms will affect the integration of cross-regional synergistic governance and carbon market mechanisms. Third, data security and privacy risks, the risks of data concentration and exposure in digital monitoring systems have yet to be regulated and improved. Fourth, environmental-technological contradictions, the discursive conflict between "variety improvement" and "ecological protection" in ecology suggests an institutional tension between technology application and ecological conservation.

Future research and policy practice should focus on: improving local implementation capacity, strengthening national standards, and building a national-level digital climate governance platform to promote technology implementation and data security. At the same time, the institutional agenda for ecological protection and technology application should be reconfigured to ensure democratic governance pathways and technological accountability.

5. Conclusion

Through quantitative word frequency extraction, artificial semantic clustering and contextual text analysis, this study systematically reveals the evolution of digital technology discourse and governance mechanism in China's climate governance policies between 2015 and 2024. From the six modules of "policy framework and institutional design" to "monitoring, evaluation and capacity building", we identify that digital technology not only runs through the construction path of policy tools, but also plays a key role in promoting the innovation of policy tools and institutional synergy. In the following, we summarize the core findings and their significance from a multidimensional perspective, and look forward to future research directions and implications for governance practice.

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