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Navigating ecological civilisation: Polycentric environmental governance and policy regulatory framework in China

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ABSTRACT

Amidst global environmental and energy crises, China has institutionalized its Ecological Civilisation as a transformative governance paradigm, synergising multiple policy instruments with environmental modernization. This paper utilises Grounded Theory to systematically analyse 56 environmental policies with significant energy governance components encompassing 510,000 words, identifying three primary categories in China's environmental policy pathways: pollution control, carbon reduction, and green expansion. Further analysis using the Institutional Grammar Tool deconstructs the regulatory components of these pathways. The analysis reveals a tripartite regulatory framework: (1) AIC (Attributes, Aim, Conditions) strategic policy statements (41 % of policies), which establish both implementation flexibility and structured policy experimentation, enabling local governments to adapt and innovate while ensuring the central objectives; (2) ADIC (Attributes, Deontic, Aim, Conditions) normative statements (44 %), balancing market autonomy with state direction; and (3) ADICO (Attributes, Deontic, Aim, Conditions, Or Else) rule-based statements (15 %), enforcing stringent compliance in high-stakes sectors such as fossil fuel industries. The findings demonstrate how China's polycentric governance model strategically calibrates regulatory rigidity and flexibility, challenging conventional dichotomies between command-and-control and market-based approaches. The study advances theoretical debates on modern environmentalism and institutional design while providing actionable insights for environmental and energy policymakers navigating the trade-offs between central stringent regulation and local adaptation and flexibility. By elucidating the textual architecture of environmental regulation, particularly in energy-related policies accounting for a significant portion of China's environmental mandates, this research contributes a novel policy science perspective to environmental and energy governance systems, with implications for both hierarchical and decentralized governance systems.

1. Introduction

Environmental degradation and climate change have emerged as critical global challenges, with energy production and consumption representing their primary drivers [1]. As nations strive to combat these interconnected crises, the need for urgent, comprehensive, and temporally sensitive policy measures—spanning both national and global scales—has become undeniable [2]. The international community has responded with diverse policy frameworks, particularly in renewable energy deployment and fossil fuel phase-out policies, yet their effectiveness hinges on nuanced implementation strategies that account for political and institutional contexts [3]. China's experience offers particularly valuable insights, as the country is the world's largest energy consumer transitioning toward low-carbon systems [4,5].

Recent scholarship has illuminated three political dimensions of China's environmental policy framework: authoritarian environmentalism [6], implementation flexibility [7], and the interplay between Ecological Civilisation discourse and extractive governance [8]. These studies reveal how China's unique political economy shapes policy outcomes [9], though significant gaps remain in understanding the regulatory mechanisms that translate political priorities into implementable measures.

The critical role of environmental regulation as a policy instrument warrants particular examination. Despite extensive economic studies on

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environmental regulation in energy sectors [10–12], critical gaps persist in policy science—particularly in decoding regulatory narratives and designing governance frameworks [13]. This gap is especially pronounced in studies of China's regulatory framework, where most research focuses either on economic outcomes or political narratives, neglecting the structural composition of regulatory provisions within policy texts [14,15]. Understanding how regulations are formally articulated during policy formulation represents a crucial yet overlooked dimension of environmental governance. The inherent complexity of environmental regulation necessitates a systematic deconstruction of its constituent components—encompassing policy goals, requirements, sanctions, and restrictions—all of which are multidimensional and comprise numerous prescriptive statements dictating specific actions under defined conditions [16,17].

Notably, the Institutional Grammar Tool (IGT) provides a robust analytical framework for dissecting these regulatory elements, as evidenced by its extensive application in contemporary policy analysis [18–20]. Within the IGT framework, regulatory configurations can be categorised into three distinct types based on their compositional attributes: (1) AIC statements represent strategic policy formulations that lack both constraining and sanctioning elements [13]. Consequently, they exhibit lower regulatory intensity but afford greater implementation flexibility, enabling adaptive governance tailored to local contexts; (2) ADIC statements are characterized by explicit deontic modalities (e.g., "must"). These statements impose a higher degree of regulatory intensity [17], typically resulting in reduced flexibility, and function as prescriptive directives that narrow discretionary implementation; (3) ADICO statements, as the most stringent regulatory configuration, incorporate not only binding obligations but also explicit sanctions for non-compliance [19]. This design ensures the highest enforceability and compliance rates, reflecting a top-down, rule-based approach to governance. This tripartite configuration elucidates how variations in regulatory design—from flexible strategies to rigid prescriptions—mediate the translation of political priorities into actionable policy measures [21].

Therefore, this study employs Grounded Theory and the IGT to analyse 56 Chinese environmental policies totaling 510,000 words. This research seeks to clarify the pathways of Chinese environmental policymaking and examine the structural configuration of policy regulation within these pathways. Additionally, it explores the underlying mechanisms underpinning environmental policy regulation, making significant contributions to research in three primary areas: (1) It clarifies the range of environmental policy pathways that China has developed, providing a macroscopic and holistic perspective that counterbalances the current overemphasis on micro-approaches in environmental studies. (2) It demonstrates how Grounded Theory and the IGT can be applied to develop a systematic understanding of the constitutive components of regulatory design in environmental policies, thereby extending the methodological scope of research on environmental policy. (3) It constructs and elaborates a theoretical framework for policy regulation based on empirical analyses, offering new insights into public policy and environmental governance theories. These contributions not only deepen the understanding of policy formulation processes in environmental and energy system, but also serve as a crucial reference for governments seeking to enhance their approach to achieving environmental sustainability.

2. Research context

2.1. The political economy of environmental and energy policy in China

China's environmental and energy governance provides a critical case for examining how centralized policy frameworks interact with localized implementation flexibility to drive sustainability transitions. While economic perspectives have dominated much of the literature on environmental regulation [11], a growing body of scholarship has examined the political dimensions of China's environmental and energy policy, particularly its unique blend of centralized authority and localized flexibility [8,9]. This section situates our study within this evolving discourse, synthesizing analyses of the political economy of China's environmental and energy governance while identifying persistent gaps in regulatory design.

Historically, China's development of environmental and energy policies dates back to the enactment of the Environmental Protection Law in 1979, marking the nascent stage of its focus on environmental protection and low-carbon development. Since the 1990s [2], China has progressively introduced more policy initiatives for environmental protection and sustainable development (Fig. 1). The 18th National Congress of the Communist Party of China institutionalized "Ecological Civilisation" as a core environmental framework, embedding sustainability into national development agendas [5,22]. This shift reflects what scholars term a mode of environmental and energy governance where top-down directives coexist with experimental policy implementation [6,7].

Energy governance has long occupied a central position within China's environmental policy framework, serving as both a linchpin and a bellwether for its distinctive approach to sustainability. China's energy transition paradigm, particularly its renewable energy deployment and coal phase-down policies, reveals a polycentric governance model that defies conventional dichotomies between state intervention and market mechanisms. Whereas advanced economies predominantly rely on carbon pricing mechanisms and technology-driven market solutions [23], China has institutionalized a hybrid system characterized by the strategic interplay of top-down national targets and bottom-up provincial policy experimentation [22]. This structural configuration diverges markedly from both India's decentralized renewable energy governance model [24] and the state-led frameworks observed in early-adopting countries like Vietnam and Mexico [25]. Crucially, China's energy transition exemplifies a dual regulatory logic: stringent, rule-based hierarchical controls over fossil fuel sectors coexist with flexible, incentive-laden support for renewable energy development, thereby enabling both policy coherence and regional adaptability [13].

Recent political analyses have illuminated the dynamics of environmental and energy policy enforcement in China's hybrid governance system. For instance, Lo's (2024) work on forest conservation in the Greater Khingan Range demonstrates how local governments negotiate central mandates through "implementation flexibility" [7], adapting rigid policies such as fossil energy consumption quotas to regional socioeconomic realities—a phenomenon that contrasts with the centralized enforcement models observed in Western environmental governance systems [3,6]. Similarly, studies on extractive governance reveal how China navigates Ecological Civilisation discourses and ecopolitics [8], highlighting political trade-offs distinct from the market-driven sustainability transitions documented in the EU and North America [3].

The extant literature systematically deconstructs essentialized representations of Chinese environmental and energy governance regimes by foregrounding their dialectical tension between structural determination and emergent complexity. This tension diverges from the institutional pluralism seen in federal systems yet aligns partially with the "experimentalist governance" approaches noted in EU climate and energy policy [26]. Environmental governance in China [6] combines top-down targets like national renewable portfolio standards with localized adaptation—a hybridity that is less pronounced in Western counterparts where market-based instruments dominate regulatory design. Such comparative insights underscore how China's polycentric model challenges conventional dichotomies between command-and-control and market-based approaches [13], offering a unique institutional alternative to global sustainability governance [2,3]. This regulatory duality is particularly evident in China's dual-track approach to energy governance, where strict controls on coal power coexist with flexible incentives for renewables [22].

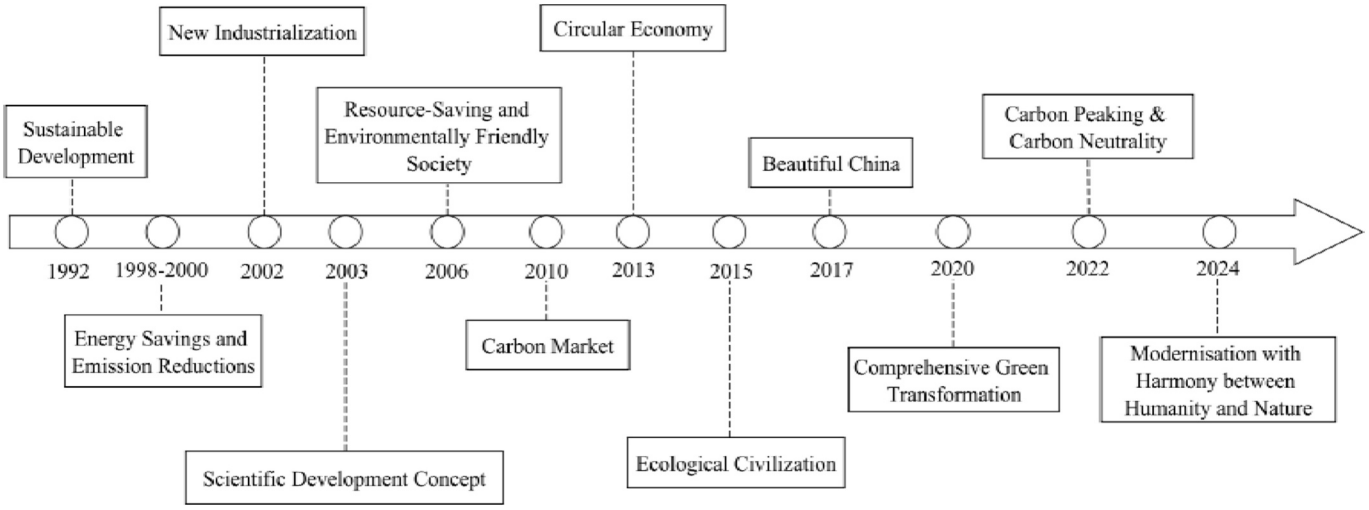

Fig. 1. Key environmental and energy initiatives in China.

However, despite these advances, critical gaps remain in understanding how environmental regulation is formally structured within political institutions or policy texts. While scholars have extensively analysed the economic impacts of environmental regulation or its political legitimation functions, few have systematically deconstructed the institutional and policy architecture of regulatory provisions [13]. This oversight is particularly striking given China's reliance on codified policies to steer governance outcomes. As Lo (2024) notes [7], even flexible implementation hinges on the design of environmental policies—yet the compositional logic of these policy texts remains underexplored. On a deeper level, while the politics of China's environmental and energy governance are well-documented, the policy science of its regulatory design remains nascent. Our analysis bridges this divide, demonstrating how policy textual codification mediates between central political intentions and local governance outcomes—a crucial yet overlooked dimension in current research.

2.2. Environmental regulation expressed through policy perspective

Environmental problems are often characterized by negative external effects, necessitating robust policy regulation to address these challenges effectively [27,28]. Policy regulation, in this context, involves the strategic use of regulatory instruments within environmental policies, such as renewable portfolio standards and energy efficiency benchmarks, to ensure compliance by targeted entities. These instruments, commonly referred to as environmental regulation, consist of a series of provisions designed to mitigate carbon emissions and pollution [29,30].

Scholars have typically classified environmental regulation into two main types: command-and-control and market-based regulations [12,15,31]. Command-and-control regulations mandate specific measures such as coal plant emission standards and technological specifications, while market-oriented regulations incentivize sustainable practices through mechanisms like green electricity trading and emission fees.

Despite the type, environmental regulation has significantly contributed to mitigating carbon emissions and pollution, supporting green transformations, and fostering sustainable development [10,14,32]. A notable framework for understanding the impact of environmental policy on economic performance is the "Porter hypothesis", which suggests that environmental regulation can enhance economic performance by stimulating efficiency and innovation [33]. This hypothesis argues that environmental regulations prompt enterprises to modify production routines, which can lead to reduced costs and increased resource efficiency [11]. Empirical studies have consistently supported this view, demonstrating that environmental regulation positively affects enterprise performance, market competitiveness, and economic advancement [34,35]. Furthermore, environmental regulation often drives innovations in materials, technology and products, which are crucial for achieving a sustainable environment and energy transition [36,37].

However, while existing literature extensively analyses the economic impacts of environmental regulation, it seldom explores these regulations from the perspective of policy formulation, instead mostly focusing on analysing its impacts on development, performance, efficiency, productivity, competitiveness, and innovation. More importantly, according to our investigation, there is a lack of academic research that empirically investigates how environmental regulation is considered during the policy design process through the encoding and deconstruction of policy texts [13].

To bridge this gap, this study employs the Grounded Theory and the IGT to first encode and then systematically deconstruct the regulatory components of China's core environmental policy pathways. This research aims to explain the underlying mechanisms of environmental policy regulation in China, contributing a novel perspective to the field of policy science and environmental governance. It provides essential insights for both theorists and practitioners focused on the dynamics of policy pathways and regulatory frameworks in sustainable environmental initiatives and energy transition.

3. Materials and methods

3.1. Materials

This research involved an in-depth analysis of 56 formal documents (Appendix I), representing a comprehensive range of environmental policies in China, with significant energy governance components, which collectively encompass 510,000 Chinese words. To ensure exhaustive coverage and strong representativeness, this study employed a rigorous data collection methodology that integrated comprehensive sampling with a multi-source retrieval strategy, thereby systematically capturing the full spectrum of China's national environmental policy landscape (Fig. 2).

The initial phase of document acquisition involved systematic retrieval of environmental policy instruments from authoritative government databases, most notably the Central Government Policy Database (https://www.gov.cn/search/zhengce/), with the collection period extending through November 2024 to encompass the complete

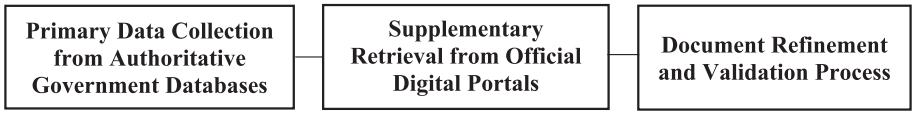

Fig. 2. The three-stage process for policy collection and identification.

trajectory of environmental policy evolution following China's national strategic objectives toward Ecological Civilisation.

To augment the primary dataset and ensure comprehensive policy coverage, the study incorporated supplementary queries through China's official governmental portals at the national level, which represent the most authoritative policy compilations within state institutions. This secondary collection phase facilitated critical cross-validation of documents through systematic comparative analysis, thereby significantly enhancing both the reliability and completeness of the assembled policy corpus.

The final methodological stage implemented a sophisticated filtering mechanism to isolate environment-specific policy instruments, incorporating two key refinement processes: (1) multi-level content analysis employing semantic and contextual evaluation frameworks to distinguish between superficial terminological matches and documents containing substantive policy interventions, with assessments conducted at lexical, discursive, and normative levels to ensure comprehensive evaluation of each document's alignment with core environmental objectives; (2) systematic keyword optimization utilizing the China National Knowledge Infrastructure (CNKI) platform, whose advanced semantic search algorithms enabled dynamic expansion of the initial keyword set through identification of conceptually related terms within China's unique policy discourse [38]. This comprehensive document refinement and validation process ensured that the final document set achieved both exhaustive coverage and precise alignment with the study's analytical focus on environmental governance.

The tripartite methodology described herein represents a significant methodological advancement in policy document collection techniques, particularly for studies examining complex, evolving policy systems, as it establishes a new standard for comprehensiveness in environmental, energy, and climate policy research through its innovative integration of direct governmental sources with validated academic repositories and implementation of robust validation protocols.

3.2. Methods

This research employs two qualitative approaches: Grounded Theory and the IGT as depicted in Fig. 3. Grounded Theory is particularly adept at encoding policy texts, allowing for a rigorous delineation of China's environmental policy pathways. Following this initial analysis, the IGT is used to dissect the regulatory elements within these pathways. This dual-method approach facilitates a detailed examination of the theoretical underpinnings of policy regulation within the context of China's environmental policies.

(1) Ground theory: Clarifying environmental policy pathways

Ground theory, a qualitative research methodology, was originally developed by the sociologists Glaser and Strauss in 1967 [39]. This method involves three key procedures: open coding, axial coding, and selective coding. These steps are designed to iteratively generalize data, extracting conceptual insights that lead to the development and elucidation of a comprehensive theory [40]. Due to its structured yet flexible coding processes, Grounded Theory is extensively applied across various fields within the humanities and social sciences, including management, education, psychology, sociology, and policy studies [13,41,42]. Specifically, in the realm of public affairs, practitioners utilise Grounded Theory to deepen their understanding of intricate governance and policy dynamics [42,43]. In this research, Grounded Theory is applied through a structured, methodical approach involving three distinct coding stages [44].

(1) Open coding is used to categorise statements from the environmental policy texts that directly pertain to policy pathways, identifying original categories. The initial phase involved line-by-line analysis of policy texts to identify original categories capturing discrete initial concepts (e.g., "energy efficiency audit system"). These emergent codes were transcribed verbatim to retain their original meaning, with constant comparative analysis used to refine the original categories [13]. For example, the initial concepts including "energy efficiency audit system" and "energy efficiency audit report" yielded the original category "energy efficiency audit".

(2) Axial coding focuses on integrating and refining these original categories into main categories through detailed textual analysis, contextual interpretation, and identification of inter-category relationships (e.g., grouping original categories such as "energy efficiency audit" and "energy budget" into the main category "control of total energy consumption and intensity"). This phase employed paradigm modeling to map causal conditions, strategies, and outcomes, ensuring logical coherence between hierarchical levels [41].

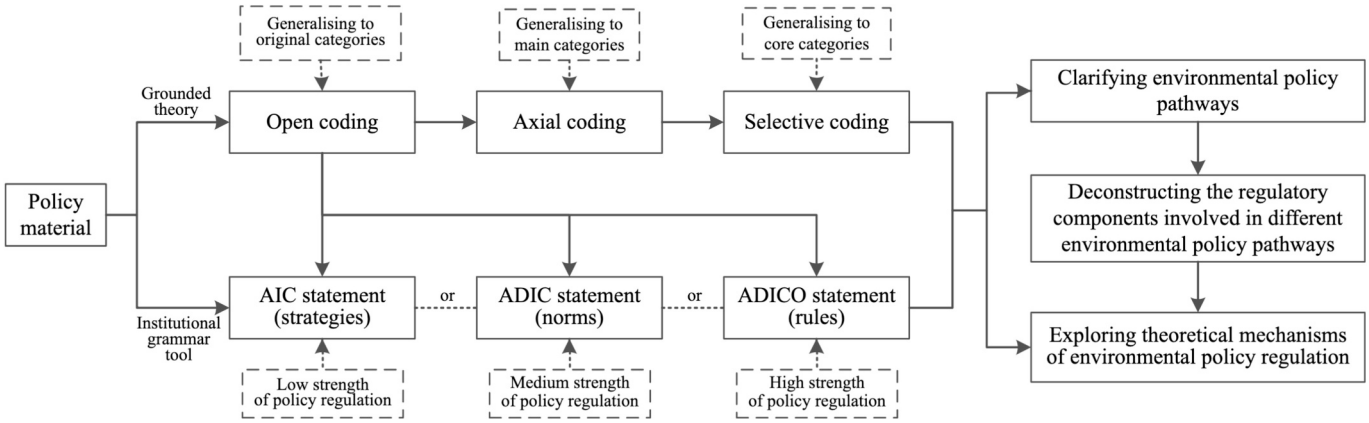

Fig. 3. Roadmap for research methodology.

(3) Selective coding, examines the interconnections among these main categories to establish the core category framework for understanding the environmental policy pathways. In this study, theoretical integration distilled main categories into three core categories constituting China's environmental policy pathways.

The threefold coding process reached conceptual saturation upon examination of 85 % of policy samples, with the remaining 15 % yielding no additional categorical developments or novel interconnections [42,45]. To address potential analytical subjectivity, a 20 % stratified random subset underwent independent evaluation by three domain specialists. Inter-rater consistency was measured via Krippendorff's alpha coefficient ($\alpha = 0.91$), comfortably surpassing the established 0.80 benchmark for reliable consensus [46,47]. This analytical measure was preferred to Cohen's kappa owing to its enhanced applicability for studies involving multi-coder (three coders versus kappa's two-rater limitation) and datasets containing multifaceted classification systems [47,48].

Given the substantial corpus of 510,000 words drawn from environmental policy documents in this study, it is methodologically imperative to clarify that policy coding was selectively applied only to text segments explicitly addressing defined environmental policy pathways [13]. This targeted approach ensures analytical precision by excluding content lacking specific policy prescriptions. For example, consider the original policy statement, "Implement dynamic adjustments to the energy budget management plan for this region". This statement explicitly pertains to the specific policy approach of "energy budget" and is thus selected for coding in this research. In contrast, the policy statement "it is necessary to strengthen ecological environmental protection in an all-round, all-territorial and all-process manner" does not specify a particular environmental policy pathway. As a result, it is not included in the encoding process for this study.

(2) **IGT: Deconstructing environmental policy regulation**

Grounded Theory, with its robust coding capabilities, initially clarifies the pathways within China's environmental policies. Building upon this foundational work, this research employs the IGT, originally developed by Crawford and Ostrom in 1995 and subsequently refined by Basurto et al. (2010) and Siddiki et al. (2011; 2022) [18,20,49,50]. The IGT is a critical component of the Institutional Analysis and Development (IAD) framework, which analyses institutional and policy texts by breaking down each statement into grammatical components. This tool is widely utilised to analyse policy regulation [17], and is effective in deconstructing the regulatory components within policies, helping to evaluate the compliance levels of policy implementers and the overall efficacy of governance [21,51]. IGT analysis invovles 5 elements (A, D, I, C, O): Attributes (A): Represents the actor responsible for executing the policy action. This could be an individual or a collective entity like governments, NGOs, or enterprises. Deontic (D): Indicates the prescriptive nature of the policy action, detailing obligations, permissions, or prohibitions through terms such as 'must (not)', 'should (not)', or 'may (not)'. Aim (I): Describes the primary action or objective mandated by the policy. Condition (C): Defines the circumstances under which the policy action applies, including procedural, temporal, spatial, and other contextual details. Or Else (O): Outlines the consequences or sanctions for non-compliance with the policy.

In this study, each statement within the Chinese environmental policy documents was categorised based on these components into AIC strategies, ADIC norms, or ADICO rules [20], facilitating a nuanced understanding of policy regulation within different environmental pathways: (1) AIC configurations include Attributes, Aim, and Condition but lack Deontic and Or Else, resulting in strategic guidance with greater implementation flexibility but weaker regulatory stringency [13]. (2) ADIC configurations add a Deontic component, increasing normative pressure and compliance incentives compared to AIC [17]. (3) ADICO configurations incorporate all five elements, including explicit sanctions (Or Else), making them the most binding and enforceable regulatory form with the highest compliance rates [19]. This methodical classification underscores the varied nature of policy regulations and their implications for enforcement and compliance within environmental governance.

Employing the IGT methodology, we systematically deconstructed each policy statement into its five constituent elements (A, D, I, C, O) to precisely classify its regulatory configuration as either an AIC (strategy), ADIC (norm), or ADICO (rule) formulation [19–21]. For example, a typical ADIC statement in China's environmental policy declares, "All regions should comprehensively strengthen the coordination and integration of work related to addressing climate change and eco-environmental protection……to promote the modernisation of the eco-environmental governance system and governance ability" (Table 1). In this statement, the Attribute (A) is "all regions," the Deontic (D) is "should," the Aim (I) involves promoting the modernization of the environmental governance system and enhancing governance capabilities, and the Condition (C) specifies the need to strengthen coordination and integration of related activities. Although the ADIC framework is classified as a normative instrument due to its prescriptive character, its lack of explicit sanctions or consequences for non-compliance reveals a degree of regulation deficiency. This design feature, while potentially attenuating formal compliance rates, simultaneously enhances market autonomy, reflecting China's environmental governance approach that strategically balances state regulation and local adaption [52].

To enhance the validity and reliability of the IGT methodology used in this study, the research team implemented a commonly used reliability test in academic research [19]. This involved three researchers independently deconstructing China's environmental policies. Any discrepancies in their analyses were addressed through collaborative brainstorming sessions until a consensus was achieved, ensuring the robustness of the findings.

Table 1
Three categories and examples of policy statements deconstructed by IGT.

Categories	Examples
AIC statement (Strategy)	"All regions improve the fiscal, taxation, financial, investment and price policies and standard systems that support green development." A: All regions; I: Improve the fiscal, taxation, financial, investment and price policies and standard systems; C: Support green development.
ADIC statement (Norm)	"All regions should comprehensively strengthen the coordination and integration of work related to addressing climate change and eco-environmental protection …… to promote the modernisation of the eco-environmental governance system and governance ability." A: All regions; D: Should; I: To promote the modernisation of the eco-environmental governance system and governance ability; C: Strengthen the coordination and integration of work related to addressing climate change and eco-environmental protection.
ADICO statement (Rule)	"All regions should strengthen the control of carbon emissions target responsibility, and listed as an important element of the eco-environment assessment system, …… local officials who fail to fulfill their targets will be summoned for a regulatory talk." A: All regions; D: Should; C: Listed the control of carbon emissions target responsibility as an important element of the eco-environment assessment system; I: Strengthen the control of carbon emissions target responsibility; O: Be summoned for a regulatory talk.

3.3. China's three-pillar framework for environmental policy pathways: pollution control, carbon reduction, and green expansion

This study employs a rigorous three-phase qualitative coding methodology to systematically clarify China's environmental policy pathways, progressing from broad thematic identification to precise core categorisation (Table 2).

First, the open coding procedure was systematically employed to inductively derive the fundamental original categories inherent in China's environmental policy framework.

Second, axial coding serves to identify and articulate the connections and underlying logic among the initially identified categories [44]. This phase focuses on consolidating these original categories into more cohesive and structured groups, enhancing their clarity and analytical utility [42]. During this process, the study maintains close adherence to the original environmental policy statements, ensuring that the refinement of categories remains grounded in the actual policy text. Specifically, the study aggregates the diverse original categories into 25 main categories, during which the meanings of the initial texts are meticulously examined to preserve the accuracy and scientific integrity of the categorisation process.

Third, selective coding is the final stage where the main categories are analysed to establish their interconnections and then integrated into distinct core categories [40]. This detailed examination helps to distill the extensive data into more focused groups that represent the central themes of the research [43]. Through this analytical process, this study successfully clarified three pivotal core categories: pollution control, carbon reduction, and green expansion, which are comprehensively listed in Table 2.

Table 2
Results of axial coding and selective coding.

Original categories	Main categories	Core categories
Urban black-smelling water governance, Industrial park sewage remediation, Rural water protection, Drinking water quality enhancement, Groundwater pollution prevention, River water pollution control, Lake water pollution control, Investigation of river (lake) sewage outfalls, Sea water pollution control	Water pollution prevention and control	Pollution control
Ozone pollution control, vehicle emission pollution prevention and control, dust control, catering pollution control, straw burning prevention and control, noise pollution control, hydrofluorocarbon management	Air quality improvement initiatives	
Soil pollution risk control, agricultural Pollution prevention and control, Construction land pollution control, Waste-free city construction, Solid waste governance, Heavy metal pollution control, New pollutants prevention and control	National territory pollution prevention and control	
Government environmental information disclosure, Enterprise environmental behaviour rating information, Pollution information access, Pollution information disclosure time limit, Pollution information disclosure channels, Pollution information disclosure methods	Information disclosure system of pollution	
Full coverage supervision of pollution sources, Full process supervision of pollution sources, Full closed-loop supervision of pollution sources, Full trace supervision of pollution sources, Automatic monitoring equipment for pollution sources, Monitoring technology innovation for pollution sources	Supervision of pollution sources	
Pollution discharge licence, Hierarchical management of pollution permits, Classified management list of pollution permits, Unified code management of pollution, National Pollution Permit Management Information Platform, Pollution permit implementation reporting system	Pollution discharge permit system	
Chemical oxygen demand, Sulphur dioxide, Soot, Industrial dust, Petroleum species, Cyanide, Arsenic, Mercury, Lead, Cadmium, Hexavalent chromium, Industrial solid waste (12 major pollutants)	Control of total pollution discharge	
Collection of pollutants charges, Use of pollutants charges	Charges for pollutants	
Environmental impact assessment, Socioeconomic impact assessment, Red line for ecological protection, Bottom line for environmental quality, Top line for resource utilisation, Inventory system of environmental access	Classified and hierarchical control of eco-environment	
Energy-saving and carbon reduction industry, Environmental protection industry, Resource recycling industry, Green and low-carbon transformation of energy, Ecological protection, restoration and utilisation, Green upgrading of infrastructure, Green services	Green industry development	

(continued on next page)

4. The tripartite regulatory framework of China's polycentric governance model

The following section explores several critical aspects of this study and its analysis: (1) the deconstruction of environmental policy regulation, (2) the theoretical foundations and governance implications of tripartite regulatory framework (AIC—ADIC—ADICO): specifically, AIC strategic statements concerning implementation flexibility and local experimentation; ADIC normative statements regarding state guidance and market autonomy; and ADICO rule-based statements pertaining to hierarchical control and stringent regulation, thereby providing comprehensive theoretical and empirical insights into these distinct regulatory configurations within environmental policy architecture.

4.1. Deconstruction of environmental policy regulation

Following the original categorisation through Grounded Theory's open coding, this research applied the IGT to further analyse the environmental policy texts. This secondary analysis involved dissecting the policy statements to extract and define the five key components: Attributes (A), Deontic (D), Aim (I), Condition (C), and Or Else (O). These components were then categorised into three distinct regulatory configurations: AIC, ADIC, and ADICO, which structure the complexity of policy regulation [21].

In total, the comprehensive process of coding and deconstructing the regulatory elements was applied to a corpus of 56 policy documents, encompassing 510,000 words, with the findings summarized in Table 3. Here it can be seen that China's environmental policy statements are dominated by ADIC normative statements (930, with 44 %), followed by AIC strategic statements (866, with 41 %), while ADICO rule-based statements are the fewest, with only 316, with 15 %. In this analysis, the relatively few AIC strategic statements suggest a shift in China's environmental policy design—from previously ambiguous strategies to more defined normative statements. The presence of the Deontic (D) component in ADIC statements introduces explicit constraints and obligations, thereby increasing the likelihood of regulatory compliance

Table 2 (*continued*)

Original categories	Main categories	Core categories
Control of total carbon emissions, Control of carbon emission intensity, Carbon assessment, Industrial carbon control, Enterprise carbon control, Project carbon evaluation, Carbon footprint, Carbon labelling	Control of total carbon emissions and intensity	Carbon reduction
Inventory management, Window guidance, Spot governance, Admission conditions, Differential tariffs, Normalised regulation, Transformation of high-emission industries	Control of high emission industries and projects	
Governance of dual-control targets for energy consumption, Fossil energy consumption, Energy budget, Energy efficiency audit, Multi-disciplinary interface with dual-control of energy consumption, Target warning	Control of total energy consumption and intensity	
Specialised actions to reduce and replace fossil energy consumption, Control of fossil energy in key industries, Control of total coal consumption, Reduction of non-electricity coal consumption, Low-carbon transformation of coal power plants, Control of new smelting capacity.	Control of fossil energy consumption	
Wind energy, Photovoltaic solar energy, Hydropower projects, Offshore wind power, Biomass energy, Hydrogen energy, Pumped storage, New energy storage, Distribution grid renovation to match new clean energy	New clean energy development and utilisation	
Direct air carbon capture, Carbon recycling, Point source carbon capture and storage, Carbon verification mechanism, Biological carbon capture, utilisation and storage (Bio-CCUS), Ecological carbon capture, utilisation and storage (EcoCCUS), Commercialisation of CCUS, Industrialisation of CCUS	Carbon capture, utilisation and storage (CCUS)	
Green factory, Clean production, High-efficiency decarbonisation technologies, Catalytic conversion technologies, High-efficiency low-emission technologies, Ultra-low emission technologies, Whole chain technologies of new energy 'production-storage-transmission-utilisation', Ecological carbon sink technologies	Carbon reduction science and technology innovation	
National carbon trading system (ETS), China certified emission reductions (CCER), Energy saving trading system, Electricity market, Energy rights trading system, Green power certificate trading system	Carbon markets	
Carbon tax, Carbon fund, Carbon credit, Carbon bond, Carbon insurance, Carbon subsidy, Carbon guarantee, Carbon trust, Carbon discount	Carbon finance	
Zero-carbon cities, Zero-carbon economic development zones, Zero-carbon industrial parks, Zero-carbon chemical parks, Zero-carbon factories, Zero-carbon roads, Zero-carbon harbours, Zero-carbon communities, Zero-carbon campuses, Zero-carbon businesses, Zero-carbon villages	Zero-carbon pilots	
National-level nature reserves, Local-level nature reserves, Natural ecosystem protection, Rare and endangered wildlife distribution areas, Natural monuments protection areas	Construction of nature reserves	Green expansion
Biodiversity survey, assessment and monitoring, In situ conservation of biodiversity, Relocation conservation of biodiversity, Rational use and benefit sharing of biological genetic resources, Management of invasive alien species, Management of GMO safety, Scientific research on biodiversity, Mechanisms and partnerships for public participation on biodiversity	Biodiversity conservation	
Landscape areas, ecological reserves, geoparks, historical preservation areas, recreational areas, scientific research areas	Construction of national parks	
Atmospheric environment restoration, Water environment restoration, Soil environment restoration, Solid waste environment restoration	Ecological environment restoration	
Mountains, Water, Forests, Fields, Lakes, Grasses, Sand, Ice, Mines, Land, Sea, Plantations	Greening of the whole national territory	

among policy implementers [17]. However, the most effective regulatory framework appears to be the ADICO statements, which include clear accountability and sanctions for non-compliance, representing the stringent model for policy enforcement [53]. The stringent nature of ADICO configurations offers the highest level of regulatory strength and compliance from those implementing the policies [54].

4.2. The tripartite regulatory framework: theoretical foundations and governance implications

The systematic deconstruction of China's environmental policy pathways reveals three distinct regulatory models—AIC (strategic), ADIC (normative), and ADICO (rule-based)—each serving unique governance purposes. These models reflect deliberate design choices tailored to different governance contexts, actors, and policy stages, rather than a hierarchy of effectiveness. Grounded in the IGT [54], these configurations align with China's polycentric governance paradigm, where rigidity and flexibility are strategically balanced [7].

The polycentric governance paradigm enables China to address complex environmental challenges through differentiated approaches (Fig. 4). First, the AIC model, which lacks deontic and sanction components, prioritizes guidance over coercion and is often designed for local adaptation and flexibility. This strategic flexibility proves particularly valuable for policy implementation in contexts where local conditions vary significantly [55]. Second, the ADIC model, with deontic but no sanctions, directs market actors through economic incentives (e.g., carbon markets). The emerging sectors like renewable energy benefit from ADIC's normative guidance that encourages market innovation and autonomy while maintaining policy direction [13]. Third, the ADICO model, with full components, imposes hierarchical control and stringent regulation, particularly targeting carbon-intensive sectors like fossil fuel extraction (e.g., coal mining) and primary steel production. It establishes explicit compliance boundaries and sanction mechanisms [56].

This tripartite framework challenges conventional dichotomies between "command-and-control" versus "market-based" regulation [12,31]. Instead, it demonstrates what van der Heijden and Hodge (2021) identifies as "smart regulation"—the contextual application of regulatory pressure [57]. This conceptual framework aligns with China's Ecological Civilisation paradigm, which advocates for differentiated governance approaches that simultaneously address

Table 3
Coding and deconstruction results based on Grounded Theory and IGT.

Core categories	Main categories	Deconstruction results of policy statements from IGT		
		AIC strategic statements	ADIC normative statements	ADICO rule-based statements
Pollution control	Water pollution prevention and control	41	49	16
	Air quality improvement initiatives	42	51	18
	National territory pollution prevention and control	34	39	14
	Information disclosure system of pollution	28	32	13
	Supervision of pollution sources	36	41	16
	Pollution discharge permit system	38	45	13
	Control of total pollution discharge	35	43	12
	Charges for pollutants	34	39	11
	Classified and hierarchical control of eco-environment	39	47	13
	Green industry development	32	35	9
Carbon reduction	Control of total carbon emissions and intensity	41	40	23
	Control of high emission industries and projects	42	46	19
	Control of total energy consumption and intensity	37	38	21
	Control of fossil energy consumption	36	37	20
	New clean energy development and utilisation	43	35	12
	Carbon capture, utilisation and storage (CCUS)	19	24	8
	Carbon reduction science and technology innovation	28	33	15
	Carbon markets	34	36	8
	Carbon finance	46	48	9
	Zero-carbon pilots	26	30	7
Green expansion	Construction of nature reserves	26	22	8
	Biodiversity conservation	29	25	9
	Construction of national parks	18	21	5
	Ecological environment restoration	39	39	9
	Greening of the whole national territory	43	35	8
Total (percentage)		866 (41 %)	930 (44 %)	316 (15 %)

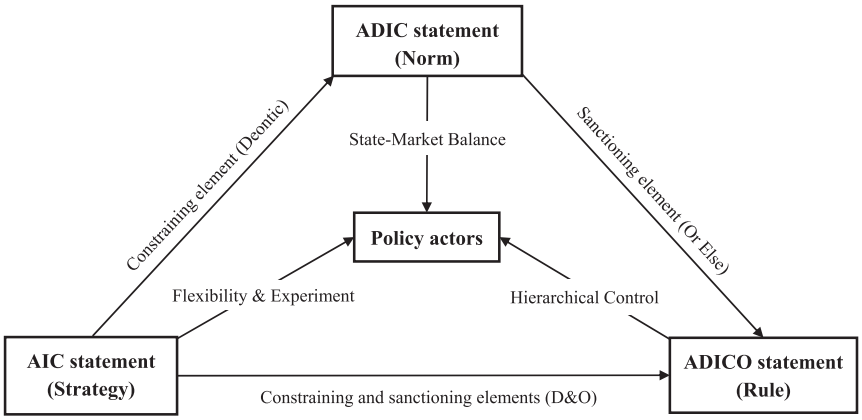

Fig. 4. The tripartite regulatory framework of environmental policy.

environmental protection, economic development, and social stability, while calibrating to local ecological and socioeconomic contexts [5].

This framework finds concrete application in major national initiatives such as the Yangtze River Economic Belt (YREB), where the interplay of regulatory types addresses complex energy transition challenges: (1) The AIC strategic policies are exemplified by the YREB's distributed renewable energy development plan. The policy requires municipal governments to achieve significant renewable energy penetration within a specified timeframe, while permitting flexible implementation pathways. This enabled Jiangsu to focus on industrial rooftop solar integration, while Sichuan prioritized small hydropower development—both fulfilling central mandates through locally optimized strategies that accounted for regional resource endowments [58]. (2) The ADIC normative statements govern energy transition, exemplified by the YREB's coal consumption control policy. The policy requires provinces to meet coal-use reduction targets, while allowing regional discretion in implementation. Jiangsu achieved this through distributed energy systems, while Sichuan leveraged hydropower integration—each adapting to local resource endowments under unified national standards. (3) The ADICO rules enforce critical energy thresholds, as demonstrated by the "Ultra-Low Emission Reform" mandate for coal-fired plants [59]. The policy compels plants along the Yangtze to install scrubbers by set deadlines, with statutorily prescribed sanctions and mandatory shutdowns for non-compliance. This achieved substantial reductions in particulate emissions from covered plants during the implementation period, demonstrating ADICO's effectiveness in high-stakes energy sectors.

The empirical evidence substantiates the theoretical significance of this tripartite framework through its calibrated flexibility continuum. Specifically, AIC policies formalize institutional niches for localized innovation, while ADIC norms mediate between state-mandated regulation and market-based incentives. ADICO rules, in turn, codify non-negotiable thresholds—collectively constituting an operational paradigm of "tiered polycentrism". This configuration empirically problematizes the presumed trade-off between centralized standard-setting and decentralized implementation in sustainability transitions, particularly within the energy-environment governance nexus [13].

(1) **AIC strategic statements: Implementation flexibility and local experimentation**

The AIC's omission of deontic and sanction elements represents a flexible governance mechanism that aligns with Ostrom's (2005) principle of institutional diversity in polycentric systems [60]. This design choice facilitates what Kostka (2016) identifies as China's "command without control" in environmental governance—a process where central authorities establish strategic priorities while subnational actors retain operational flexibility [61]. Our analysis of ecological environment restoration policies (Table 3) reveals how AIC frameworks accommodate regional disparities through China's calibrated decentralization in environmental policy implementation. For instance, in the Yangtze River Economic Belt, AIC-based soil remediation guidelines enabled Jiangsu Province to prioritize industrial brownfield rehabilitation while Yunnan adapted protocols for agricultural land restoration. This empirical evidence substantiates the argument about contextualized sustainability transitions in the process of environmental governance.

The AIC configuration also serves as essential tools for fostering experimental governance, innovation and accommodating regional diversity. The flexibility of AIC proves particularly advantageous during policy experimentation phases. Their strength lies in enabling context-sensitive implementation, particularly valuable in China's vast and heterogeneous territory. For instance, China's low-carbon city and green finance pilots extensively employed AIC statements to encourage local innovation and experiment while monitoring outcomes for potential scaling [55,62]. This approach generated valuable insights about effective experiments before they are extended to binding regulations across the whole country. This mirrors "experimental governance" [26], where central governments set broad goals while localities devise implementation specifics.

The AIC framework's theoretical contribution lies in its innovative reconciliation of central steering with local discretion, offering a distinct model of environmental governance that transcends traditional command-and-control and market-based paradigms. By systematically omitting deontic and sanction elements, AIC configurations operationalize what Ostrom (1992) conceptualized as "crafting institutional" in complex governance systems [63]. This approach has enabled China to achieve "directed innovation", where national environmental objectives are pursued through contextually-adapted local solutions. Furthermore, AIC's contribution to global governance emerges through its demonstration of how experimentalist approaches can function within hierarchical political systems [64], challenging the Western-centric assumption that environmental federalism requires democratic decentralization. The framework's capacity to generate policy learning is exemplified by China's photovoltaic poverty alleviation programme, where AIC-enabled local experimentation in Anhui and Gansu provinces yielded various distinct implementation models before national standardization [65].

Notably, the AIC framework's flexibility comes with notable trade-offs, particularly in accountability and equity. First, the absence of binding deontic elements creates accountability gaps, for example, some cities in the Blue Sky campaign achieved targets through temporary measures rather than systemic reforms. Second, its reliance on local implementation capacity often widens regional disparities. These structural weaknesses suggest the need for complementary accountability mechanisms and capacity-building support to ensure equitable policy outcomes.

(2) **ADIC normative statements: Balancing state guidance and market autonomy**

ADIC's inclusion of deontic but not sanctions balances prescription with market autonomy. ADIC embodies market-incentivized regulation, bridging the "Porter Hypothesis" and political economy critiques [9,33]. Its prevalence signals China's shift from administrative command-and-control to negotiated governance. This model prevails in market-oriented policy frameworks like green electricity trading, where participation is driven by economic incentives rather than regulatory coercion. A case in point is China's green electricity trading mechanism, which leverages ADIC norms to encourage voluntary renewable energy transactions through market-based rewards, avoiding punitive default measures.

ADIC configurations have emerged as China's primary tool for market-based environmental governance. Their strength lies in creating predictable business environments while preserving corporate innovation capacity. The green electricity trading market development provides a compelling example, where ADIC statements established trading frameworks while allowing firms flexibility in compliance strategies [13]. The normative nature of ADIC proves particularly effective in technology-intensive sectors. China's renewable energy policies extensively use ADIC to guide industry development without stifling technological innovation [66]. This approach contributed to China's global leadership in solar panel and electric vehicle manufacturing.

The ADIC framework represents a sophisticated institutional innovation in market-based environmental governance, making significant theoretical and practical contributions. Theoretically, it operationalizes what van der Heijden and Hodge (2021) term "smart regulation" [57] by combining state guidance with market autonomy, effectively bridging the Porter Hypothesis with political economy realities. This hybrid approach has enabled China to achieve "regulated flexibility" in its green electricity trading system, where ADIC norms established mandatory participation frameworks while allowing firms to develop innovative compliance strategies. The model's practical value is evidenced by China's renewable energy sector, where ADIC-based policies guided the photovoltaic industry's explosive growth while maintaining technological diversity. Furthermore, ADIC configurations exhibit significant institutional adaptability, enabling effective coordination of power plants within China's national green electricity trading framework. By flexibly incorporating regional pilot disparities, this mechanism operationalises the synergistic equilibrium between state-mandated targets and market-driven autonomy.

However, the ADIC model may exhibit two weaknesses that could constrain its effectiveness: (1) The framework's reliance on voluntary adherence proves challenging in institutional environments with limited regulatory capacity, as evidenced by notable non-compliance cases among small enterprises in Guangdong's carbon market. This reflects structural difficulties in enforcing standards without robust sanctions. (2) The model's market-based approach creates uneven participation patterns, with state-owned enterprises demonstrating substantially higher engagement levels than private firms, highlighting systemic implementation biases across different ownership structures. These limitations suggest that ADIC configurations require strengthened monitoring capacities and graduated enforcement mechanisms to fulfill their governance potential, particularly in sectors with low profit margins and high compliance costs.

(3) **ADICO rule-based statements: Hierarchical control and stringent regulation**

The ADICO model represents the most stringent regulatory configuration in China's environmental governance, combining clear Attributes (A), obligatory Deontic (D), specific Aim (I), contextual Conditions (C), and explicit Or Else (O) sanctions. This approach is particularly effective in high-stakes sectors like heavy industry pollution control and carbon intensity reduction, where lax enforcement could derail national targets. The integration of environmental performance into the cadre evaluation system (e.g., the "One-Vote Veto") illustrates ADICO's hierarchical control function [67]. By linking sanctions to career advancement, ADICO aligns local implementation with central mandates, mitigating the principal-agent problem common in decentralized governance [68].

The ADICO model embodies stringent regulatory mechanisms within a hierarchical framework, ensuring that policy objectives are met with rigor and accountability. Unlike flexible approaches (AIC) or market-based incentives (ADIC), ADICO's strong enforcement component is designed to address the complexities of environmental governance in heavily polluting, energy-intensive, and high-emission industries, such as traditional fossil fuels. This hierarchical control and stringent regulation are crucial for achieving robust and consistent outcomes.

For example, in the Yangtze River Economic Belt, ADICO-based water pollution regulations (e.g., mandatory sewage outfall monitoring with sanctions for non-compliance) significantly reduced violations. Similarly, the Blue Sky campaign against air pollution relied on ADICO rules to enforce coal boiler replacements, leading to a notable decrease in PM2.5 levels across the whole country [69]. These outcomes align with Ostrom's (2009) Institutional Analysis Framework [70], demonstrating how clear rules with sanctions reduce transaction costs in environmental monitoring.

The ADICO framework's theoretical significance lies in its operationalization of regulatory environmentalism, through institutionalized accountability mechanisms. By incorporating explicit sanctions (O) into policy design, ADICO configurations transcend the limitations of conventional command-and-control approaches, which often suffer from enforcement deficits in decentralized systems. This model aligns with Crawford and Ostrom (1995) institutional design principles [18] by creating clear boundaries (Attributes), graduated sanctions (Or Else), and monitoring mechanisms (Conditions), thereby addressing collective action problems in environmental governance. The framework's effectiveness is particularly evident in China's "River Chief System", where ADICO rules assign specific pollution control targets to local officials (A), mandate regular inspections (D, I, C), and impose sanctions for non-compliance (O), resulting in measurable water quality improvements across the whole country.

Practically, ADICO's strength emerges in its capacity to synchronize multilevel governance. For instance, the carbon peaking and carbon neutrality policy employs ADICO statements to enforce sectoral emissions caps (Aim) through legally binding targets (Deontic), with non-compliance triggering fiscal penalties and production suspensions (Or Else) [13]. This case highlights ADICO's capacity to operationalize political priorities through enforceable mandates—a key driver of rapid environmental compliance in carbon-intensive and highly polluting sectors, where non-stringent enforcement leads to severe ecological consequences.

However, the ADICO model has its weaknesses. First, its heavy reliance on hierarchical control risks over-centralisation, stifling local innovation. For example, rigid ADICO rules in coal phase-out programme led to abrupt plant closures, causing economic disruption and potentially unjust transition [71]. Second, the model's punitive focus may foster compliance avoidance rather than genuine behavioural change. In Guangdong's emission trading system, enterprises facing ADICO penalties for exceeding carbon quotas often resorted to temporary production halts rather than investing in long-term decarbonisation. These limitations suggest that while ADICO excels in priority enforcement, it requires complementary mechanisms (ADIC's market incentives or AIC's participatory flexibility) to address complex, context-specific sustainability challenges.

5. Conclusions

Environmental degradation is increasingly evolving into a crisis with profound and far-reaching implications for humanity's future. As the world's largest developing country and second-largest economy, the environmental and energy policies of China are of critical and great concern to countries worldwide. The significance of conducting this study within the Chinese context cannot be overstated. As a major global player on the environmental front, China's policies and their outcomes have worldwide implications.

By analysing 56 documents (510,000 words), this study identifies 25 main aspects of China's environmental policy making, with a strong emphasis on energy-related policies. These are grouped into three core categories: (1) pollution control, which include 10 aspects of water pollution prevention and control, air quality improvement initiatives, national territory pollution prevention and control, information disclosure system of pollution, supervision of pollution sources, pollution discharge permit system, control of total pollution discharge, charges for pollutants, classified and hierarchical control of eco-environment, green industry development; (2) carbon reduction, also with 10 aspects such as controls on carbon and energy intensities, clean energy development and carbon finance; and (3) green expansion, which includes efforts like the construction of nature reserves and national parks.

Using the IGT method, this study further systematically deconstructed the regulatory components of these policy pathways. The results demonstrate that: (1) AIC (Attributes, Aim, Conditions) statements represent 41 % of the policies. These strategic statements offer flexible guidance and are particularly useful for experimental and nascent policy areas, such as low-carbon city pilots. (2) ADIC (Attributes, Deontic, Aim, Conditions) statements account for 44 % of the policies. These normative statements provide strong market incentives and are well-suited for market-facing policies, such as carbon finance and renewable energy development. (3) ADICO (Attributes, Deontic, Aim, Conditions, Or Else) statements comprise 15 % of the policies. These rule-based statements feature stringent regulatory enforcement and are most effective in high-stakes, heavy industry sectors, such as traditional fossil fuels.

On the basis of deconstruction of the policy regulation involved in different environmental pathways, this analysis reveals distinct regulatory logic and underlying mechanisms of China's environmental governance. In essence, the tripartite regulatory framework reflects a polycentric governance approach, where rigidity and flexibility are strategically balanced to address different governance contexts and actors. This framework challenges the traditional command-and-control versus market-based dichotomy, presenting a more nuanced conceptualization of environmental policy design that considers the complexity of environmental challenges. This tripartite regulatory framework also highlights the importance of balancing enforcement with flexibility, particularly in carbon and green electricity trading system and innovation-intensive sectors. This aligns with institutional crafting and adaptive governance paradigms, where regulatory configurations can be dynamically adjusted to meet changing policy needs. The robust qualitative analysis, particularly the use of IGT, has been instrumental in dissecting policy regulation. Moreover, the exploration and deconstruction of policy regulation provides a critical foundation for enhancing global environmental and energy governance. The articulated distinctions in regulatory logic across different configurations offer strategic insights that are not only relevant to China's policy environment but also adaptable to other nations facing similar complex governance issues.

The tripartite regulatory framework advanced in this study, while conceptually robust in its endeavor to reconcile regulatory flexibility with accountability mechanisms, nevertheless presents certain implementation challenges within China's distinctive environmental governance context. As this framework garners increasing scholarly attention, researchers may likely raise concerns regarding how its hybrid architecture could generate interpretative flexibility—a characteristic that might be strategically leveraged by both local regulatory bodies and market participants, potentially undermining environmental and energy policy implementation outcomes. The AIC component's emphasis on strategic flexibility, though designed to accommodate regional disparities, has in practice led to inconsistent policy interpretations across jurisdictions. This is particularly evident in renewable energy adoption, where provincial governments have leveraged the framework's conditional clauses to justify varying timelines and standards for clean energy integration, resulting in a fragmented national energy transition landscape. Similarly, The ADIC model—designed to mediate between state

guidance and market autonomy—presents certain tensions in its normative structure. While its deontic "should" clauses seek to encourage voluntary compliance (e.g., through green electricity trading participation), the absence of binding sanctions appears to allow for selective adherence, particularly among enterprises with limited financial resources. This tendency toward soft compliance may somewhat attenuate the model's postulated synergy between state regulatory systems and market paradigms. Meanwhile, the ADICO regulations' rigid compliance requirements have been criticized for fostering superficial adherence rather than meaningful environmental improvements. Traditional fossil energy industries subject to these regulatory requirements frequently exhibit a tendency toward perfunctory compliance—manifested through the installation of mandated monitoring apparatus and pro forma reporting—while continuing unsustainable production practices behind the scenes.

To address these challenges while preserving the framework's adaptive strengths, several targeted refinements could enhance its effectiveness. First, the AIC component could benefit from establishing clearer boundaries for permissible local adaptations, ensuring that regional flexibility doesn't compromise national environmental objectives. This might involve developing tiered implementation guidelines that recognize different regional capacities while maintaining core performance benchmarks. Second, the framework could better leverage market mechanisms by introducing innovation incentives within the ADIC component, such as creating compliance credit systems that reward enterprises for exceeding environmental standards or pioneering green technologies. Third, the ADICO regulations should evolve beyond procedural compliance metrics to incorporate outcome-based evaluation criteria that assess actual environmental impact rather than just technical adherence. This shift would require strengthening monitoring systems to capture real-time emissions data and ecological indicators.

These adaptations would maintain the framework's core architecture while addressing its current limitations—reducing regulatory arbitrage opportunities, discouraging performative compliance, and better aligning market incentives with sustainability goals. Importantly, such refinements should be accompanied by capacity-building initiatives for local regulators, particularly in less developed regions, to ensure consistent implementation quality across diverse governance contexts. By incorporating these strategic improvements, the tripartite framework could evolve into a more robust and responsive governance tool capable of driving meaningful environmental progress while accommodating varying socioeconomic realities across nations.

CRediT authorship contribution statement

Cheng Zhou: Writing – original draft, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Wanhao Zhang:** Writing – original draft, Supervision, Software, Project administration, Methodology, Conceptualization. **Clare Richardson-Barlow:** Writing – original draft, Validation, Methodology, Formal analysis, Conceptualization.

Informed consent

Informed consent was obtained from all individual participants included in the study.

Ethics approval

This article does not contain any studies with human participants or animals performed by any of the authors.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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Data availability

The policy data of this study has been uploaded in the Appendix.

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