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Regulatory overload or incentive deficit? Forty years of structural imbalances in China's marine environmental policy instruments

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China's marine environmental governance faces a persistent paradox: despite four decades of expanding policy effort and institution building, outcomes have lagged behind expectations. In light of this, we ask whether the core problem lies not in implementation but in a structural imbalance within the policy instrument mix. We develop a Supply–Environment–Demand (SED) framework and apply computational text analysis, combined with framework analysis, to quantify the evolution of, and diagnose structural issues in, marine environmental governance using 57 national-level policies from 1982 to 2024. The findings show that the instrument mix is persistently imbalanced: the Supply, Environment, and Demand functions appear in an approximate ratio of 7:1:1.7, indicating continued Supply-side dominance. Within the Supply function, command-and-control tools—such as bans and penalties—remain foundational, with a recent shift toward planning and zoning. Market-based incentives and property-rights instruments remain underdeveloped and do not scale, while information disclosure on the Demand function expands faster than participatory authority, leaving participation largely procedural. Overall, the system exhibits a structural trilemma—strong supply, anemic environment, and fragmented demand—in which episodic diversification has not produced sustained rebalancing. The governance implication is that policy sequencing and institutional design matter more than adding new instruments. The priority is to embed enforceable ex ante controls and a transparent system for monitoring, reporting, and independent verification through spatial planning, zoning, and legally binding environmental thresholds. On that basis, institutionalize price- and rights-based incentives and enable genuinely empowered public participation so that market signals and social oversight operate effectively at scale. The SED lens thus reframes the implementation gap as a problem of functional allocation and coordination and offers a transferable toolkit for structural rebalancing in coastal jurisdictions.

KEYWORDS

marine environmental governance, policy instrument, SED framework, computational text analysis, structural imbalance

1 Introduction

The ocean, the cradle of Earth's life systems, is vital for regulating global climate, ensuring food security, and driving economic prosperity (Wisiz et al., 2020). Globally, however, it is under unprecedented anthropogenic pressure, confronted by a multifaceted crisis encompassing pollution, overfishing, habitat degradation, and climate change (Dugoua, 2023). This confluence of threats makes effective marine environmental governance an urgent global imperative (Sardà et al., 2014). In this context, the case of China—a major maritime power and the world's second-largest economy—is particularly critical. The health of its marine environment is not merely a matter of domestic concern, vital to the well-being of its 1.4 billion people and the success of its national Ecological Civilization initiative, but also has profound implications for achieving global sustainable development goals (Fu, 2020).

As a major maritime power with vast jurisdictional waters equivalent to one-third of its landmass, China's national destiny is inextricably linked to that of the ocean. However, the rapid expansion of its marine economy has placed its coastal ecosystems under intensifying environmental pressure. Frequent pollution incidents and ongoing ecosystem degradation now pose a significant impediment to the nation's sustainable development trajectory (Yu and Bi, 2019). In response to this challenge, China has elevated marine environmental protection to an unprecedented level of national strategic priority. This strategic resolve is reflected in a series of coherent, top-level political directives, including President Xi Jinping's profound call to "cherish the ocean as we cherish our own lives"; the grand blueprint for building China into a strong maritime power, articulated at the 18th and 20th National Congresses of the Communist Party of China; and the recent instruction from the Central Economic Work Conference to tap the ocean for productivity and new growth drivers while upholding land-sea coordination. To translate this political will into tangible action, China has, over the past four decades, progressively constructed a sophisticated governance system composed of laws, plans, and standards.

Nonetheless, a perplexing paradox persists: despite growing policy inputs and an increasingly sophisticated institutional framework, governance outcomes have repeatedly fallen short of expectations. The system's effectiveness has long been hindered by chronic issues, notably the implementation gap and departmental fragmentation (Ren et al., 2022). This has created a significant gap between grand policy ambitions and actual environmental improvements. This study argues that the key to resolving this paradox lies in a systematic examination of the engine behind the governance system: policy instruments. As the specific mechanisms governments employ to achieve public objectives, the selection, combination, and application of these instruments directly determine governance efficiency and effectiveness (Howlett, 2014). Compared to macro-level institutional analyses, focusing on policy instruments provides a more granular and precise lens to reveal the strengths and bottlenecks within the governance process. Moreover, the effectiveness of any policy-instrument mix hinges on a solid foundation—comprehensive and accurate monitoring data on the

marine environment. The absence of such data constitutes, in itself, a fundamental challenge for marine governance and may exacerbate the structural problems associated with the implementation of policy instruments. Therefore, this study is guided by the following core research questions: What evolutionary trajectory and structural characteristics does the policy instrument system for China's marine environmental governance exhibit? What systemic imbalances exist in the current policy mix, and how do these imbalances affect overall governance effectiveness? How can the policy mix be optimized to enhance governance performance? The motivation for this study is to offer a novel and practical analytical perspective for addressing this long-standing governance dilemma by systematically diagnosing the toolbox of China's marine environmental governance.

This study holds significant theoretical and practical implications. At the theoretical level, it applies policy instrument theory to the complex and dynamic domain of China's marine environmental governance. By introducing the refined Supply–Environment–Demand (SED) analytical framework, this research enriches the paradigm for studying environmental policy instruments and provides valuable empirical evidence for understanding the evolutionary logic and implementation challenges of environmental policy in transitional states. On a practical level, the contribution of this study, through its systematic assessment of policy instruments, extends beyond China itself. It aims to provide an empirically grounded diagnostic framework and a set of transferable optimization pathways for other transitional economies and developing nations facing the shared challenge of balancing rapid economic growth with marine ecological health. The findings provide policymakers in these countries with evidence-based insights to inform more scientific policy design and resource allocation, ultimately enhancing their overall governance effectiveness.

The marginal contributions of this study are threefold: First, the research transcends conventional analyses focused on single policies or macro-level institutions by systematically employing the three-dimensional SED framework. This approach enables a comprehensive and structural analysis of the entire suite of policy instruments for China's marine environmental governance. Second, the study goes beyond merely identifying the well-documented phenomenon of overreliance on command-and-control (C&C) instruments and the deficit of market-based and society-based tools. More critically, it uncovers the underlying structural imbalance among Supply-side, Environment-side, and Demand-side instruments, directly linking this imbalance to suboptimal governance effectiveness. This provides a more powerful micro-level mechanism for explaining policy failure. Third, building on the in-depth diagnosis, the study proposes an optimization pathway that shifts the governance paradigm from unidirectional regulation to a synergistic approach that simultaneously engages the Supply, Environment, and Demand sides. This provides forward-looking and actionable policy implications for China, and by extension, for other nations facing similar challenges.

The remainder of this paper is structured as follows: Section 2 presents a literature review, surveying the current state of research

on marine environmental governance and policy instruments, both internationally and in China. Section 3 introduces the analytical framework and research methodology. Section 4 uses a dictionary-based computational text analysis aligned with the SED framework to quantify the evolution of China's marine environmental policy instruments and diagnoses their current structural imbalances. Section 5 provides a discussion of the underlying causes of the policy instrument imbalance and its profound impacts on governance performance. Finally, Section 6 offers conclusions and actionable recommendations, summarizing the key findings and proposing concrete strategies for optimizing the policy mix in China's marine environmental governance.

2 Literature review

2.1 Macro-paradigms and theoretical lenses in marine governance

Global research on marine environmental governance has undergone a profound paradigm shift, evolving from single-issue, fragmented management to integrated, systems-based thinking. Early governance models were dominated by a C&C approach, focusing on specific pollution sources or the management of single resources (Costanza et al., 1998). This reliance on state-led regulation was not unique to any one nation but rather a common feature of environmental policy in its early stages worldwide. The policy trajectories of many developed nations, including the United States with its landmark Clean Water Act and the European Union with its early directive-based policies, were initially characterized by a strong dependence on such instruments (Jordan et al., 2003). The key point of divergence lies in the subsequent evolutionary path. In many Western countries, the inefficiencies and high compliance costs exposed by purely top-down methods catalyzed a second wave of policy innovation centered on market-based instruments, aimed at enhancing cost-effectiveness (Stavins, 2003). The inability of the traditional model to address inherent complexity and interconnectedness—a limitation dramatically amplified in the marine domain (Jennings and Kaiser, 1998)—spurred the search for more holistic frameworks. Consequently, more integrative governance paradigms emerged from both academia and practice. Among these, Ecosystem-Based Management (Sardà et al., 2014) and Marine Spatial Planning (Ehler and Douvère, 2009) have been the most influential, collectively raising the scientific rigor and forward-looking nature of governance to new heights. At the EU level, this turn was institutionalized in the Marine Strategy Framework Directive (MSFD): anchored in Good Environmental Status (GES), it adopts an ecosystem approach and a six-year rolling governance cycle—initial assessment, GES determination, targets and indicators, monitoring programs, and programs of measures—and operationalizes GES through eleven qualitative descriptors spanning environmental domains (European Commission, 2008; Bigagli, 2014; Freire-Gibb et al., 2014). The MSFD sets objectives and procedures rather than prescribing instruments, requiring

Member States to assemble their own policy mixes under EU law and the regional sea conventions (OSPAR, HELCOM) (van Leeuwen et al., 2012). In parallel, the United States, beginning with the Coastal Zone Management Act (CZMA, 1972), established a federal and state partnership for Integrated Coastal Zone Management (ICZM), thereby coordinating federal actions with state programs via the federal consistency provision (CZMA§307; 16 U.S.C.§1456). In the twenty-first century, An Ocean Blueprint for the 21st Century and Executive Order 13547—Stewardship of the Ocean, Our Coasts, and the Great Lakes further strengthened national-level coordination and marine (coastal) spatial planning, which consolidated the institutional platform for the shift from sectoral to integrated governance (Yu and Bi, 2019).

To analyze and guide these complex governance processes, scholars have introduced a variety of theoretical lenses. The multi-level governance framework has been employed to dissect coordination challenges across transnational, national, and local levels (Muccitelli et al., 2023), while theories of institutional change provide analytical tools for understanding the evolutionary logic of governance structures (Banikoi et al., 2023). However, while these macro-frameworks and theories illuminate the what and the why of governance, they often fall short in detailing the how—that is, the design and configuration of an optimal policy mix to drive behavioral change. This leaves a pervasive last-mile gap between grand concepts and practical governance implementation. Policy instrument theory provides a critical analytical framework to bridge this very gap.

Twentieth-century research on policy instruments broadly followed two trajectories: domain-specific comparisons that examined instrument preferences across regimes for particular issues (Ackerknecht, 1948), and a cross-domain generalization approach (Dahl and Charles, 1953). A key contribution of late twentieth century was the development of comparable taxonomies, which pursued balancing parsimony with generality. In *The Tools of Government*, Hood (1983), Hood, 2007) advanced the NATO framework, grounded in a cybernetic logic that distinguishes two core functions—information acquisition and behavior modification—and characterizes governmental leverage via four resource bases: Nodality, Authority, Treasure, and Organization. Vedung (1998) “Carrots–Sticks–Sermons (C–S–S)” triad, by contrast, uses a minimalist structure to foreground the behavioral logics of economic incentives, regulation, and information, and has become a baseline reference in environmental and regulatory policy studies. The frameworks are complementary: NATO illuminates the resources-to-function dimension of state action, while C–S–S clarifies mechanisms of effect (behavioral change), jointly enabling cross-sectoral comparability. Parallel generic schemes include Elmore (1987), who distinguishes four categories—mandates, inducements, capacity building, and system-changing tools—and Schneider and Ingram (1990), who propose a fivefold typology: authority tools, incentive tools, capacity tools, symbolic or hortatory tools, and learning tools. Over the past two decades, instrument classifications have converged on three broad families—C&C, market-based incentives, and information-based and voluntary approaches (Stavins, 2003; Brouhle et al., 2009)—with frontier advances along two lines: policy mix and

policy design (Yao et al., 2023). First, research on policy mix has moved beyond inventories toward system-level analysis of interactions, trade-offs, and synergies, emphasizing elements–processes–features and temporal dynamics (e.g., stringency, specificity, sequencing) to support multi-goal (environment, economy, equity) optimization over time (Rogge and Reichardt, 2016; Kivimaa and Kern, 2016). Second, studies on policy design drill down to bundles of attributes (goal targeting, implementation rules, compliance costs, monitoring and enforceability) and procedural instruments; through the lens of instrument constituencies, they show how the supply side—expert networks, consultancy markets, and bureaucratic communities—drives diffusion and path dependence (Béland and Howlett, 2016; Simons and Voß, 2018). Collectively, these advances refocus analysis on instrument interactions and system-wide effects, equipping marine governance with an operational yardstick that shifts attention from whether particular tools are present to how objectives can be achieved with minimal distortion, while also enabling diagnosis of deeper structural problems.

2.2 Research landscape of China's marine environmental governance

Research on China's marine environmental governance evolves in parallel with national practice, presenting a rich landscape characterized by interwoven macro- and micro-level perspectives. At the macro level of systemic evolution, a scholarly consensus holds that China's governance system has followed a dynamic trajectory: from a legal vacuum, to the establishment of a rudimentary system, and, subsequently, to the pursuit of systematic integration (Yu and Bi, 2019). This body of research has profoundly revealed two long-standing challenges confronting the governance system. The first is the problem of “nine dragons stirring the sea” (jiǔ lóng zhì hǎi), a metaphor for severe departmental fragmentation. This fragmented management model leads to policy conflicts and regulatory gaps. Despite institutional reforms aimed at promoting land-sea coordination (lù hǎi tǒng chóu)—notably the establishment of the Ministry of Natural Resources in 2018 and the 2024 revision of the Marine Environmental Protection Law—inter-governmental coordination remains a formidable challenge (Jin and Yu, 2025). The second is the last-mile problem in policy enforcement, commonly identified as the implementation gap, which is considered the key bottleneck constraining governance effectiveness (Ren et al., 2022).

At the micro-level of policy instruments, research confirms a clear evolutionary trend in China's policy toolbox: a gradual shift from an early, heavy reliance on C&C instruments to a more diversified approach that incorporates market-based and information-based tools (Ma et al., 2023; Gong et al., 2024). For instance, Pan et al. (2023) analysis of Bohai Sea governance policies finds that government regulatory instruments accounting for 67.5%, while market-based and social participation tools are markedly under-represented at 16.5% and 16%, respectively. Using content analysis, Fu (2020) quantifies China's marine environmental policies from 2014–2017 and shows that the annual frequencies

of coercive, mixed, and voluntary instruments remained roughly stable at a 4.1:1.8:1 ratio—i.e., a stratified pattern approximating a geometric progression. Applying the same method to marine pollution-control policies in Zhejiang Province (2016–2020), Chen and Zhu (2021) report that environmental regulatory instruments dominate (60%), followed by public participation instruments (25%), with market-based instruments lowest (15%). Specifically, environmental regulation is led by total pollutant load control, market-based instruments by third-party pollution control, and public participation by environmental education and outreach. Similarly, evolutionary studies of specific instruments, such as marine ecological compensation, show that while the concept has evolved over time, it continues to face the practical dilemmas of policy fragmentation and low implementation efficiency (Huang et al., 2024). Furthermore, other research employing methods such as network analysis to assess policy synergy finds that while goal synergy is acceptable, there are significant shortcomings in instrument and process synergy, illustrating how macro-level departmental fragmentation cascades down to the micro-level of tool implementation (Yao et al., 2023).

2.3 Critical review and research gap

Regarding instrument choice in China's marine environmental governance, scholarship converges on a two-level consensus: at the macro level, there is sectoral fragmentation and implementation slippage, and at the micro level, there is C&C dominance and imbalanced policy mixes. Nevertheless, the literature has not translated this consensus into testable structural diagnostics or operational pathways for improvement. Three gaps stand out.

First, there is a disconnect from typological description to functional diagnosis. Mainstream three- or fourfold typologies of policy instruments tell us what the tools are, but rarely where along the causal chain they act or how they take effect. Rather than stopping at a static accounting of type shares, the critical task is to test whether the policy mix exhibits systemic imbalance across the three functional dimensions—Supply–Environment–Demand (SED). Without a functional lens, type shares alone cannot yield a mechanistic explanation of structural skew and policy failure.

Second, the problem diagnosis remains superficial. Regarding the imbalance, the literature primarily focuses on the quantitative imbalance of instruments rather than on the imbalance in governance logic. While this judgment is correct, it is no longer sufficient to explain the complexity of the current input–output paradox. It fails to probe deeper into whether a more profound functional imbalance exists within the internal logic of the governance system itself. Specifically, does government intervention focus predominantly on end-of-pipe control after problems have arisen, does it give equal weight to reducing pressure at the source by guiding socioeconomic development, or does it instead prioritize empowering meaningful public participation to strengthen co-governance?

Third, empirical evidence and testable pathways require reinforcement. Existing regional and topic-specific studies

indicate a high reliance on C&C instruments, with market mechanisms, public participation, and process coordination all underdeveloped. To reach more explanatory conclusions, however, nationwide, long-horizon evidence spanning multiple policy cycles is needed—evidence that systematically traces the governance process, the sequencing of instrument configurations, and shifting phase priorities.

Situated at the intersection of international comparison and instrument theory, this study combines computational text analysis with framework analysis on national-level policy documents (1982–2024) to provide evidence on the structural profile of China's marine policy instruments, the mechanisms of imbalance, and feasible pathways to rebalance. Compared with descriptive work that emphasizes the prevalence of instrument types, it makes three marginal contributions. First, methodological: a reproducible pipeline for computational text analysis—constructing dictionaries of keyword clusters, matching at the sentence and paragraph level, and mapping hits to SED functional loci—thereby addressing gaps in methodological transparency and quantitative backing. Second, explanatory: an empirical shift from tool inventories to a structural diagnosis of functional balance and coordination, clarifying the long-standing input–output gap. Third, policy-relevant: an operational rebalancing pathway, in dialogue with international experience—boundary-setting through spatial planning and zoning with legally binding environmental thresholds and an admissibility list; incentive discipline via market-based incentives and tradable permits calibrated to source-pressure reduction; and social oversight through empowered participation with monitoring, reporting, and independent verification. On balance, the study enhances the comparability and replicability of research on China's marine governance and offers portable tools and transferable evidence for policy calibration in other coastal states.

3 Methodology

3.1 The SED analytical framework

To systematically deconstruct the long-standing policy input–governance output paradox in China's marine environmental governance, this study goes beyond traditional policy instrument typologies (e.g., Bressers and O'Toole, 1998; Howlett, 2011) by constructing an integrated analytical framework focused on governance functions—the SED framework. While traditional classifications are effective in identifying instrument attributes, their ability to illuminate the dynamic synergies and functional complementarities within complex governance systems is often limited. Adopting a functionalist perspective, the SED framework goes beyond simple typologies to dissect the policy mix based on a dual logic of core governance functions and primary acting subjects. This approach is guided by a central diagnostic question: Who acts, and through what mechanism? This logic yields three distinct governance dimensions: the Supply Side, where the state acts through direct command, regulation, and planning; the

Environment Side, where the market acts through price signals and property rights; and the Demand Side, where society acts through public supervision and participation. By mapping policy instruments along these three axes, the framework provides a penetrating analytical lens to diagnose the structural imbalances within the current policy system, as illustrated in Figure 1.

1. **Supply-side Policy Instruments.** Instruments in this dimension constitute the foundational architecture of state intervention, with their core function being the direct provision of environmental regulations and public goods. Through the establishment of mandatory standards, the implementation of direct controls, and the execution of strategic planning, they transmit the state's governance will in a top-down fashion, aiming to shape and constrain the behavior of core governance targets (Salamon, 2002). This embodies the state's role as the primary supplier of environmental governance. These primarily encompass two categories: The first are C&C instruments, the most direct means of supply, which include environmental quality and pollutant emission standards, permitting systems, mandatory technology adoption, Environmental Impact Assessments, and prohibitions. The second category comprises Planning and Zoning Instruments, which, through tools such as Marine Functional Zoning, Integrated Coastal Zone Management, and the “Three Lines and One List” (3L1L) system—delineating ecological protection redlines, environmental quality bottom lines, resource utilization upper limits, and an environmental access list—impose proactive layouts and constraints on spatial and developmental activities.
2. **Environment-side Policy Instruments.** The function of instruments in this category is not to issue direct commands, but rather to indirectly guide actors' behavior in an environmentally friendly direction by constructing and optimizing a rational incentive environment. They leverage market mechanisms and economic levers, operating on the policy logic that internalizing environmental protection from an external cost into an actor's intrinsic economic calculation will enhance governance efficiency (Stavins, 2003). This dimension mainly includes two categories: First, Economic Incentive Instruments, which utilize prices, taxes, and subsidies, such as pollution fees, environmental taxes, ecological compensation mechanisms, green finance (credit and bonds), and fiscal rewards for environmental performance. Second, Property Rights-based Instruments, which create tradable markets by clearly defining and allocating rights for resource use or pollution discharge, such as Emissions Trading Systems (ETS) and the application of Individual Transferable Quotas in fisheries management.
3. **Demand-side Policy Instruments.** Instruments in this dimension are dedicated to cultivating and stimulating effective demand for high-quality environmental

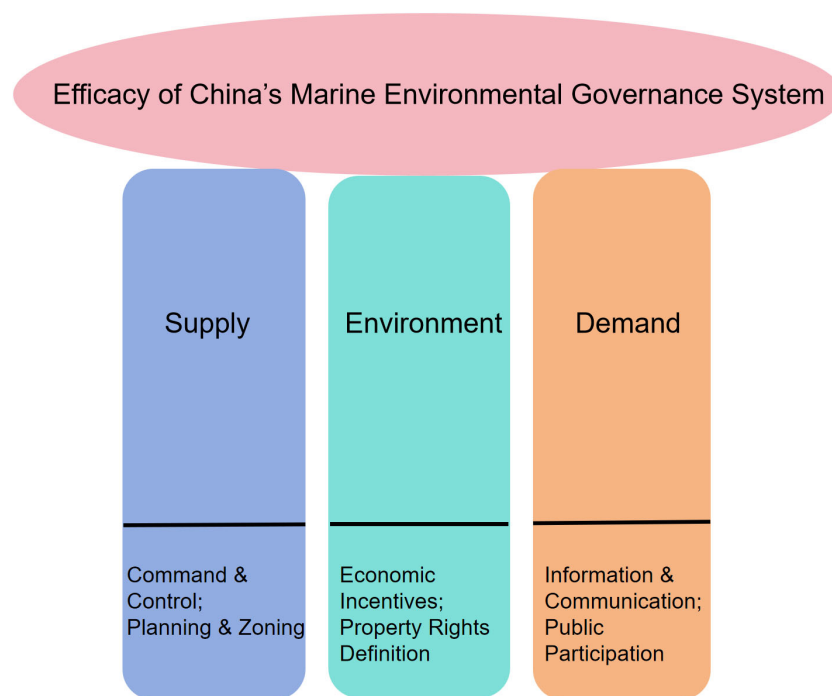


FIGURE 1
Conceptual diagram of the SED framework.

governance at the societal level, and to converting this demand into supervisory pressure on both the government and polluters. Through information and participation empowerment, they aim to construct a bottom-up social oversight network, thereby enhancing the responsiveness and resilience of the governance system (Newig and Fritsch, 2009). They primarily comprise two categories: First, Information and Communication Instruments, designed to overcome information asymmetry, such as mandatory environmental information disclosure, corporate environmental credit ratings and public disclosure, state of the environment reports, public hearings, and environmental awareness and education programs. Second, Public Participation and Empowerment Instruments, which grant substantive participatory and oversight rights to citizens and social organizations, such as environmental public interest litigation, public reporting and reward mechanisms, and the social supervisor system within the “Bay Chief” scheme.

In summary, a robust and efficient governance system is the result of the synergistic evolution and functional complementarity of these three SED instrument types. Over-reliance on, or the absence of, any single dimension can lead to systemic imbalance. Therefore, the SED framework provides this study with a diagnostic tool to assess the evolutionary trajectory, structural features, and inherent functional deficiencies of the policy instrument mix in China’s marine environmental governance.

3.2 Integrated approach: framework analysis and computational text analysis

3.2.1 Framework analysis

This study employs a mixed research design, combining qualitative and quantitative approaches. On the qualitative side, it utilizes Framework Analysis. This systematic and matrix-based technique for qualitative data management and analysis is particularly suited for policy-oriented research driven by specific research questions and an *a priori* theoretical framework (Ritchie and Spencer, 1994). Its key advantage lies in its capacity to ensure both systematic rigor and transparency throughout the analytical process, while also providing a structured interpretation of rich, in-depth qualitative texts, thereby effectively bridging the gap between theoretical constructs and empirical evidence (Gale et al., 2013). The analytical process in this study strictly adheres to the five core stages of Framework Analysis proposed by Srivastava and Thomson (2009):

1. Familiarization and Framework Operationalization. This stage involved a thorough immersion in the theoretical underpinnings of the SED framework. The framework was then operationalized into a detailed codebook, complete with explicit definitions, classification criteria, and identification indicators for each policy instrument category.
2. Thematic Indexing. In this stage, the selected policy literature was systematically reviewed. Guided by the codebook, specific policy measures and regulatory articles

within the texts were identified and precisely indexed under the corresponding categories of the SED framework.

3. Charting. The indexed information was distilled and summarized into an analytical matrix. This matrix was structured with historical periods forming the rows and SED instrument sub-categories forming the columns, enabling a condensed and structured presentation of the evidence extracted from the key policy documents.
4. Mapping. Based on the charted data, the evolutionary patterns of the policy mix were mapped at a macro level. This involved identifying the dominant instrument types in each era, charting the trajectory of instrument diversity, and analyzing the quantitative and functional balance across the three SED categories.
5. Interpretation. The final stage involved an in-depth interpretation of the mapped patterns and phenomena. This analysis went beyond merely describing what the patterns were, to explaining why they had formed. This was achieved by situating the findings within the broader context of China's macro-institutional setting, its stages of economic development, and its shifting governance philosophies, ultimately revealing the deep-seated mechanisms driving the observed evolutionary path and structural imbalances.

To ensure the rigor and consistency of our analysis, this study has operationalized the SED framework into a detailed classification protocol. This protocol serves as the analytical blueprint for identifying and categorizing policy instruments throughout the historical review in the subsequent chapter. [Table 1](#) presents this operationalization and serves as the SED codebook, detailing each functional dimension and its subcategories, with each subcategory's functional definition and specific instruments. By anchoring the analysis in this explicit framework, this study can systematically map the evolutionary trajectory and diagnose the structural imbalances within China's marine policy mix over the past four decades.

3.2.2 Computational text analysis

Computational text analysis, also known as text-as-data, refers to using reproducible algorithms to convert large-scale text into numerical representations for description, measurement, and causal identification. Its aim is to augment, not replace, close reading, and it calls for transparent reporting of text sampling, metadata handling, and preprocessing choices ([Grimmer and Stewart, 2013](#); [Schoonvelde et al., 2019](#)). Guided by this approach, we employ sentence- and paragraph-level dictionary matching of keyword clusters as a quantitative complement to the Framework Analysis. The workflow is implemented in Python, and the keyword cluster dictionary is provided in [Supplementary Table S2](#).

We assemble a corpus of 57 national-level (central government) policy documents directly pertinent to marine environmental governance, issued in 1982–2024 (officially promulgated versions).

All documents are converted to UTF-8; non-normative components (e.g., tables of contents, annex lists) are removed; and the texts are segmented by Chinese punctuation into sentences and natural paragraphs, which constitute the minimal units of analysis. We count only normative and operational statements (e.g., prohibitions, admissibility and entry rules, restrictions, inspections, evaluations, penalties and sanctions, compensation), excluding background narrative and slogans. Within any sentence or paragraph, a given specific instrument is counted at most once to avoid synonym-driven double counting. After preprocessing and initial matching, we identify $N = 2,173$ sentences and paragraphs associated with policy instruments. The detailed steps are as follows.

1. Constructing keyword cluster dictionaries. Guided by the SED codebook, we build a keyword cluster for each specific instrument (synonyms, near-synonyms, and fixed collocations) and impose a semantic co-occurrence threshold: an instrument term counts as a hit only if it co-occurs in the same sentence or paragraph with at least one restrictor—environment, ecology, marine, pollution, emissions, dumping, coastal reclamation, shoreline, sea area—thereby reducing false positives. No separate negative list is used; noise is controlled through the restrictor co-occurrence rule and a conservative “one count per sentence or paragraph per instrument” policy.
2. Automated matching and aggregation. We run dictionary matching at the sentence and paragraph level, first determining hits at the specific-instrument level, then rolling them up from instrument to subcategory and, ultimately, to the SED functional dimension. Results are aggregated by document, year, and phase to produce frequencies and relative shares.
3. Consistency check. To assess agreement between automated coding and human judgment, we draw a stratified random sample of $n = 180$ sentences or paragraphs as the validation sample from the corpus—4 phases $\times$ 3 SED functional loci (15 per stratum). Human coders apply the SED codebook and the same co-occurrence threshold to render binary hit or no-hit decisions; the program uses identical thresholds and the same de-duplication rule (a given instrument is counted at most once within a sentence or paragraph). A 2×2 contingency table is then constructed (a = both hit; b = human only; c = program only; d = both no-hit) and simple percent agreement computed as $P_O = (a+d)/(a+b+c+d)$. We obtain $P_O = 92.78\%$, and Cohen's kappa (κ) = 0.7767, indicating substantial agreement after correcting for chance (see [Supplementary Table S3](#), for the contingency table and calculations). This procedure aligns with the text-as-data emphasis on workflow transparency and validation ([Grimmer and Stewart, 2013](#); [Schoonvelde et al., 2019](#)).

TABLE 1 SED codebook.

Functional dimension	Subcategory	Functional definition	Specific instruments (codebook terms)
Supply-side	Command-and-Control (C & C)	Directly constrains polluting or damaging behaviors through mandatory regulations, standards, and permits.	Bans & Mandates Penalties & Corrective Measures Inspection & Enforcement EIA Approval Standards & Limit Values Permits & Licensing Use & Operational Restrictions
	Planning & Zoning	Pre-sets development boundaries and ecological bottom lines through spatial arrangements and functional designations.	Spatial Planning & Zoning Three Lines & One List (3L1L) Marine Protected Areas (MPAs) Environmental Capacity & Carrying Capacity.
Environment-side	Economic Incentives	Indirectly guides behaviors by altering the cost-benefit calculations of stakeholders through market-based mechanisms.	Environmental Fees & Taxes Eco-compensation (PES) Third-Party Environmental Services & PPP Subsidies & Green Finance
	Property Rights	Creates a basis for market transactions and accountability by defining ownership or usage rights of marine resources/space.	Discharge Rights & Emissions Trading Fisheries Quota Systems Marine Area Use Rights Environmental Credit & Offsets
Demand-side	Information	Empowers public supervision and enhances accountability by ensuring the transparency and accessibility of environmental information.	Information Disclosure Monitoring Network & MRV Eco-labeling & Green Certification
	Participation	Absorbs societal forces into the governance process through institutionalized channels for input, oversight, and litigation.	Hearings & Public Consultation Public-Interest Litigation & Remedies Whistleblowing & Public Oversight Co-management Education & Capacity-building

Column 4 enumerates the canonical instrument labels; in the computational matching (Section 3.2.2), each label is operationalized via a keyword cluster (synonyms/phrases) detailed in [Supplementary Table S2](#), and hits are counted at the specific instrument level.

3.3 Data sources and selection criteria

The analytical data for this study comprise authoritative policy literature directly pertaining to marine ecological environmental protection, enacted at the national level in the People's Republic of China since 1982. To ensure analytical depth and representativeness, this study employs a purposive sampling strategy (Patton, 2015), targeting 57 key texts that possess landmark significance and paradigm-shaping power within the evolution of the governance system, as presented in [Supplementary Table 1](#). The specific selection criteria are as follows:

1. Legal Cornerstone. This includes core legal statutes that serve as the fundamental basis of the governance system, most notably the Marine Environmental Protection Law of the People's Republic of China and its key revisions over time.
2. Strategic Guidance. This covers programmatic documents that define the nation's strategic direction and priorities for specific periods, such as the marine ecological protection chapters within the Five-Year Plans for National Economic and Social Development and the National Marine Economy Development Plans.
3. Institutional Innovation. This refers to landmark policies that introduced novel governance mechanisms or deployed

significant new initiatives, such as the Notice on Establishing the National Marine Inspection System.

4 Evolutionary trajectory and structural diagnosis of China's marine policy instruments

4.1 Phasing of governance

China's marine environmental governance is periodized with reference to foundational legal revisions and reorganizations of central environmental institutions, yielding four phase: Phase I—Institution-Building Foundation (1982–1997); Phase II—Enforcement Intensification (1998–2007); Phase III—Spatial-Control Intensification (2008–2017); and Phase IV—Restructuring and Proceduralization (2018–present). The specific criteria for phase demarcation, together with representative policy samples and counts by phase, are reported in [Table 2](#).

In 1982, the Marine Environmental Protection Law of the People's Republic of China (MEPL) was enacted, establishing the basic legal framework and division of responsibilities for marine environmental protection. In 1998, the National Environmental Protection Agency was upgraded to the State Environmental

TABLE 2 Phase definitions of China's marine environmental governance and distribution of the document sample.

Phase	Period	Legal/institutional Basis	Representative laws/policies	Number of documents
Phase I: Institution-Building	1982–1997	1982 Marine Environmental Protection Law of the People's Republic of China (MEPL, effective 1983), which for the first time established the fundamental legal framework for marine environmental protection	Supporting regulations and ministerial measures issued successively	9
Phase II: Enforcement-Intensification	1998–2007	1998 elevation of the National Environmental Protection Agency to State Environmental Protection Administration (SEPA); 1999 first comprehensive revision of the MEPL	Total load control, special rectification campaigns, and institutionalization of emergency response mechanisms	5
Phase III: Spatial-Control Intensification	2008–2017	2008 establishment of the Ministry of Environmental Protection (MEP); 2012 incorporation of “ecological civilization” into top-level design; 2013 proposal of the “Maritime Power” strategy and the Belt and Road Initiative; 2016/2017 revision and amendment of the MEPL	Promotion of Marine Spatial Planning (MSP); institutionalization of ecological redlines and restoration policies; ecological compensation mechanism pilot, expansion of public participation and information disclosure	19
Phase IV: Restructuring & Proceduralization	2018–present	2018 institutional reform: establishment of the Ministry of Ecology and Environment (MEE) and the Ministry of Natural Resources (MNR), achieving land–sea integrated governance; 2023 comprehensive revision of the MEPL (effective 2024)	“Dual Carbon” targets (2020) and the 14th Five-Year Plan as guiding frameworks; blue carbon initiatives, nationwide monitoring networks, and strengthened rolling governance	24

Protection Administration (SEPA), a full ministerial body. In 1999, the MEPL underwent its first systematic revision, institutionalizing total pollutant load control, targeted clean-ups, and emergency response. In 2008, SEPA was formally elevated to the Ministry of Environmental Protection (MEP), a constituent ministry of the State Council, bringing ministerial-level regulation. The MEPL was revised again in 2016 and 2017, strengthening information disclosure, monitoring and evaluation, and responsibility allocation, while advancing national marine spatial planning (MSP) and the ecological redline program. In 2018, a wide-ranging institutional reform created the Ministry of Ecology and Environment (MEE) and the Ministry of Natural Resources (MNR), achieving land–sea integration. In 2023, the MEPL underwent a comprehensive revision (effective 2024) that, under the “dual-carbon” and Fourteenth Five-Year Plan strategies, strengthens the national monitoring network, institutionalizes rolling governance cycles, and advances ecological restoration and blue-carbon initiatives.

4.2 Overall evolution

Over four decades examined, the usage shares of Supply-side (S), Environment-side (E), and Demand-side (D) instruments are 71.7%, 11.6%, and 16.8%, respectively (Figure 2). Supply-side instruments dominate, whereas Environment-side and Demand-side instruments are markedly underutilized and largely marginalized. In particular, the Environment-side (E) has the lowest share.

From the internal composition, the use of subcategories within S, E, and D is uneven. As Figure 3 shows, within the S bundle, C&C accounts for the largest share (72.1%); within D, Information instruments predominate (64.6%), while Participation remains comparatively small; within E, Economic Incentives and Property Rights are used at roughly similar frequencies but have low overall shares. This pattern suggests that S relies on hard norms to maintain

baseline constraints; D is embedded in governance through information duties and procedural obligations; and E's price- and rights-based levers have yet to scale into an institutionalized supply.

At the level of specific instruments (see Table 3 and Figure 4), the Top 8 (share $\geq 5\%$) are Bans & Mandates, Penalties & Corrective, Monitoring & MRV, Standards & Limit Values, Marine Protected Areas (MPAs), Three Lines & One List (3L1L), Spatial Planning & Zoning, and Inspection & Enforcement, contributing 68.6% in the aggregate. Of these, seven fall under S, one under D, and no E instrument enters the Top 8. By contrast, the least-used instruments (share $\leq 1\%$) cluster at the tail end of the E and D distributions—Fisheries Quota Systems, Environmental Credit & Offsets, Whistleblowing & Public Oversight, Public-Interest Litigation & Remedies, Hearings & Public Consultation, Eco-labeling & Green Certification, and Third-Party Environmental Services & PPP—indicating a pilot-rich yet difficult-to-scale pattern of marketization and public participation in the marine domain.

Further examining the usage frequencies of specific instruments within each of the three SED functional dimensions (see Table 4), three key findings can be summarized. First, S. The top three contrast, the least-used instruments (share $\leq 1\%$) cluster at the tail end of the E and D distributions—Bans & Mandates, Penalties & Corrective Measures, and Standards & Limit Values contrast, the least-used instruments (share $\leq 1\%$) cluster at the tail end of the E and D distributions—together account for 50.7%, indicating that rule-setting and enforcement remain the institutional bedrock. The remaining instruments are diffusely distributed, consistent with a broad-spectrum, multi-pronged supply-side mix. Second, E. The top three contrast, the least-used instruments (share $\leq 1\%$) cluster at the tail end of the E and D distributions—Environmental Fees & Taxes, Marine Area Use Rights, and Discharge Rights & Emissions Trading—sum to 73.4%, whereas Credit & Offsets, PPP, Eco-compensation, and Subsidies occupy minimal shares. This pattern suggests a hard-constraint market orientation: China tends to drive behavioral change in the marine domain by internalizing costs and

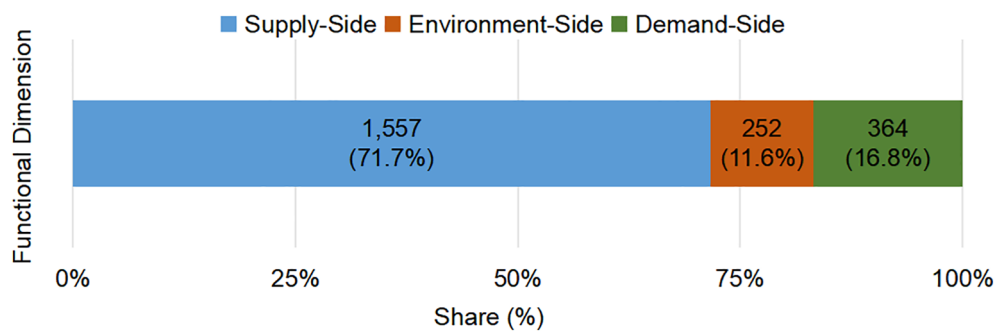


FIGURE 2

Overall SED instrument mix (1982–2024) The overall S:E:D instrument ratio of 7:1:1.7 reveals a structural imbalance heavily skewed towards Supply-side interventions.

defining rights boundaries, rather than relying primarily on positive incentives such as fiscal subsidy. Third, D. The top three—Monitoring Network & MRV, Education & Capacity-building, and Co-governance—reach 80.8%, with Monitoring Network & MRV alone at 51.1%, reflecting an intensified tilt toward proceduralization and datafication. Governance priorities have been shifting from end-of-pipe remediation toward target-monitor-evaluate-account process management, with data and evidence becoming central to enforcement and performance control. In sum, the evidence indicates that China has assembled a full-spectrum toolkit in quantitative terms; however, it continues to exhibit the structural trilemma: strong supply, anemic environment, and fragmented demand.

Over time, across all four phases the functional shares follow an $S > (E, D)$ configuration (Figure 5), while peak–trough fluctuations and rank reversals reveal shifts in policy emphasis. Overall, S, though variable, remains dominant in every period, consistently exceeding one-half of the total; E never becomes the leading dimension, rising only briefly in Phase II before receding; and D remains secondary and fragmented for most of the period, with a marked surge only in Phase IV.

Figure 6 further traces the temporal reconfiguration of subcategories within S, E, and D—that is, their redistribution

across the four phases. Within S, subcategories shift from C&C toward Spatial Planning & Zoning. Within E, all subcategories display a “brief uptick followed by retreat” pattern. Within D, subcategories rise markedly only in Phase IV, and the increase is information-led with participation lagging.

4.3 Four-phase profiles: evolution of instrument structure and governance mechanisms

4.3.1 Phase I: institution-building foundation (1982–1997)—supply-side overwhelming dominance

The formal inception of China’s modern marine environmental governance system is marked by the promulgation of the MEPL in 1982. Against the specific historical backdrop of the early Reform and Opening-Up era, the state’s overriding agenda was economic development. Environmental issues were consequently viewed as an unavoidable by-product of development, leading to a governance paradigm that was typically problem-driven and reactive (Xu, 2017). In response to emerging marine pollution, the state’s primary response was to establish a foundational legal order.

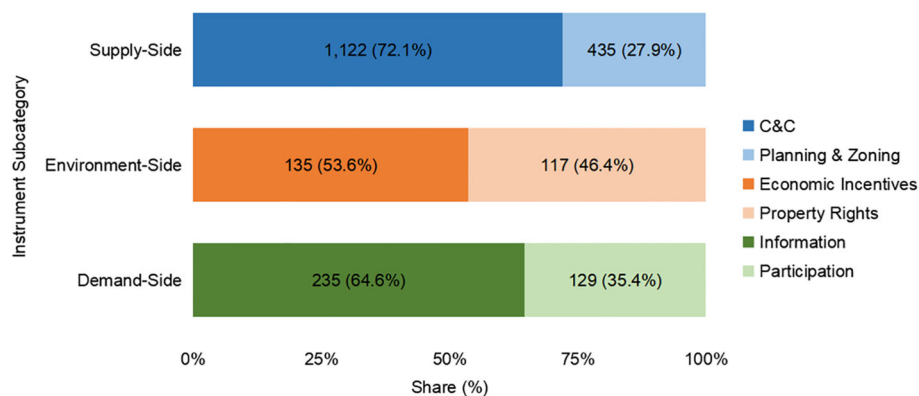


FIGURE 3

Instrument subcategory mix by SED (1982–2024). At the subcategory level, C&C and Information are the most frequently used instruments, while Economic Incentives and Property Rights are roughly balanced.

TABLE 3 Specific policy instruments across SED: frequencies and shares (1982–2024).

Functional dimension	Subcategory	Specific instrument	Frequency (N)	Share (%)
Supply-side	C&C	Bans & Mandates	382	17.6
		Penalties & Corrective Measures	261	12.0
		Standards & Limit Values	146	6.7
		Inspection & Enforcement	125	5.8
		Use & Operational Restrictions	79	3.6
		EIA Approval	75	3.5
		Permits & Licensing	54	2.5
	Planning & Zoning	Marine Protected Areas (MPAs)	133	6.1
		Three Lines & One List (3L1L)	129	5.9
		Spatial Planning & Zoning	128	5.9
		Environmental Capacity & Carrying	45	2.1
Environment-side	Economic Incentives	Environmental Fees & Taxes	70	3.2
		Eco-compensation	25	1.2
		Subsidies & Green Finance	25	1.2
		Third-Party Environmental Services & PPP	15	0.7
	Property Rights	Marine Area Use Rights	64	2.9
		Discharge Rights & Emissions Trading	51	2.3
		Environmental Credit & Offsets	1	0
		Fisheries Quota Systems	1	0
Demand-side	Information	Monitoring Network & MRV	186	8.6
		Information Disclosure	39	1.8
		Eco-labeling & Green Certification	10	0.5
	Participation	Education & Capacity-building	59	2.7
		Co-management	49	2.3
		Hearings & Public Consultation	9	0.4
		Public-Interest Litigation & Remedies	9	0.4
		Whistleblowing & Public Oversight	3	0.1
Total	N/A	N/A	2173	100

Shares are computed from unrounded counts and reported to one decimal; N = 2,173. Values below 0.05% are displayed as 0.0%; see the Frequency column for the underlying counts (e.g., 1/2,173 = 0.046%). MRV, Monitoring, Reporting & Verification; EIA, Environmental Impact Assessment.

As Figure 5 shows, Phase I features S high, E and D low. S = 86.4%, the peak across all four phases, indicating that the toolbox was almost entirely Supply-side. E and D remained nascent and marginal; neither market mechanisms nor societal capacities had yet formed. Table 5 reports the frequencies and shares of specific

instruments in Phase I. The top five are Penalties & Corrective Measures, Bans & Mandates, Standards & Limit Values, MPAs, and Use & Operational Restrictions. In short, C&C held a high share, while Spatial Planning & Zoning was still at an embryonic stage.

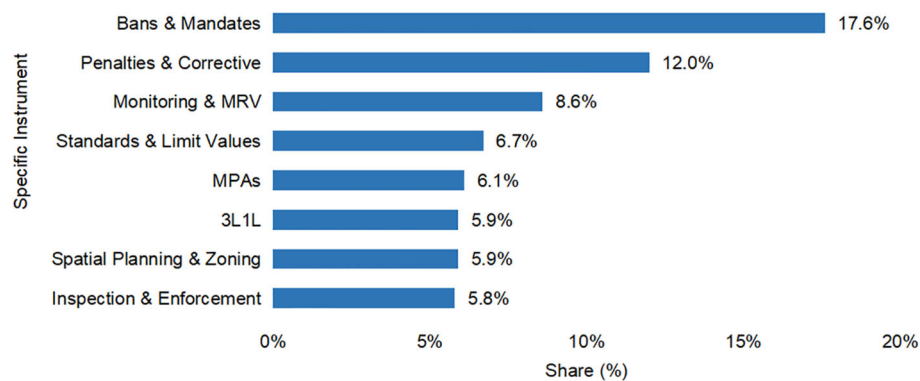


FIGURE 4

Top eight specific instruments by share (1982–2024) Note: “Top” instruments are those with a share $\geq 5\%$ of total sentence hits; N = 2,173.

Implementation centered on legislative boundary-setting and targeted clean-ups, rapidly accomplishing a “zero-to-one” regulatory build-out: statutory bans, limits, standards, and penalties set binding minimum standards for conduct, supplemented by end-of-pipe operational restrictions to consolidate order. MPAs had emerged, but mostly as principled, pointwise designations—not yet an *ex ante* mechanism tightly coupled with spatial and use governance. The net effect was to establish order and enhance enforceability; however, market incentives and empowered public participation did not substantively backstop execution.

The tool mix reflected a top-down, single-supply pathway. With weak market infrastructure and undeveloped societal capacity, C&C delivered rapid enforceability at relatively low institutional transaction costs. At the same time, the E lacked institutionalized supply, and D’s empowerment procedures were largely absent. Statutory and regulatory provisions corroborate this pattern. The 1982 MEPL, along with a series of subsequently promulgated regulations such as the Regulations on Environmental Protection in Offshore Oil Exploration and Development (1983), the Regulations on the Control of Marine Dumping (1985), and the Regulations on the Prevention of Marine Pollution from Land-based Sources (1990), collectively constructed a regulatory framework centered on C&C. Its operational mechanism was clear and direct: establishing prohibitions, defining standards, and imposing penalties through legislation. For instance, the law explicitly prohibited the dumping of specific toxic and harmful substances into the sea (Article 28 of the 1982 MEPL) and established reactive measures such as fines. These instruments represented the hard constraints of environmental regulation, directly delivered to society by the state as the sole purveyor of public goods. Their advantage lay in their ability to rapidly establish order and define behavioral baselines, playing an irreplaceable role in the zero-to-one phase of governance. During this period, although Environment-side and Demand-side instruments showed nascent signs in legal texts, their status was marginal and their function weak, reflecting a form of symbolic empowerment. For instance, while the “polluter pays” principle was mentioned, it

primarily manifested as a pollution fee system with exceptionally low rates and lax enforcement, falling far short of constituting a meaningful economic incentive capable of altering corporate cost-benefit calculations. Consequently, the role of Environment-side instruments remained extremely limited. Similarly, although the law granted “units and individuals” the right to “report and file charges” (Article 6 of the 1982 MEPL), this provision was largely

TABLE 4 Top three specific instruments within each SED function (1982–2024).

Functional dimension	Rank	Specific instrument	Share within function (%)
Supply-side	1	Bans & Mandates	24.5
	2	Penalties & Corrective Measures	16.8
	3	Standards & Limit Values	9.3
Environment-side	1	Environmental Fees & Taxes	27.8
	2	Marine Area Use Rights	25.4
	3	Discharge Rights & Emissions Trading	20.2
Demand-side	1	Monitoring Network & MRV	51.1
	2	Education & Capacity-building	16.2
	3	Co-management	13.5

Shares are calculated within each function based on sentence hits (denominators: Supply-side = 1,557; Environment-side = 252; Demand-side = 364).

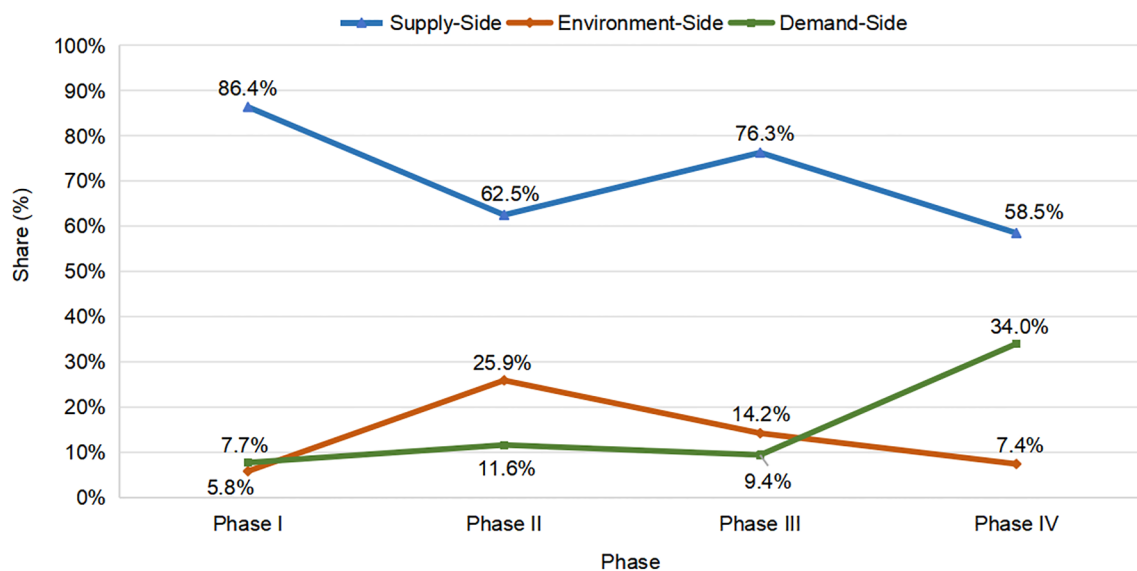


FIGURE 5

Phase-wise shares of SED instruments (1982–2024) Note: Shares are calculated within each phase based on sentence hits (denominators: Phase I = 568; Phase II = 301; Phase III = 646; Phase IV = 658). Shares for some phases may not sum to exactly 100% due to rounding. This figure highlights the persistent dominance of S instruments across all four phases, alongside a short-lived surge of E tools in Phase II and a significant rise of D tools in Phase IV. This is reflected in the changing hierarchy: from S>D>E (Phase I) to S>E>D (Phases II–III), and back to S>D>E (Phase IV).

declarative in nature, lacking concrete procedural safeguards and institutionalized channels for public participation. As a result, the societal supervisory power on the Demand Side remained dormant and largely unexercised.

Overall, Phase I exhibited a highly one-dimensional instrument structure: near-absolute dominance of the Supply-side, with the

Environment- and Demand-sides marginal. This configuration was indispensable for rapid rule-setting and the establishment of binding minimum standards, however, it seeded structural vulnerabilities—under-incentivization and weak coordination—thereby entrenching strong path dependence on S. The inherent shortcomings of this model were also evident: high governance costs, a lack of flexibility,

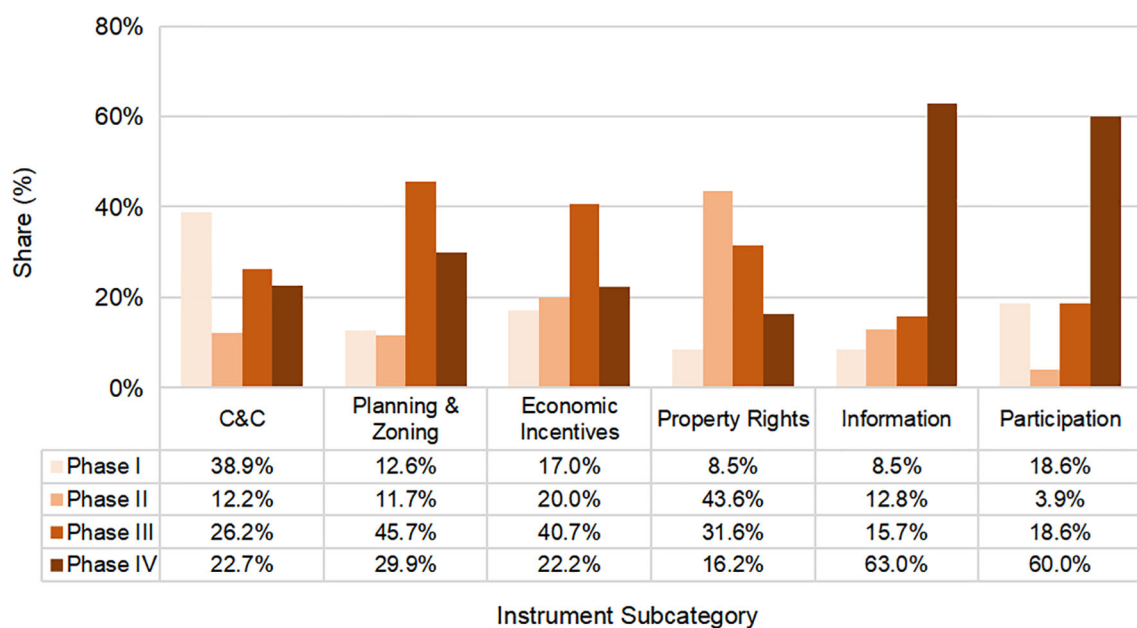


FIGURE 6

Phase-wise composition within each instrument subcategory (1982–2024) Note: Shares denote, for each instrument subcategory, the ratio of its occurrences in a given phase's policy texts to its total occurrences across all four phases (denominators: C&C = 1122; Planning & Zoning = 435; Economic Incentives = 135; Property Rights = 117; Information = 235; Participation = 129). Some columns may not sum to exactly 100% due to rounding. This figure shows a key trend: a pivot from C&C to Planning & Zoning within the S, and faster growth in Information than Participation within the D.

TABLE 5 Top five specific instruments in Phase I (1982–1997).

Phase	Specific instrument	Frequency (N)	Share (%)
Phase I	Penalties & Corrective Measures	168	29.6
	Bans & Mandates	136	23.9
	Standards & Limit Values	51	9.0
	Marine Protected Areas (MPAs)	32	5.6
	Use & Operational Restrictions	25	4.4

Shares denote, for each of the top five instruments in Phase I, the proportion of its occurrences in Phase I policy texts relative to the total occurrences of all instruments in that phase (denominator = 568).

and a widespread phenomenon where the cost of compliance exceeded the cost of non-compliance. This was because the model failed to stimulate endogenous motivation for environmental protection among polluters and society.

4.3.2 Phase II: enforcement intensification (1998–2007)—limited diversification of the toolbox

The major reconfiguration of national environmental administration in 1998 and the 1999 revision of the MEPL shifted both the style and focus of marine environmental governance. Subsequent expansions of supporting institutions brought Environmental Fees & Taxes as well as Marine Area Use Rights into view as market-oriented additions to the toolbox and opened a window to embed proceduralization and datafication.

As Figure 5 shows, in Phase II the share of S fell to 62.5%, while E and D both rose. E increased sharply to 25.9%, surpassing D (11.6%) for the first time. Table 6 indicates that the Top 5 instruments were, in order: Marine Area Use Rights (1st), Bans & Mandates (2nd), Spatial Planning & Zoning (entering the top three for the first time), and Monitoring Network & MRV and Use & Operational Restrictions (tied for fourth). Overall, the structure displays a nascent regulatory–market dual track alongside limited diversification.

The Top 5 instruments point to three parallel pathways of implementation: (1) baseline constraints remain the immediate lever—centered on Bans & Mandates together with Use & Operational Restrictions—yet within S the center of gravity shifts from hard commands and penalties toward planning and admissibility; (2) entry-point and spatial governance begins to take shape, led by Marine Area Use Rights and Spatial Planning & Zoning; and (3) a monitoring-and-reporting spine advances proceduralization and informatization, building the governance “nervous system” that undergirds subsequent performance evaluation and accountability.

The rise of E was opened by policy windows created through institutional changes and legal revisions. However, it struggled to deliver sustained, scalable supply under constraints in

contemporaneous trading rules, market infrastructure, and unstable property-rights expectations; it functioned largely as a supplementary layer. In contrast, planning and admissibility, as well as monitoring and reporting, integrated more rapidly because they coupled tightly with the existing administrative and enforcement apparatus, offered high implementability, and interfaced seamlessly with “hard-enforcement” settings such as targeted clean-ups, total load control, and emergency response. Following the Environmental Impact Assessment Law (2003), procedural requirements for major marine-related projects—ex ante assessment, information disclosure, and public comments—reinforced this trajectory, facilitating a shift from one-dimensional end-of-pipe constraint toward a chain-based regime of risk prevention at entry, process supervision, and end-stage correction.

Overall, Phase II displays a nascent regulatory–market dual track: the Supply-side remains primary, but its internal weight reallocated from hard commands and penalties toward front-loaded planning and use admissibility; E’s emergence reflects the introduction of price and rights elements; D’s take-off signals the embedding of proceduralization and informatization. However, this diversification is additive rather than substitutive: incentives remain weak and procedures still emergent, insufficient to dislodge the core position of command and control; the depth and breadth of paradigm change thus remain limited.

4.3.3 Phase III: spatial-control intensification (2008–2017)—toolkit enrichment with aggravated structural snap-back

The establishment of MEP in 2008 and the systemwide rollout of marine spatial-governance tools—exemplified by the National Marine Functional Zoning (2011–2020) issued in 2012—served as institutional triggers for this phase. The 18th National Congress of the Communist Party of China elevated Ecological Civilization to a strategic priority within the nation’s Five-in-One overall plan, and advanced the Maritime Power strategy, signaling that marine environmental governance had been incorporated into top-tier national security and development agendas.

As Figure 5 show, the share of S rebounded to 76.3%, while E and D both declined (E = 14.2%, D = 9.4%), with a sharper drop for E, indicating that market incentives and property-rights tools did not translate into sustained, large-scale supply. Table 7 shows Spatial Planning & Zoning rising as the core lever; MPAs entered the top three for the first time; and Bans & Mandates again took the top position—together marking a clear re-centering on S. The surge in MPAs is closely tied to the zoning plan’s target—raising MPA coverage to 5% of jurisdictional sea area by 2020—embedded in a spatial- and use-control framework. In tandem, MPAs and marine spatial planning (MSP) established ex ante constraints through a zoning–admissibility–use sequence, shifting regulatory emphasis from end-of-pipe enforcement to source and spatial prevention while reducing administrative discretion and evidentiary costs through clear boundaries and control rules.

This phase consolidated an execution style of front-loaded planning paired with end-of-pipe remediation. Clarifying spatial and use boundaries and tightening admissibility reduced

TABLE 6 Top five specific instruments in Phase II (1998–2007).

Phase	Specific instrument	Frequency(N)	showsShare(%)
Phase II	Marine Area Use Rights	43	14.3
	Bans & Mandates	38	12.6
	Spatial Planning & Zoning	30	10.0
	Monitoring Network & MRV	25	8.3
	Use & Operational Restrictions	25	8.3

Shares denote, for each of the top five instruments in Phase II, the proportion of its occurrences in Phase II policy texts relative to the total occurrences of all instruments in that phase (denominators = 301).

enforcement costs, while penalties and corrective measures reinforced constraints at the back end. By comparison, the empowerment effects of market incentives and public participation remained limited. Consistent with this pattern, annual bulletin indicators—such as the share of coastal waters meeting good-quality standards and inorganic-nitrogen metrics—showed episodic improvement, suggesting that source prevention plus spatial constraint strengthened the pathway to effectiveness.

Between 2012 and 2015, the National Marine Functional Zoning (2011–2020), the National Island Protection Plan, and the National Marine Main Functional Zoning established a layered planning system comprising main functional zones, marine spatial elements, and marine functional zones, thereby advancing front-end coordination of development and conservation. During this period, Eco-compensation appeared more frequently in the texts (15 mentions in our sample, the highest among the four phases). Marked by the 2011 Guiding Opinions on Pilot Marine Ecological Compensation, it introduced a conceptual turn toward using economic levers to redress development and conservation imbalances; however, it largely remained at the level of principle and pilots, without scaling into a marketized supply.

In sum, Phase III presents spatial-control intensification alongside regulatory snap-back: the toolkit broadened, but the structural imbalance deepened—S rose, E remained anemic, and D grew only modestly. This configuration shifts the governance focus further upstream to the management of spatial boundaries and ecological thresholds.

4.3.4 Phase IV: restructuring & proceduralization (2018–present)—information-led procedural turn and marketization stagnation

The 2018 reorganization of the environmental governance apparatus (creation of MEE and MNR) and the nationwide rollout of 3L1L, coupled with the “dual-carbon” targets and the

2023 revision of the MEPL, integrated MRV, information disclosure, rolling evaluations, and central eco-environmental inspections into a compliance–accountability loop, triggering a systemic lift in proceduralized governance.

As Figure 5 shows, in Phase IV, D rose sharply to 34.0% (with Information at 22.5% and Participation at 11.6%), E declined further to 7.4%, and S fell to a historical low of 58.5%. Table 8 reports 3L1L jumping to second, Co-management entering the Top 5, and monitoring instruments—led by Monitoring Network & MRV—rising markedly. The policy-mix structure thus exhibits proceduralization on the rise, marketization stalled, and S relatively lower yet still the main pillar. Within S, a structural reallocation is evident—from regulation toward planning–thresholds–admissibility.

Policy execution in this phase is organized around a government-led compliance–inspection–accountability chain, with the workflow shifting from end-of-pipe remediation to a full target–monitor–evaluate–account sequence. The 3L1L pre-positions ecological protection redlines, environmental quality bottom lines, resource utilization upper limits, and an environmental access list at the decision entry point, thereby establishing rigid thresholds and list-based governance that reduce enforcement uncertainty and evidentiary costs. The elevation of Monitoring & MRV makes a “high-frequency monitoring, information disclosure, inspection, and rectification” loop the routine infrastructure, improving problem detection and correction efficiency. The entry of Co-management into the Top 5 indicates an organizational step-up in cross-actor collaboration, while participation remains largely procedural, with limited substantive embedding and resource provision by societal actors.

The core mechanism can be summarized as “three strengths on the process side, one weakness on the structural side.” Within S, the mix is optimized—shifting from regulation toward planning, and extending planning from spatial governance to thresholds and admissibility, thereby enabling ex ante control at the entry point. D exhibits a procedural surge: information duties, MRV, rolling evaluations, and routine inspections scaffold a procedural platform. However, on Participation, public engagement continues to be administratively led, with weak role definition and limited societal organization. E remains anemic: price- and rights-based incentives (e.g., tradable discharge, sea-use quotas, scaled eco-compensation) lack institutionalized supply and operational levers, hindering stable cost–effectiveness improvements and cross-actor coordination. The result is a one-sided reinforcement along the S and D (information and accountability) axes with E mostly absent, which weakens internal complementarities in the policy mix and solidifies the structural trilemma of strong supply, anemic environment, and fragmented demand, with signs of further intensification in this phase.

Overall, Phase IV presents a proceduralization upturn with a marketization stall: governance becomes more traceable and accountable, but weak incentives and limited coordination constrain the transmission from strengthened processes to improved outcomes, in both depth and breadth.

TABLE 7 Top five specific instruments in Phase III (2008–2017).

Phase	Specific instrument	Frequency(N)	Share(%)
Phase III	Bans & Mandates	122	18.9
	Spatial Planning & Zoning	75	11.6
	Marine Protected Areas (MPAs)	74	11.5
	Penalties & Corrective Measures	45	7.0
	Standards & Limit Values	41	6.3

Shares denote, for each of the top five instruments in Phase III, the proportion of its occurrences in Phase III policy texts relative to the total occurrences of all instruments in that phase (denominators = 646).

4.4 Integrated diagnosis: the structural trilemma—strong supply, anemic environment, and fragmented demand

Based on an in-depth analysis of the evolutionary trajectory outlined above, this study posits that the core contradiction within China's marine environmental governance policy system lies not in a scarcity of instruments, but rather in a severe imbalance in the policy mix. This imbalance can be diagnosed as the structural trilemma: strong supply, anemic environment, and fragmented demand—that is, regulation and planning dominate; market incentives are chronically underprovided, and social instruments rise episodically but lack stability—manifesting as regulatory overload with an incentive deficit (Figure 7). Quantitatively, S is consistently and significantly higher than E and D across the full period; the Top 8 specific instruments are persistently S-led, with no E instrument entering. By phase, the pattern is clear: Phase II shows a brief rebalancing; Phase III snaps back; Phase IV delivers an information-led procedural turn while E weakens further.

First, strong supply and path dependence. The governance system is heavily reliant on Supply-side instruments, primarily represented by C&C regulations and administrative supervision, which has fostered a strong path dependence. This suite of tools is rapidly responsive and demonstrably effective in tackling urgent, single-source pollution incidents. However, their inherent drawbacks—high administrative costs, immense pressure on local governments, and the rigidity of a one-size-fits-all approach—render them ill-suited for addressing complex, systemic marine ecological issues such as ecosystem degradation, climate change impacts, and non-point source pollution. Consequently, they are highly susceptible to diminishing marginal returns in policy effectiveness. The quantitative results indicate that S fluctuates over time but remains the structural pillar. Within S, weight shifts from C&C toward planning—thresholds—admissibility, and 3L1L

TABLE 8 Top five specific instruments in Phase IV (2018–present).

Phase	Specific instrument	Frequency(N)	Share(%)
Phase IV	Monitoring Network & MRV	129	19.6
	Three Lines & One List (3L1L)	100	15.2
	Bans & Mandates	86	13.1
	Inspection & Enforcement	56	8.5
	Co-management	45	6.8

Shares denote, for each of the top five instruments in Phase IV, the proportion of its occurrences in Phase IV policy texts relative to the total occurrences of all instruments in that phase (denominators = 658).

gains salience—evidence that strong supply has not diminished but has been re-anchored upstream at the entry point.

Second, anemic environment and market failure. Environment-side instruments, primarily based on market mechanisms, are underdeveloped and anemic in their application. The fundamental cause lies in the failure to establish a mature and vibrant institutional environment where protectors are sustainably rewarded and polluters genuinely bear the costs. The absence of a robust market framework means that enterprises and local governments lack effective mechanisms to transform marine environmental protection into an endogenous economic driver. Consequently, the fundamental conflict between marine environment and development cannot be effectively reconciled nor achieve Pareto improvements through market-based approaches, and the decisive role of the market in allocating marine environmental resources remains far from realization. The quantitative results show that E only edges up modestly in Phase II before declining, and that no E instrument reaches the Top 8 at any point, indicating that an anemic environment is a structural condition rather than a transitory deviation.

Third, fragmented demand and the absence of collaborative governance. Demand-side instruments, primarily focused on information disclosure and public participation, remain fragmented. Although legal rights are granted, there is a severe deficit in effective participatory channels, procedural safeguards, and the empowerment of social organizations. This fragmentation hinders the effective integration of social forces, preventing the formation of a sustained, stable, and rational bottom-up mechanism for supervision and cooperation. The needs and insights of the public have yet to be systematically incorporated into the governance process, leaving the ideal paradigm of collaborative governance far from achieved. The quantitative results indicate that D rises notably in Phase IV, but its composition is information-heavy and participation-light. Although Co-management appears in the Top 5, the increase reflects more frequent references to

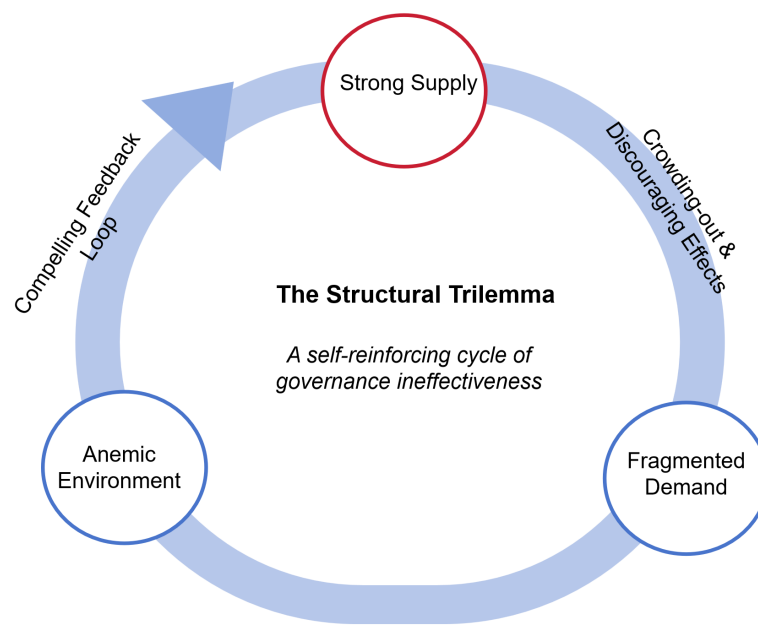


FIGURE 7
The structural trilemma of marine environmental governance.

organizational forms rather than institutionalized participatory authority; societal actors remain thinly embedded and under-resourced. In short, fragmented demand amounts to episodic upticks without a stable social–market co-governance base.

This trilemma collectively shapes the current state of China's marine environmental governance. On the one hand, there is forceful and escalating policy investment by the state (strong supply); on the other hand, governance outcomes remain stagnant, with persistent, unresolved systemic problems largely due to the failure of the anemic environment and fragmented demand to provide effective support. Evidently, overcoming this trilemma can no longer be achieved by merely increasing the quantity or intensity of Supply-side instruments. Instead, it requires a fundamental shift in focus towards the structural rebalancing of the entire policy instrument system.

5 Discussion

Our diagnosis of a structural trilemma prompts a deeper examination of the persistent challenges hampering China's marine environmental governance. A widely accepted explanation posits an implementation gap, where local protectionism and growth-oriented incentives lead to selective or discounted policy enforcement (Ren et al., 2022). A plausible counterargument, then, is that a top-down, C&C system could, in principle, succeed if coupled with an extensive monitoring program and uncompromisingly aggressive enforcement. Our findings, however, compel a more fundamental inquiry: is this pervasive gap the root cause of governance failure, or is it a predictable symptom of the structural imbalance in policy instruments we have identified? We contend that an overreliance on Supply-side

instruments inherently fosters such gaps. This is because such a system struggles with the information processing and adaptive demands of complex social-ecological systems (Folke et al., 2005); its reliance on coerced compliance is far less resilient than the normative commitment built through public engagement (May, 2005); and recent evidence confirms that even when maximally enforced through campaign-style inspections, this high-cost model fails to achieve lasting change (Guo, 2023). Therefore, the structural imbalance diagnosed in this study should be conceptualized as a deep-seated pathology that underlies and perpetuates the implementation gap, offering a more foundational explanation for why even a theoretically perfected C&C system consistently underdelivers in practice.

Having established the inherent limitations of a Supply-side dominant model, a second critical debate concerns the viability of the Environment-side instruments themselves. Indeed, the effectiveness of market-based tools such as ETS is a subject of intense global debate (e.g., Grubert, 2025). However, this critique is often aimed at the ultimate goal of absolute zero emissions, whereas the regional pollutant management central to this study targets control within environmental carrying capacities—a context that provides a viable application space for market mechanisms. Substantial domestic evidence substantiates this potential, showing that similar trading mechanisms have successfully spurred efficiency gains and technological innovation in China's carbon (Wang et al., 2023) and water rights markets (Yan et al., 2024; Chen et al., 2021). More directly, the feasibility of such systems in the context of China's maritime shipping has been confirmed through modeling studies, which demonstrate that a well-designed marine ETS (METS) can effectively incentivize investment in cleaner technologies and achieve significant carbon reductions (Zhu et al., 2018). Furthermore, the latest systematic

assessments of the EU's extension of its ETS to the maritime sector indicate that such systems can achieve emissions reductions at a lower societal cost while incentivizing innovation (Kotzampasakis, 2025). Crucially, these same studies underscore the profound conditionality of ETS success, highlighting institutional risks such as emissions leakage and allocative inequity. This conditionality powerfully reinforces our core thesis: before market instruments can be effectively deployed, the state must prioritize the construction of robust institutional infrastructure, including clear property rights, reliable monitoring, and equitable rules. This is a strategic sequencing to ensure the eventual success of market-based instruments.

The emergence of this trilemma is no coincidence; it is the inevitable outcome of the interaction between China's specific state governance logic and the complex nature of the marine environment. Consistent with the foregoing evidence, this predicament takes the form of process-side strengthening alongside structure-side imbalance: front-end thresholds, monitoring, and accountability have tightened, yet they have not automatically translated into a functional rebalance of the instrument mix.

First, the roots of strong supply lie in statist governance inertia and a crisis-driven policy preference. Confronted with urgent legitimacy challenges—such as coastal ecosystem degradation and frequent pollution incidents—the state naturally resorts to its most familiar and direct tools: C&C administrative interventions. This preference is mutually reinforced by strong, accountability-driven administrative mobilization. In practice—e.g., marine inspections and Blue Bay remediation—the pursuit of immediate, visible results has been converted into continual ratcheting-up of Supply-side tools such as mandatory bans, discharge standards, shoreline controls, and entry-stage planning, which over time has hardened into pronounced path dependence. In contrast, Environment-side and Demand-side instruments—which require long-term cultivation and yield indirect results—are relegated to a subordinate position within the policy hierarchy.

Second, the predicament of the anemic environment profoundly reflects a core causal mechanism: the failure of cost internalization. This mechanism is triggered by the institutional frictions that market mechanisms encounter in the vast and fluid marine domain. The effectiveness of Environment-side instruments is highly dependent on institutional infrastructure, including clear property rights and low monitoring costs. However, the physical attributes of the ocean—its fluidity, connectivity, and the inherent difficulty in defining clear property rights for mobile resources and diffuse pollutants—systematically undermine these preconditions. This dilemma is vividly illustrated by the case of eco-compensation for marine ranching. The high transaction costs arise not only from the scientific complexity of assessing the ecosystem service value of a given sea area but are more fundamentally rooted in the near impossibility of tracing liability for damages. How can one precisely quantify the cross-regional, non-point source damage inflicted on a specific ranch by upstream land-based pollution or adjacent aquaculture activities? Without clear liability, costs cannot be internalized, and the market mechanism collapses. This case

exemplifies a classic market failure driven by intractable externalities and severe information asymmetries. Consequently, because polluters are not compelled to bear the true costs of their environmental impact, policy advocacy for market-based change remains largely aspirational. Market-oriented instruments thus tend to produce “loud thunder but little rain” in the absence of clearly delineated tradable rights, a robust measurement and verification base, and aligned fiscal and price signals. This results not only in a governance approach that is economically inefficient and unsustainable (Guo, 2023), but also locks the system into a structural trap of anemic application.

Finally, fragmented demand reveals the complex dynamics of state-society relations in the specialized field of marine governance. Empowering Demand-side instruments implies ceding a degree of oversight power to society. In practice, however, public participation is often designed as a form of proceduralized and narrowly circumscribed involvement. It is channeled towards downstream stages, such as EIA hearings for projects, while remaining unable to influence upstream strategic decisions concerning marine functional zoning or major land reclamation projects. Information disclosure faces similar constraints; publicly released materials are often limited to overview-style water quality reports, whereas more detailed, process-specific information with greater oversight value—such as data on specific pollution sources or enforcement actions—remains relatively scarce. This design constitutes a core causal mechanism: a malfunctioning feedback and trust loop. When meaningful participation remains limited, the perceived procedural justice of the governance system is eroded. This, in turn, undermines the public's normative commitment and willingness to comply, severing a vital feedback loop that signals emerging problems and societal preferences to policymakers. In consequence, the state is compelled to rely more heavily on a top-down, coercive compliance model, which is inherently less resilient and sustainable than one built on social trust and voluntary buy-in (May, 2005). This dynamic traps public concerns over issues such as microplastic pollution or fisheries depletion into isolated incidents, failing to coalesce into systemic pressure that can drive the continuous optimization of the marine governance system, and ultimately leaving the Demand Side in a fragmented state. However, this characterization of a fragmented Demand requires a nuanced interpretation that distinguishes it from outright ineffectiveness. The dynamic reflects what scholars term “consultative authoritarianism,” where the state fosters a symbiotic rather than confrontational relationship with society (Ho, 2001). This means civil society actors are not passive victims but active agents who strategically “find a way in” (Cooper, 2014). By framing themselves as non-political partners and providing professional services, they trade cooperation for access and policy influence. This model of state-guided effectiveness is also evident in the legal domain, where the Environmental Public Interest Litigation system, despite being state-led, is acknowledged even by its critics for making a significant contribution to environmental protection (Li and Song, 2024). Therefore, the fragmentation observed in our analysis is not an absence of influence, but a specific mode of state-channeled participation. It is effective on a case-by-case or project-specific

basis but is institutionally constrained from consolidating into a pressure capable of challenging the dominant C&C governance paradigm. We acknowledge the practical constraints: in a highly coordinated, compliance-oriented administrative system, advancing participation upstream and enhancing its authority faces institutional limits. This calls for gradually expanding workable participation interfaces and information accessibility—without inducing institutional conflict—and embedding these features in *ex ante* planning and use-allocation processes.

Furthermore, we argue that the structural trilemma diagnosed in this study rests on a more fundamental constraint: the persistent, systematic deficits in marine environmental monitoring data. Indeed, effective monitoring of vast and dynamic marine ecosystems is globally costly and technically demanding (Nygård et al., 2016). In China, this poses a particularly salient governance challenge, because it requires sustained, large-scale public finance as well as long-term political will and cross-sectoral coordination—resources that must contend with more immediate developmental objectives. This inherent fiscal and operational pressure helps explain why the state tends to rely on more easily manageable C&C tools at the Supply Side, while investments in market-based instruments and public oversight mechanisms, which require complex data infrastructures, remain comparatively limited. The data deficit is not merely a technical problem, while it generates and exacerbates the imbalances among policy instruments that we observe. First, this data deficit is a critical technical bottleneck driving the weakness of the Environment Side. Market-based instruments, exemplified by emissions trading and ecological compensation, depend on a robust MRV system. If emissions or the value of ecosystem services cannot be measured with precision and credibility, property rights cannot be clearly defined, and trading cannot proceed. This largely explains why, in China's marine environmental policy, market-based tools have long remained in pilot stages with limited traction, because the institutional infrastructure supporting their operation—the data base—is not yet fully established. Second, data scarcity also distorts the effectiveness of Supply-side instruments. Without sufficiently high spatial-temporal resolution environmental data, C&C tools struggle to achieve precise regulation and tend to default to coarse, one-size-fits-all management. At the same time, because policymakers cannot accurately assess the actual environmental outcomes of interventions, they tend to respond by increasing the number of regulations and tightening penalties, reinforcing path dependence on Supply-side tools rather than optimizing their efficiency. Finally, on the Demand Side, the accessibility of monitoring data is the key to turning public participation from formalism into substance. If authoritative data on environmental quality and pollutant discharges are not publicly available, public supervision becomes “water with no source.” Therefore, ensuring public access to data is not merely a technical or procedural step but a profound governance transformation, as it entails a reallocation of power and information between government and society. The absence of mandatory, standardized data disclosure mechanisms is precisely the institutional root of the observed phenomenon on the Demand Side—information disclosure exceeding actual

empowerment of participation. Consequently, the data deficit is not only an obstacle to the implementation of individual policy tools but also an underlying mechanism that cements the current structural imbalance and impedes the policy system from evolving toward a more efficient, coordinated governance regime.

This diagnosis carries significant theoretical implications for the broader field of marine governance theory. It enriches the analytical dimensions of policy mix theory. While traditional research has focused on the diversity of instrument types (Yao et al., 2023), the SED framework introduces a function-based analytical perspective. It demonstrates that a marine policy mix that appears diverse in type can, in reality, remain monolithic in function. This suggests that assessing the effectiveness of a marine environmental policy mix requires looking beyond mere diversity to its functional balance. A truly effective policy mix should exhibit functional synergy, wherein the Supply, Environment, and Demand dimensions mutually reinforce each other and engage in constructive interaction. More broadly, this structural diagnosis provides comparative relevance: for other coastal states—whether characterized by strong state mobilization or greater decentralization—the design of policy sequencing may matter more than the transplantation of individual instruments. Priority should be to establish enforceable *ex ante* thresholds and credible monitoring platforms, while creating the institutional conditions under which price and rights signals and empowered public participation can operate effectively. This helps avoid a lock-in to process-heavy yet structurally imbalanced governance.

6 Conclusion and actionable recommendations

By constructing the SED analytical framework, this study has systematically traced the forty-year evolutionary trajectory of China's marine environmental policy instruments. It reveals that the core paradox of China's marine environmental governance—the mismatch between policy inputs and governance outcomes—is deeply rooted in a “strong supply, anemic environment, and fragmented demand” structural trilemma. Specifically, state-led Supply-side instruments are overly dominant; Environment-side instruments, intended to establish incentive mechanisms, suffer from anemic application due to a weak institutional foundation; and Demand-side instruments, aimed at empowering society, are rendered fragmented in their effectiveness due to restrictive design. The study argues that this functional imbalance constitutes the fundamental obstacle underlying the current governance implementation gap. Therefore, the key to overcoming this impasse lies in a profound structural rebalancing of the policy instrument system. Meanwhile, rising marine climate risks, the deepening of marine spatial planning, and the accelerated rollout of the blue economy make the shift from problem-driven responses to structural rebalancing and resilience building increasingly urgent. The SED framework offers an operational approach and a clear evaluative baseline for this shift.

This study proposes a systematic pathway to resolve the dilemma. At its core, this approach focuses on rebalancing the policy system through a three-dimensional, synergistic strategy: “activating the Environment Side, empowering the Demand Side, and refining the Supply Side,” thereby reshaping the landscape of marine environmental governance.

First, activate the Environment Side by building the institutional infrastructure necessary for market-based instruments. Overcoming the anemic application of Environment-side instruments requires the state to undergo a crucial role transition: from merely advocating policies to actively constructing robust institutional infrastructure. On one hand, to accelerate the legal clarification of marine resource property rights, particularly through bold piloting and formal confirmation in areas such as pollution rights and aquaculture carrying capacity rights, with the aim of fundamentally reducing market transaction costs. On the other hand, it is critical to establish a robust Monitoring, Reporting, and Verification (MRV) system, the essential data backbone that translates abstract property rights into quantifiable, tradable assets. This system is the non-negotiable cornerstone for ensuring market instruments are not only operable and settlement-ready but also credible and trustworthy. Based on this MRV foundation, the state must define the objects of rights for trading and compensation, together with their corresponding spatial units, through MSP and 3L1L; and link watershed total-load control with nearshore quotas and compensation to create an integrated land-sea accounting boundary. Building on this, establish regional platforms for ecological compensation and trading aligned with MSP and 3L1L boundaries, standardize valuation and settlement rules, and leverage fiscal co-funding to crowd in blue bonds and results-based financing, directing private capital toward marine ecological restoration and sustainable industries and thereby internalizing externalities. On incentives and pricing, develop tradable discharge and sea-use quotas and performance-based payments; incorporate shadow pricing and carbon pricing into major project appraisal, and remove perverse subsidies. Align pricing and settlement with legally binding climate-ecological thresholds and cumulative impact assessment baselines, with explicit baseline calibration and risk adjustment. Taken together, these arrangements move market instruments from scattered pilots to standardized, scalable supply, creating mechanisms that are auditable, settlement-ready, and replicable, and that are functionally coupled with front-end planning and the information-assessment-inspection chain of accountability.

Second, empower the Demand Side by shifting public participation from procedural to substantive engagement. The fundamental solution to the fragmented state of the Demand Side lies in establishing participation and oversight mechanisms capable of exerting meaningful influence on decision-making. A prerequisite is deep information transparency. More specifically, the mandatory, standardized, and real-time disclosure of key environmental monitoring data is the essential precondition for transforming public participation from a procedural formality into a substantive, evidence-based process. This entails mandating the disclosure of critical information—including pollution discharge

permits of key enterprises and the entire environmental impact assessment process for major projects—and incorporating climate and ecological monitoring indicators, as well as licensing and performance data for blue-economy projects, into a unified, standardized disclosure framework, thereby converting data into public supervisory capital. Subsequently, institutional channels for public participation must be substantively strengthened. Introduce binding deliberative mechanisms at the front end of major decisions, such as marine functional zoning. Move participation interfaces *ex ante* to the preparation of marine MSP, to use-admissibility decisions, and to linked basin-coast-nearshore decision nodes. Establish a closed-loop procedure with fixed consultation windows, response cycles, and statements of adoption, and release any adjustments in sync with the integrated spatial “one map.” Finally, consolidating a vibrant civil society requires the cultivation of professionalized social organizations. Through support mechanisms such as government procurement of services, marine environmental NGOs should be enabled to mature into key bridges between government and the public. Community monitoring and citizen science should be incorporated into the MRV system to provide a societal backstop for problem detection and correction.

Third, refine the Supply Side by prioritizing entry-point optimization, namely planning *ex ante*, rigid thresholds, and admissibility control. We recommend coordinating MSP, 3L1L, basin-wide total-load control, and coastal-zone regulation under a single system of targets and indicators, a common monitoring-evaluation mechanism, and an integrated spatial information platform (“one map”). Marine environmental quality objectives (MEQOs) should define shared cross-sectoral responsibilities and lines of accountability. In licensing and planning, set climate-adaptive thresholds and buffers (e.g., sea-level rise, extreme weather) and conduct cumulative impact assessment (CIA). For blue-economy projects, including offshore wind, aquaculture, marine tourism, adopt closed-loop entry-performance-exit management to avoid countervailing externalities from “blue growth.” In enforcement, implement risk-tiered, differentiated enforcement; routinize remote sensing, radar, and Automatic Identification System (AIS) monitoring alongside third-party compliance audits; and apply linked measures for repeat violations, including license withdrawal, blacklisting, credit sanctions, and fiscal constraints. These advanced monitoring technologies should be integrated into a comprehensive “Smart Ocean” system. Such a system serves a dual purpose: it enables precision enforcement by shifting from reactive patrols to predictive, data-driven interventions, and it facilitates the dynamic evaluation of policy effectiveness, creating a feedback loop for the adaptive management of plans and regulations. This ultimately transforms C&C from coarse management into verifiable, accountable, and coordinated precision governance within a land-sea integration framework.

Pragmatically, these reforms should follow a deliberate, phased three-step roadmap to ensure their effectiveness. Step 1: Institutionalize the Foundation (Refine S). The starting point is to translate science-based environmental quality baselines and total

pollutant load caps into legally binding, spatially explicit admissibility controls. This *ex ante* institutional design, supported by a transparent MRV system, serves as the cornerstone upon which subsequent steps can operate effectively. Step 2: Activate Market Incentives (Scale E). On the foundation of a clear cap and credible MRV data, market-based instruments are endowed with tradable assets and a basis for settlement, enabling them to genuinely guide efficient resource allocation through price signals. Step 3: Deepen Public Participation (Empower D). With the public disclosure of environmental data and market transaction information, public oversight gains a solid evidentiary basis. This empowers the public to conduct substantive supervision of both the government's enforcement of baselines and corporate market behaviors, thereby providing long-term resilience and legitimacy to the entire marine governance system. This sequencing logic is paramount, as it circumvents the failures associated with premature reforms on a weak institutional foundation and offers a pragmatic and powerful pathway out of the structural imbalance.

While this study forges a new path for understanding China's marine governance, its limitations also highlight clear directions for future scholarly inquiry. Using the SED framework, we diagnose structural imbalance but do not causally identify its institutional-political drivers. Two obstacles remain. First, the multilayered interactions across organizational processes and institutional arrangements exceed what current text-as-data can support for robust causal inference. Second, key variables—such as participatory authority and enforcement intensity—lack consistent, comparable measurement at the national scale. Within this framework, future research could combine multi-source evidence with cross-context comparisons to identify how thresholds, incentives, and participation are coupled; alternatively, it could construct a policy instrument balance index and use econometric methods to assess its relationship to governance performance, compliance costs, and scope conditions. Beyond these methodological extensions, the broader value of the SED framework lies in its utility as a transferable diagnostic lens to reveal the distinct structural imbalances that may exist in other maritime nations. For instance, in a context with a strong tradition of environmental civil society (e.g., Japan), the SED framework would likely identify a highly active Demand Side (D). Consequently, its core structural challenge might not be a deficit of participation, but rather the dynamic tension between a strong state-led Supply Side (S) and an equally empowered societal Demand Side (D). This points to a different governance dilemma, one centered on reconciling state-society conflicts rather than overcoming public apathy. Conversely, in some developing ASEAN nations, the framework might diagnose a more foundational condition, where the core challenge would be a “tri-sector capability gap.” The true value of the SED framework, therefore, lies not in offering a standardized template for reform, but in its analytical capacity to delineate the distinct structural deficits inherent to a specific context, thereby providing a solid starting point for crafting tailored governance reform pathways.

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Supplementary material

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