

Article

The Logic of Collaborative Strategy Selection for Regional Environmental Sustainability: An Empirical Study of Intergovernmental Relations in the Beijing–Tianjin–Hebei Region

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Abstract

Effective intergovernmental collaboration is essential for regional environmental sustainability. Using the Beijing–Tianjin–Hebei (BTH) region as a case study, this research examines how different collaborative relationships influence governance behaviors and outcomes. By classifying collaborations into formal and informal types, we employ a Probit model to analyze their intrinsic dynamics. The key findings are as follows: (1) Under different types of intergovernmental collaborative relationships, governments adopt distinct collaborative governance behaviors. The Probit estimates indicate that under hierarchical pressures, Multi-level relations significantly increase the likelihood of formal tools ($\beta = 1.010$, $p < 0.05$), whereas Diagonal ties strictly favor flexible informal mechanisms ($\beta = -1.116$, $p < 0.01$). (2) Cumulative cooperation experience reduces transaction costs, driving a profound shift toward informality at the 1% significance level across all baseline models. (3) When addressing collaborative governance matters that require cross-provincial cooperation, governments tend to adopt formal collaborative behavior models. (4) When facing urgent environmental issues that demand rapid resource mobilization and immediate decision-making, collaborative governance participants prefer informal collaborative governance approaches. This study clarifies the behavioral logic of local policy tools, offering an institutional framework to optimize regional collaborative networks and advance long-term environmental sustainability in complex eco-corridors.

Keywords: regional sustainability; collaborative strategies; cross-provincial cooperation; environmental governance; Probit framework

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1. Introduction

Achieving transboundary environmental sustainability represents a paramount global challenge, requiring fragmented jurisdictions to integrate their administrative goals. The cross-jurisdictional and negative-externality nature of environmental pollution has created opportunities for local governments to break through traditional administrative boundaries and implement intergovernmental collaborative governance [1–3]. The relevant provisions on deepening ecological and environmental institutional reform in the Decision of the Central Committee of the Communist Party of China on Further Comprehensively Deepening Reform and Advancing Chinese Modernization, adopted at the

Third Plenary Session of the 20th CPC Central Committee, have further laid a solid institutional foundation for intergovernmental environmental collaborative governance. Regional environmental coordination is no longer merely an administrative adjustment but a crucial pathway for long-term sustainability transitions [4]. However, a prominent challenge in transboundary sustainability is determining how fragmented jurisdictions choose between binding formal agreements and agile informal pacts when navigating asymmetric power dynamics.

In recent years, Chinese governments at all levels have continuously innovated environmental collaborative governance practices to address increasingly frequent regional and composite environmental pollution problems. Examples include the Taihu Lake Blue Algae Prevention and Control Collaboration Mechanism Agreement for comprehensive water environment management in the Taihu Basin, the Beijing–Tianjin–Hebei and Surrounding Areas Air Pollution Prevention and Control Joint Prevention and Control Mechanism for improving air quality, and the Yangtze River Delta Regional Cooperation Office for integrated high-quality development [5–7]. The strategic alignment of digital tools and smart public services further accelerates the efficacy of these diverse behavioral choices. Such collaborative practices inherently embed diverse collaborative governance behaviors, including formal mechanisms characterized by joint documents, cooperation agreements, and working mechanisms, as well as informal mechanisms characterized by thematic training, working meetings, and emergency coordination [8]. While these practices document what collaborations exist, existing literature lacks a systematic empirical understanding of why local governments choose specific collaborative mechanisms under different intergovernmental relationship contexts. This knowledge gap hinders the optimization of governance for sustainability. This study, therefore, seeks to answer a critical question: What determines the choice between formal and informal intergovernmental collaborative strategies in the pursuit of regional environmental sustainability?

Objectively, the diversification of collaborative behaviors constitutes an important foundation for enhancing the effectiveness of regional public affairs collaborative governance, while deeply exploring the behavioral choice logic and preferences of local governments in collaborative governance is a necessary prerequisite for further optimizing collaborative governance approaches. Existing literature heavily emphasizes the outcomes of environmental governance, yet a profound research gap persists regarding the endogenous behavioral choices of local governments under asymmetric authority. To address this deficiency, this study collates and synthesizes relevant case materials on inter-regional ecological environment collaborative governance in the Beijing–Tianjin–Hebei region during the period 2013–2023; constructs a quantitative dataset; and, based on this, deeply explores the logical relationship between different types of inter-governmental collaborative relationships and collaborative governance behaviors. The Beijing–Tianjin–Hebei region involved in this study is shown in Figure 1.

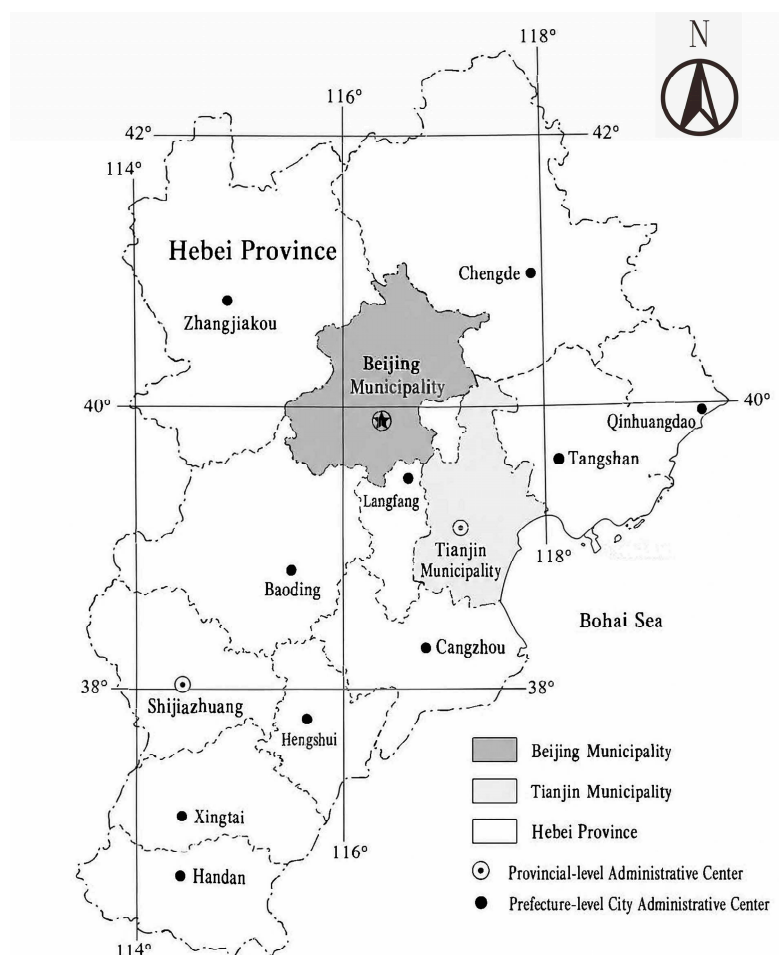


Figure 1. Diagram of the Beijing–Tianjin–Hebei Region.

The scientific contribution is twofold: logically, it unpacks the behavioral preferences of horizontal versus vertical intergovernmental ties; methodologically, it introduces an objective text-coding and validation framework to quantify empirical governmental interactions. The findings will provide actionable insights for policymakers and practitioners to design more effective, context-specific collaborative governance frameworks, thereby enhancing the efficiency and resilience of environmental sustainability efforts.

2. Literature Review and Research Hypotheses

2.1. Intergovernmental Collaborative Relations and Types of Collaborative Governance Behavior

In intergovernmental collaborative relationships, influenced to varying degrees by hierarchical authority and expected benefits, intergovernmental relations can be divided into four types: multi-level intergovernmental collaboration driven by upward and downward forces, interest-driven horizontal intergovernmental collaboration, bureaucracy-dominated vertical intergovernmental collaboration, and demand-oriented diagonal intergovernmental collaboration [9,10]. Different types of intergovernmental collaborative relationships imply varying roles and modes of action in BTH ecological and environmental integrated governance.

On the one hand, in multi-level and vertical intergovernmental collaboration, which is strongly influenced by hierarchical authority, there are clear hierarchical relationships among participating entities. Under the influence of policy requirements and performance assessments, the authoritative intervention of higher-level governments as dominant ac-

tors often prompts local governments to adopt relatively formal collaborative governance behaviors such as signing cooperation agreements and establishing cooperative institutions, which serve as important criteria for assessing local governments' collaborative governance effectiveness [11,12]. From an institutional and legal normative perspective, such formal collaborative governance behaviors are often accompanied by the establishment of institutionalized organizational relationships [13,14]. These formal mechanisms not only provide clear cooperative frameworks but also enhance the binding force and enforceability of collaborative behaviors; thus, lower-level governments as participants also tend to achieve collaborative governance with higher-level governments through formal collaborative methods [15].

On the other hand, in horizontal and diagonal collaborative governance, there are no direct hierarchical relationships among participants; the key factors promoting collaboration are primarily the expected benefits and practical needs of collaborative governance. Therefore, in such intergovernmental collaborative relationships, participating local governments place greater emphasis on whether collaborative governance behaviors can fully consider the needs and preferences of all entities and expect to respond quickly to complex cross-jurisdictional public affairs and adjust collaborative strategies in a timely manner according to actual conditions [16,17]. In other words, participants in horizontal and diagonal intergovernmental collaboration expect to form informal collaborative mechanisms that are more flexible and autonomous, built on the basis of equality and voluntariness. The effectiveness of such informal collaborative mechanisms does not stem from external formal directives but is more often driven by endogenous collaborative needs [18,19]. Accordingly, this study proposes the first hypothesis:

Hypothesis 1a. *In multi-level and vertical intergovernmental collaborative relationships, local governments tend to adopt formal collaborative governance behaviors.*

Hypothesis 1b. *In horizontal and diagonal intergovernmental collaborative relationships, local governments tend to adopt informal collaborative governance behaviors.*

2.2. Cooperative Experience and Types of Collaborative Governance Behavior

Generally, in regional collaborative governance processes, existing cooperation experiences among local governments not only enhance mutual understanding and trust but also accumulate rich experience in policy formulation and implementation as well as emergency response [20]. Specifically, on the one hand, due to existing cooperative foundations, local governments can achieve more efficient communication and collaboration through diverse, flexible, and autonomous informal collaborative mechanisms when facing common problems, transforming loose cooperation into close and long-term cooperative behaviors [21]. On the other hand, existing cooperation experiences can enhance institutionalized trust among local governments [22]. Although formal means such as performance assessments can also prompt collaboration, they are mostly achieved through external pressure [23]. In contrast, informal collaboration based on established cooperative experiences better reflects internal motivation and voluntariness, thereby reducing dependence on coercive measures and lowering potential risks from excessive intervention.

In addition, existing cooperation experiences help local governments better cope with sudden public governance challenges [24]. When facing sudden regional crises, local governments can rapidly mobilize resources and information through existing cooperative networks to respond more quickly and effectively [25]. This experience-based rapid response capability often achieves results that are difficult to attain through formal procedures alone. It is worth noting that while institutional trust is an intangible asset that

drives informal mechanisms, it is empirically nurtured and proxied by historical cooperation experiences within this study. Therefore, rather than treating trust as an unobservable latent residual, this study operationalizes it via continuous interactive histories [26]. In summary, trust relationships based on historical interactions will prompt local governments to rapidly adjust strategies and take action through informal collaborative mechanisms and cooperative networks when facing new challenges, thereby avoiding the complexity and uncertainty of starting from scratch [27,28]. Accordingly, this study proposes the second hypothesis:

Hypothesis 2. *Existing cooperation experiences among local governments facilitate the adoption of informal collaborative governance behaviors in mutual interactions.*

2.3. Cross-Provincial Issues and Types of Collaborative Governance Behaviors

Research results from a game-theoretic perspective on collaborative governance indicate that repeated collaborative behaviors among participants significantly reduce cooperation risks in the collaborative governance process, while one-off or irregular collaborative behaviors are often accompanied by higher cooperation risks [29]. Therefore, to reduce the probability of such cooperation risks and ensure the achievement of collaborative goals, participants tend to constrain each other's behaviors through formalized cooperation agreements [30]. In terms of intergovernmental collaborative governance, the frequency of collaborative behaviors is closely related to the geographical locations of the parties involved. Specifically, cities within the same province often exhibit frequent collaborative interactions; cities that are geographically adjacent but belong to different provinces also achieve frequent collaborative interactions due to shared goals, whereas cities that are geographically distant and belong to different provinces exhibit significantly lower frequencies of collaborative interactions [31–33].

However, frequent regional environmental pollution events force cities belonging to different provinces to adopt joint prevention and control collaborative governance behaviors [34]. Therefore, to reduce cooperation risks arising from low cooperation frequency and ensure the achievement of collaborative governance goals, when addressing environmental pollution events with clear cross-provincial characteristics, local governments tend to adopt formal collaborative mechanisms [35]. In addition, for cities from different provinces, due to significant differences in institutional environments and often facing different superior requirements and assessments, it is difficult to form a strong goal consensus and establish stable trust relationships. This also necessitates the use of formalized collaborative mechanisms to constrain behaviors and overcome potential risks and uncertainties in the collaborative process [36]. Accordingly, this study proposes the third hypothesis:

Hypothesis 3. *Local governments tend to adopt formalized collaborative mechanisms to achieve cross-provincial collaborative governance.*

2.4. Urgency of Environmental Challenges and Types of Collaborative Governance Behaviors

Informal collaborative governance behaviors among local governments are characterized by high flexibility and autonomy, fully considering the needs and preferences of all entities, and providing greater room for negotiation and flexibility in public problem decision-making [37]. This flexibility enables collaborative participants to rapidly mobilize resources, coordinate actions, and make immediate decisions according to actual conditions when addressing urgent environmental issues [38]. At the same time, informal collaboration among local governments is based on informal relationships formed through political, economic, and interpersonal networks; participants can autonomously

choose to join or exit cooperative relationships, which helps deepen trust and overcome cooperation risks. This trust foundation makes local governments more inclined to quickly reach consensus and take action through informal methods when facing urgent environmental issues [39]. In addition, informal collaborative governance can promote knowledge sharing and information exchange among local governments, helping participants form close and long-term cooperative behaviors [30]. In emergency situations, such knowledge sharing and information exchange are crucial for quickly identifying problems, formulating response strategies, and coordinating resource allocation.

In contrast, although formal collaborative behaviors have advantages in institutional binding force, enabling them to effectively overcome potential risks and ensure the achievement of collaborative goals, their complex procedures and high costs may prevent rapid response in emergencies [33]. Clearly, in governance areas such as air pollution and water pollution—where cooperation risks are relatively high, negative externalities are strong, and emergency response is required—the advantages of informal collaboration are more evident [40]. Therefore, when facing urgent environmental issues, local governments tend to choose informal collaborative governance behaviors to achieve rapid and effective responses. Accordingly, this study proposes the fourth hypothesis:

Hypothesis 4. *When addressing urgent and high-stakes environmental sustainability challenges, local governments tend to adopt informal collaborative governance behaviors to facilitate rapid response.*

2.5. The Relationship Between Research Hypotheses

Based on the aforementioned content, this study constructs a conceptual framework diagram for explicating the hypothesized relationships among intergovernmental relationship types, contextual factors, and cooperative governance behavioral choices, as shown in Figure 2.

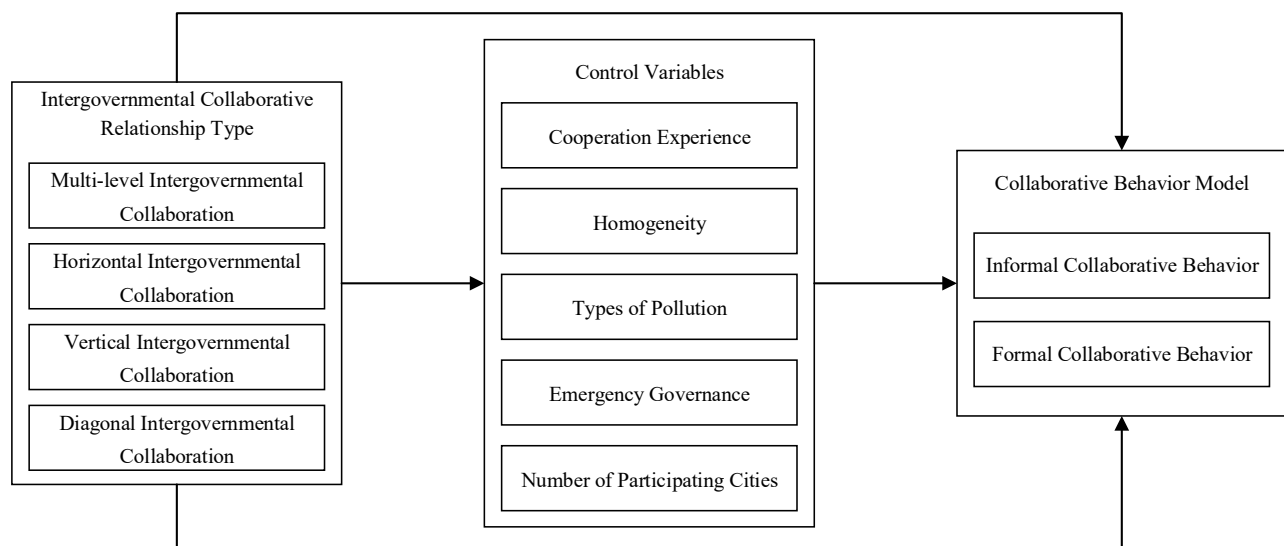


Figure 2. Diagram of the relationship between variables.

3. Research Design and Methodology

3.1. Case Introduction

BTH's ecological and environmental integrated governance is an important component of the BTH coordinated development strategy, aiming to protect and restore the regional ecological environment through regional collaborative cooperation. Shortly after the formal implementation of the BTH strategy, the governments of the BTH region clarified the core objectives of regional ecological and environmental protection and six key tasks covering industrial and energy structure adjustments through the Beijing–Tianjin–Hebei Coordinated Development Ecological and Environmental Protection Plan. Over the past decade, through measures such as delineating ecological and environmental protection red lines, implementing joint legislation and coordinated law enforcement for regional ecological and environmental governance, and establishing and improving ecological protection compensation mechanisms, the BTH region has made significant progress in air pollution prevention, watershed pollution control, and solid waste disposal, achieving substantial improvements in regional ecological and environmental governance and greatly advancing the construction of a “BTH ecological and environmental community.”

Clearly, the significant achievements in ecological and environmental protection in the BTH region are inseparable from BTH ecological and environmental integrated governance, and the success of this governance stems from a series of collaborative initiatives carried out by governments at different levels in the three provinces (municipalities) in the field of ecological and environmental protection. Through formal collaboration characterized by joint documents, cooperation agreements, and working mechanisms, as well as informal collaboration characterized by thematic training, working meetings, and emergency coordination, environmental collaborative governance in the BTH region has overall exhibited trends of diversified topics and standardized forms, with continuously improving levels of integration. Therefore, to further optimize and enhance the mechanisms and methods of BTH ecological and environmental integrated governance, it is necessary to analyze the relationship between intergovernmental collaborative relationship types and collaborative behavior models in the BTH ecological and environmental integrated governance process, thereby deeply exploring the behavioral choice logic and preferences of local governments in this process [41]. The research steps for this study are shown in Figure 3.

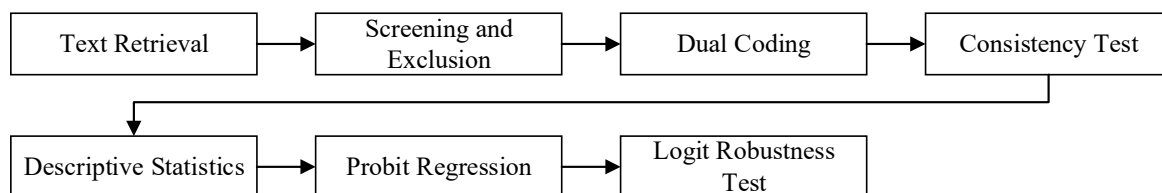


Figure 3. Research Flowchart.

3.2. Data Sources

The data used in this study were obtained through a systematic and exhaustive web-screening process across a total of 32 targeted websites. This comprehensive source pool included: the official portal of the State Council and the Ministry of Ecology and Environment; 13 municipal government portal websites and 13 environmental protection department websites of all 13 cities in the Beijing–Tianjin–Hebei region; 3 provincial-level authoritative news media platforms, including Beijing Daily, Tianjin Jin Yun, and Hebei Daily; and the Peking University Law Database. To ensure the strict representativeness of the underlying data, all available official administrative and environmental authority platforms within the BTH region were fully considered, achieving 100% institutional coverage

of the target jurisdictions. Conversely, commercial web platforms, informal social media channels, and non-official local blogs were explicitly omitted. The reasons for these omissions are that such platforms lack official administrative authority, frequently disseminate redundant or unverified secondary descriptions, and do not publish standardized text of policy agreements. Their inclusion would introduce substantial data noise into the text-coding dataset. Therefore, the selected 32 websites represent the complete, legally reliable, and authoritative universe of disseminators for intergovernmental collaborative environmental policies and events in the region. Given that this study primarily employs the Probit model to explore the relationship between intergovernmental relationship types and collaborative behavior models in BTH ecological and environmental integrated governance, most of the data used are dummy variables formed based on text material coding. Meanwhile, binary variables were selected over continuous ratings because governmental policy output at the operational level manifests as either a formal, legally binding signed text or an informal, non-binding consultative meeting, exhibiting a clear binomial distribution.

Specifically, first, keywords such as “cooperation,” “collaboration,” “joint meeting,” “agreement,” “linkage,” “joint,” and “cross-border” were used to search for text materials related to BTH ecological and environmental integrated governance on various websites. To filter out potential selection bias, text data were systematically retrieved from ministerial and municipal portals. Second, considering the broad nature of the search keywords, the retrieval results may include information on ecological and environmental collaborative governance between BTH cities and cities outside the region; therefore, such information was excluded after preliminary retrieval. Finally, considering the diversity of data sources, the same report may appear in different search channels; thus, text analysis methods were used to cross-verify and merge or eliminate redundant and invalid information. Ultimately, through data organization and cleaning, we obtained a total of 172 pieces of intergovernmental collaborative behavior data related to the integrated governance of the ecological environment in the Beijing–Tianjin–Hebei region for the period from 2013 to 2023, since the implementation of the Beijing–Tianjin–Hebei coordinated development strategy.

The sample span covers 2013 to 2023, representing the complete evaluation cycle of the first decade of the BTH Coordinated Development Strategy; data from 2024 to 2026 were excluded due to current lags in official archives and the pending completion of post-2024 environmental mid-term disclosures. To ensure objectivity and reproducibility, two independent researchers coded the 172 events based on an explicit, predefined manual. Inter-rater reliability was rigorously tested, yielding a Cohen’s Kappa coefficient of 0.864, confirming high statistical reliability and classification consistency.

3.3. Variable Description

3.3.1. Dependent Variable

The dependent variable in this study is the collaborative behavior model in BTH ecological and environmental integrated governance, which can be specifically divided into formal collaboration and informal collaboration. Based on the induction and organization of text materials and a review of collaborative governance practices among Chinese governments at all levels, collaborative governance behaviors can be roughly divided into two categories based on whether a formal written agreement is signed. One category mainly involves various forums, seminars, training sessions, thematic meetings, joint meetings, working meetings, and office meetings, which are more consultative and communicative in nature and do not form written agreements, resulting in relatively low binding force on participants; thus, they belong to informal collaborative methods. The other category involves further forming written cooperation agreements, working mechanisms,

or work plans on the basis of meetings; the relevant policy documents provide detailed provisions on specific tasks, collaborative objectives, and collaborative models for all parties, exerting stronger binding and coercive force on participants, reflecting the establishment of institutionalized organizational relationships, and thus belonging to formal collaborative methods. Based on the above principles and standards, this study codes the dependent variable: A formal collaborative event was coded as “1” if it involved the signing of a joint document or cooperation agreement or the establishment of a formal institutional mechanism. An informal collaborative event was coded as “0” if it was characterized by a working meeting, thematic training, site visit, or emergency coordination without a binding formal outcome.

3.3.2. Independent Variables

The independent variables in this study are the types of intergovernmental collaborative relationships in BTH's ecological and environmental integrated governance. Based on prior research results, intergovernmental collaborative types among Chinese governments at all levels can be divided into four categories: multi-level intergovernmental collaboration driven by upward and downward forces, interest-driven horizontal intergovernmental collaboration, bureaucracy-dominated vertical intergovernmental collaboration, and demand-oriented diagonal intergovernmental collaboration. Accordingly, this study classifies the text materials from the perspective of intergovernmental collaborative relationship types; that is, based on relevant descriptions of collaborative relationships among participants in the text materials, the intergovernmental collaborative relationship type of each data point is determined and coded as “1” for its type, while the other three types are coded as “0.” This ensures the uniqueness of the independent variable in the data materials; that is, each data point belongs to only one type of intergovernmental collaborative relationship.

3.3.3. Control Variables

Considering the specificity of the research question and referring to existing studies, the control variables in this study mainly include five types. First, cooperation experience: Existing cooperation experiences among governments at all levels can promote the formation of relatively close interdependent relationships and facilitate smooth cooperation. Therefore, if governments at various levels as collaborative participants have previously engaged in cooperation on similar ecological and environmental governance topics, it is coded as “1”; otherwise, “0.” Second, homogeneity: Generally, similarities among governments at various levels in socioeconomic conditions, natural environment, and administrative methods, as well as geographical proximity among cities, help achieve closer cooperation. Therefore, this study explores the impact of homogeneity on collaborative behavior models in BTH ecological and environmental integrated governance from the perspectives of administrative level differences and cross-provincial cooperation. Specifically, on the one hand, administrative levels of different government tiers are ranked from 1 to 4 in the order of prefecture-level cities, provincial capital cities, municipalities directly under the central government, and the central government; the administrative level difference variable is coded based on the gap between them. On the other hand, for collaborative governance among local governments, if the cooperating parties belong to different provinces, cross-provincial cooperation is coded as “1”; otherwise, “0.” Third, types of pollution: For collaborative governance among local governments, the complexity of topics and cooperation risks are significantly positively correlated. For example, in environmental protection topics, due to the spatial diffusion caused by air flow, air pollution control is often relatively complex, making it difficult to identify pollution sources and divide responsibilities among participants, with a higher likelihood of free-rider problems; thus,

cooperation risks are higher. Accordingly, this study classifies topics based on text material analysis from the perspectives of air pollution, water pollution, and solid waste pollution. If a topic belongs to one of these pollution categories, it is coded as “1”; otherwise, “0.” Fourth, emergency governance: For the governance of sudden and urgent environmental topics, due to the urgency of the problem requiring timely responses from collaborative participants, unconventional collaborative governance methods are often needed. Therefore, if a topic belongs to an urgent environmental crisis event, it is coded as “1”; otherwise, “0.” Fifth, number of participating cities: The number of participating cities also affects the type selection in local governments’ environmental collaborative governance. As the number of cooperating entities increases, greater heterogeneity among entities may make it difficult to reach a consistent goal consensus. Therefore, this study includes the number of participating cities as an important control variable. The measurement of each variable is shown in Table 1.

Table 1. Research Variables and Measurement Methods.

Variable Type	Variable Name	Specific Variable	Measurement Method
Dependent Variable	Collaborative Behavior Model		Formal collaborative behavior coded as “1”; informal collaborative behavior coded as “0”
Independent Variables	Intergovernmental Collaborative Relationship Type	Multi-level Intergovernmental Collaboration	Coded as “1” if the intergovernmental collaborative relationship type is multi-level
		Horizontal Intergovernmental Collaboration	Coded as “1” if the intergovernmental collaborative relationship type is horizontal
		Vertical Intergovernmental Collaboration	Coded as “1” if the intergovernmental collaborative relationship type is vertical
		Diagonal Intergovernmental Collaboration	Coded as “1” if the intergovernmental collaborative relationship type is diagonal
Control Variables	Cooperation Experience		Coded as “1” if participants have prior cooperation experience on similar environmental topics
	Homogeneity	Administrative Level Difference	Maximum difference in administrative status levels among participants calculated according to coding rules
		Cross-Provincial Cooperation	Coded as “1” if participants are from different provinces
		Air Pollution	Coded as “1” if it is an air pollution environmental topic
	Types of Pollution	Water Pollution	Coded as “1” if it is a water pollution environmental topic
		Solid Waste Pollution	Coded as “1” if it is a solid waste pollution environmental topic
	Emergency Governance		Coded as “1” if the topic is an urgent environmental crisis event
	Number of Participating Cities		Number of specific cities participating in collaboration

Note: Administrative levels are coded as: Central Government = 4, Municipality directly under the Central Government (Beijing/Tianjin) = 3, Provincial Capital (Shijiazhuang) = 2, Prefecture-level cities = 1. The variable is the absolute maximum difference between any two participating entities.

3.3.4. Model Specification

The dependent variable in this study is the collaborative behavior model in BTH ecological and environmental integrated governance, including formal and informal collaboration, which is a 0/1 dummy variable. Since the dependent variable y is purely binary, ordinary least squares (OLS) would suffer from heteroscedasticity and non-normal errors. We employ the Probit model under the assumption that the unobserved structural disturbances μ follow a standard normal distribution, allowing us to estimate true maximum likelihood thresholds. To address potential institutional learning and time-dependence across the 11-year span, we introduce year-fixed effects in subsequent tests. Furthermore, regarding potential bidirectional causality, that is, past strategies influence future experiences, we utilize lagged cooperation experience variables to ensure strict temporal exogeneity. The specific model expression is shown in Equation (1):

$$y = X\beta + \mu \quad (1)$$

where the collaborative behavior model y is a binary variable (1 indicates a formal collaborative model; 0 indicates an informal collaborative model). Introducing a latent variable related to X gives $y^* = X\beta + \mu^*$, where $X_1, X_2, X_3, \dots, X_n$ are explanatory variables affecting the collaborative behavior model, β is the regression coefficient, and μ^* is the error term. The correspondence between y and y^* is shown in Equation (2):

$$y = \begin{cases} 0, & y^* \leq 0 \\ 1, & y^* > 0 \end{cases} \quad (2)$$

The probability model expressions for the collaborative behavior model y are shown in Equations (3) and (4):

$$p(y = 0) = p(y^* \leq 0) = p(\mu^* \leq -X\beta) = F(-X\beta) \quad (3)$$

$$p(y = 1) = p(y^* > 0) = p(\mu^* > -X\beta) = 1 - F(-X\beta) \quad (4)$$

4. Empirical Results

4.1. Descriptive Statistics

The descriptive statistics of the relevant variables in this study are shown in Table 2. Given that most variables used in this study are 0/1 dummy variables generated based on text material coding, the analysis of descriptive statistics provides a general understanding of the specific characteristics of intergovernmental collaborative governance practices in BTH ecological and environmental integration. Specifically, first, in the intergovernmental collaborative practices of BTH ecological and environmental integration, formal collaborative behaviors represented by written cooperation agreements, working mechanisms, and work plans account for only 27.91%, indicating that actors in the BTH ecological and environmental integrated governance process tend to adopt informal collaborative methods such as forums and seminars, which are more consultative and communicative in nature and have higher flexibility and autonomy. Second, among the 172 data points included in the study, as many as 77.91% of collaborative behaviors were achieved on the basis of existing similar environmental governance experiences, indicating that existing cooperation experiences have a significant impact on deeper and sustained collaborative governance practices. Third, the statistical results of the administrative level difference variable show that its mean value of 1.1047 indicates that intergovernmental collaborative governance behaviors are more likely to occur between governments with superior-subordinate relationships rather than being limited to collaboration among governments at the same level. In other words, hierarchical authority often plays an important role in the intergovernmental collaborative governance process of BTH ecological and en-

vironmental integration. Finally, the three variables related to types of pollution show that 87.21% of topics are related to air pollution control, 40.12% to water pollution control, and 30.81% to solid waste pollution control. This indicates that, on the one hand, the BTH region has indeed achieved integrated collaborative governance of multiple pollutants in ecological and environmental governance, but on the other hand, there are still certain primary and secondary distinctions in intergovernmental collaborative governance processes for different pollutants, with air pollution collaborative governance remaining the top priority in BTH ecological and environmental integrated governance.

Table 2. Descriptive Statistics of Research Variables.

Variable Name	Sample Size	Mean/Share	Standard Deviation	Min	Max
Collaborative Behavior Model	172	0.2791	0.4499	0	1
Multi-level Intergovernmental Collaboration	172	0.1628	0.3703	0	1
Horizontal Intergovernmental Collaboration	172	0.3895	0.4891	0	1
Vertical Intergovernmental Collaboration	172	0.2849	0.4527	0	1
Diagonal Intergovernmental Collaboration	172	0.1628	0.3703	0	1
Cooperation Experience	172	0.7791	0.4161	0	1
Administrative Level Difference	172	1.1047	0.9797	0	3
Cross-Provincial Cooperation	172	0.5174	0.5012	0	1
Air Pollution	172	0.8721	0.3350	0	1
Water Pollution	172	0.4012	0.4916	0	1
Solid Waste Pollution	172	0.3081	0.4631	0	1
Emergency Governance	172	0.5407	0.4998	0	1
Number of Participating Cities	172	6.5989	4.5841	1	13

4.2. Empirical Analysis

This study uses the Probit model to explore differences in collaborative behavior models adopted under the influence of different intergovernmental collaborative relationship types in BTH ecological and environmental integrated governance, and further investigates factors influencing intergovernmental collaborative behavior models. The results are shown in Table 3. Models 1–4 present regression results with the four different intergovernmental collaborative relationship types as independent variables and the collaborative behavior model as the dependent variable.

Table 3. Baseline Regression Results.

		Model 1	Model 2	Model 3	Model 4
Intergovernmental Collaborative Relationship Type	Multi-level Intergovernmental Collaboration	1.010 ** (2.18)			
	Vertical Intergovernmental Collaboration		0.947 * (1.91)		
	Horizontal Intergovernmental Collaboration			−0.077 (−0.18)	
	Diagonal Intergovernmental Collaboration				−1.116 *** (−2.93)
Homogeneity	Cooperation Experience	−1.021 *** (−3.73)	−0.958 *** (−3.57)	−0.952 *** (−3.53)	−1.084 *** (−3.93)
	Administrative Level Difference	−0.174 (−0.91)	−0.025 (−0.15)	0.067 (0.26)	0.157 (1.05)
	Cross-Provincial Cooperation	0.363 (1.42)	1.225 *** (2.60)	0.526 * (1.87)	0.781 *** (2.99)

Types of Pollution	Air Pollution	0.130 (0.27)	0.121 (0.25)	0.069 (0.14)	0.192 (0.40)
	Water Pollution	−0.050 (−0.11)	−0.138 (−0.30)	−0.126 (−0.27)	0.097 (0.21)
	Solid Waste Pollution	0.373 (0.83)	0.420 (0.93)	0.491 (1.10)	0.255 (0.56)
Emergency Governance		−0.220 (−0.87)	−0.285 (−1.16)	−0.345 (−1.40)	−0.221 (−0.88)
Number of Participating Cities		0.002 (0.07)	0.031 (0.88)	0.010 (0.28)	0.005 (0.14)
Constant Term		−0.155 (−0.29)	−1.091 (−1.63)	−0.288 (−0.50)	−0.460 (−0.87)
Year-Fixed Effects		Controlled	Controlled	Controlled	Controlled
N		172	172	172	172
Pseudo R ²		0.1688	0.1647	0.1447	0.1921
LR chi2 (9)		34.3743	33.5439	29.4655	39.1210
Prob > chi2		0.0001 ***	0.0001 ***	0.0005 ***	0.0000 ***

Note: *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively; t-values in parentheses.

First, the empirical results provide nuanced support for our first set of hypotheses. In Model 1, the coefficient for Multi-level Intergovernmental Collaboration is significantly positive ($\beta = 1.010$, $p < 0.05$), meaning that hierarchical pressures drive authorities to solidify interactions via institutional agreements. This directly confirms Hypothesis 1a. Conversely, Model 4 demonstrates that Diagonal Intergovernmental Collaboration has a profoundly negative effect on choosing formal tools ($\beta = -1.116$, $p < 0.01$).

This confirms that when governments interact across asymmetric sectors without command lines, they actively prefer autonomous, informal mechanisms to preserve structural flexibility, thereby validating Hypothesis 1b. This means that in multi-level intergovernmental collaborative and vertical intergovernmental collaborative governance practices involving multiple levels of government, actors tend to adopt highly institutionalized and standardized formal collaborative behavior models, while in horizontal intergovernmental collaborative and diagonal intergovernmental collaborative governance practices achieved by actors without hierarchical relationships, actors tend to adopt more flexible and autonomous informal collaborative behavior models.

This further indicates that in intergovernmental collaborative relationships dominated by hierarchical authority factors (such as multi-level and vertical intergovernmental collaborative relationships), to ensure the achievement of collaborative goals, participants tend to adopt relatively formal collaborative governance behaviors such as signing cooperation agreements and establishing cooperative institutions to enhance the binding force and enforceability of collaborative governance behaviors. In contrast, in intergovernmental collaborative relationships dominated by expected benefits or practical needs (such as horizontal and diagonal intergovernmental collaborative relationships), actors place greater emphasis on whether collaborative governance behaviors can fully consider the needs and preferences of all entities and expect to respond quickly to complex cross-jurisdictional public affairs and adjust collaborative strategies in a timely manner according to actual conditions. At this time, actors more strongly expect to form informal collaborative mechanisms that are more flexible and autonomous, built on the basis of equality and voluntariness. The results provide robust support for our first set of hypotheses. Specifically, the coefficient for the 'Multi-level/Vertical relationship' variable was positive and significant, confirming Hypothesis 1a that local governments tend to adopt formal mechanisms in such relations. Conversely, the coefficient for the 'Horizontal/Diagonal relation-

ship' variable was negative, supporting Hypothesis 1b that informal mechanisms are preferred in these contexts. Thus, Hypotheses 1a and 1b are supported.

Second, observing the regression results with cooperation experience as a control variable in each model reveals that the coefficients of this variable in all four models are significantly negative at the 1% level, fully indicating that regardless of the type of inter-governmental collaborative relationship formed between actors, their past cooperation experiences significantly influence future collaborative governance behaviors and prompt actors to achieve deeper collaboration through more flexible and autonomous informal collaborative methods. The reasons are as follows: On the one hand, in the early stages of cooperation, actors have not yet established good trust relationships and need to reduce cooperation risks through formal collaboration. When actors establish trust and reciprocal foundations based on past cooperation experiences, cooperation risks decrease, and participating entities may rationally choose lower-cost and more flexible informal collaboration. On the other hand, informal collaborative methods built on historical cooperation experiences endow actors with better governance capabilities to cope with emergencies; when facing sudden events, actors can rapidly mobilize resources and information through existing cooperative networks to respond to crises more quickly and effectively. This experience-based rapid response capability is clearly difficult to achieve through formal procedures alone. Thus, Hypothesis 2 is supported.

Third, observing the regression results with cross-provincial cooperation as a control variable in each model reveals that the coefficients of this variable in all four models are positive, and those in Models 2 and 4 are significantly positive at the 1% level. This means that when facing collaborative governance matters requiring cross-provincial cooperation, actors tend to adopt formal collaborative behavior models. The reasons are as follows: On the one hand, compared with local governments within the same province, cross-provincial local governments exhibit relatively lower frequencies of collaborative behaviors, and low repetition rates of collaborative behaviors often imply higher cooperation risks; therefore, formal collaborative behaviors represented by signing cooperation agreements and establishing cooperative institutions are important ways to avoid cooperation risks. On the other hand, local governments belonging to different provinces often face different superior requirements and assessments; differences in the strictness of ecological and environmental governance requirements across provinces often make it difficult for local governments as direct actors to form a strong goal consensus and establish stable trust relationships. Therefore, to overcome potential risks and uncertainties in the collaborative process and reduce free-rider problems, formalized collaborative mechanisms must be used for constraints. Thus, Hypothesis 3 is supported.

Finally, observing the regression results with emergency governance as a control variable in each model reveals that although the coefficients of this variable in all four models are not significant, they are all negative, indicating that when facing urgent environmental issues requiring rapid resource mobilization and immediate decision-making, collaborative governance participants tend to adopt informal collaborative governance methods. In emergency situations, such informal collaborative governance methods enable rapid exchange and sharing of crisis event information, which is crucial for formulating response strategies and subsequent resource coordination and allocation. In practice, the regional heavy pollution weather emergency response mechanism established in the BTH region to address heavy pollution weather is a typical example of this informal collaborative behavior model. This emergency response mechanism effectively reduces the degree of air pollution and its impact on public health through unified planning and coordinated cooperation when heavy pollution weather occurs. Clearly, the effects produced by such highly flexible and autonomous collaborative behavior models in addressing sudden and urgent environmental issues are incomparable to those of formal collaborative behavior

models characterized by institutionalization and standardization. Thus, Hypothesis 4 is supported.

It is worth noting that in our model, except for the control variables discussed above, most control variables, including the administrative rank gap, pollution type, and number of participating cities, are not statistically significant. This indicates that the institutional and relational background represented by hierarchical or horizontal intergovernmental interactions can predict the choice of cooperation strategies more powerfully than the general socio-economic conditions within a single locality.

4.3. Robustness Analysis

To verify the stability of our Probit estimations, we re-estimated Models 1–4 using a standard Logit specification. The results are shown in Table 4. The signs, magnitudes, and statistical significance levels of our key independent variables remained highly consistent, with the negative effect of diagonal relations remaining robust at the 1% level, confirming that our inferences are not artifacts of specific distributional assumptions.

Table 4. Robustness Analysis Results.

		Model 1	Model 2	Model 3	Model 4
Intergovernmental Collaborative Relationship Type	Multi-level Intergovernmental Collaboration	1.649 ** (2.084)			
	Vertical Intergovernmental Collaboration		1.541 * (1.717)		
	Horizontal Intergovernmental Collaboration			0.041 (0.055)	
	Diagonal Intergovernmental Collaboration				−1.867 *** (−2.765)
	Control variable	YES	YES	YES	YES
	Constant Term	0.393 (−0.440)	−1.889 (−1.631)	−0.680 (−0.696)	−0.9036 (−1.0178)
	N	172	172	172	172
	Pseudo R ²	0.168	0.162	0.145	0.191
	LR chi2 (9)	34.222	33.025	29.562	38.852
	Prob > chi2	0.0001 ***	0.0001 ***	0.0005 ***	0.0000 ***

Note: *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively; t-values in parentheses.

4.4. Discussion

Based on the aforementioned empirical analysis results, it can be found that the collaborative behavior modes among local governments are not only affected by inter-governmental collaborative relationships, but also present significant differences in the collaborative behavior modes chosen by local governments under different objective conditions.

Specifically, our finding that horizontal and diagonal ties favor informal governance strongly echoes the Institutional Collective Action (ICA) framework popularized by Feiock et al. [42]. However, unlike Western decentralized systems, where informal pacts are hindered by high transaction costs, the BTH region utilizes informal mechanisms (e.g., joint emergency briefings) as an efficient tactical buffer under a highly centralized administrative umbrella. Meanwhile, our finding that informal mechanisms are preferred for urgent issues aligns with the concept of ‘emergency management networks’ proposed by Kapucu, which emphasizes flexibility and rapid information flow [43]. Our study shows that for specific, time-sensitive environmental crises in a region with established cooper-

ative experience, informality can be a more effective strategy for achieving sustainability goals. From a practical perspective, these results illuminate the nuanced “central-local” relations in China’s environmental governance. While the central government provides a formal framework, local governments, especially within a well-connected region like BTH, are leveraging their informal networks to solve pressing problems before they escalate. This suggests a functional dualism in the system. We acknowledge the potential for endogeneity, particularly concerning Hypothesis 2. While we found that past cooperation experience predicts the use of informal mechanisms, it is plausible that successful informal collaboration can, in turn, strengthen institutional trust and future cooperative experience. This positive feedback loop warrants further investigation using longitudinal data and instrumental variable approaches.

5. Conclusions

5.1. Main Findings

To analyze the relationship between intergovernmental collaborative relationship types and ecological and environmental integrated governance, this study uses the Probit regression model and takes intergovernmental collaborative behavior data related to BTH ecological and environmental integrated governance from 2013 to 2023 (since the implementation of the BTH coordinated development strategy) as the research sample to empirically investigate the objective impact of differences in intergovernmental collaborative relationship types on BTH ecological and environmental integrated governance. This study makes a novel theoretical contribution by moving beyond a simple dichotomy of formal/informal mechanisms. It reveals a conditional logic of selection, showing that the type of intergovernmental relationship and contextual pressures are the primary determinants of governance strategy, thus providing a more nuanced behavioral model for environmental governance research. Specifically, the main findings of this paper are as follows:

First, under different types of intergovernmental collaborative relationships, governments at various levels as governance subjects adopt different specific collaborative governance behaviors. Specifically, in multi-level intergovernmental collaborative and vertical intergovernmental collaborative governance practices involving multiple levels of government, actors tend to adopt highly institutionalized and standardized formal collaborative behavior models, while in horizontal intergovernmental collaborative and diagonal intergovernmental collaborative governance practices achieved by actors without hierarchical relationships, actors tend to adopt more flexible and autonomous informal collaborative behavior models. The empirical results confirm that vertical constraints dictate formal tool adoption ($\beta = 1.010$ for multi-level paths). In contrast, informal behaviors dominate regional governance, accounting for 72.09% of the total sample (124 out of 172 events), which proves that informal coordination is the operational baseline in the BTH region.

Second, in intergovernmental collaborative relationships dominated by hierarchical authority factors (such as multi-level and vertical intergovernmental collaborative relationships), to ensure the achievement of collaborative goals, participants tend to adopt relatively formal collaborative governance behaviors, such as signing cooperation agreements and establishing cooperative institutions to enhance the binding force and enforceability of collaborative governance behaviors. In contrast, in intergovernmental collaborative relationships dominated by expected benefits or practical needs (such as horizontal and diagonal intergovernmental collaborative relationships), actors place greater emphasis on whether collaborative governance behaviors can fully consider the needs and preferences of all entities and expect to respond quickly to complex cross-jurisdictional public affairs and adjust collaborative strategies in a timely manner according to actual condi-

tions. At this time, actors more strongly expect to form informal collaborative mechanisms that are more flexible and autonomous, built on the basis of equality and voluntariness.

Third, existing cooperation experiences among governments at all levels significantly influence future collaborative governance behaviors, driving both parties to achieve deeper collaboration through more flexible and autonomous informal collaborative methods. The reasons are as follows: On the one hand, in the early stages of cooperation, actors have not yet established good trust relationships and need to reduce cooperation risks through formal collaboration. When actors establish trust and reciprocal foundations based on past cooperation experiences, cooperation risks decrease, and participating entities may rationally choose lower-cost and more flexible informal collaboration. On the other hand, informal collaborative methods built on historical cooperation experiences endow actors with better governance capabilities to cope with emergencies; when facing sudden events, actors can rapidly mobilize resources and information through existing cooperative networks to respond to crises more quickly and effectively. This experience-based rapid response capability is clearly difficult to achieve through formal procedures alone.

Fourth, when facing collaborative governance matters requiring cross-provincial cooperation, governments at various levels tend to adopt formal collaborative behavior models. The reasons are as follows: On the one hand, compared with local governments within the same province, cross-provincial local governments exhibit relatively lower frequencies of collaborative behaviors, and low repetition rates of collaborative behaviors often imply higher cooperation risks; therefore, formal collaborative behaviors represented by signing cooperation agreements and establishing cooperative institutions are important ways to avoid cooperation risks. On the other hand, local governments belonging to different provinces often face different superior requirements and assessments; differences in the strictness of ecological and environmental governance requirements across provinces often make it difficult for local governments as direct actors to form a strong goal consensus and establish stable trust relationships. Therefore, to overcome potential risks and uncertainties in the collaborative process and reduce free-rider problems, formalized collaborative mechanisms must be used for constraints.

Finally, when facing urgent environmental issues requiring rapid resource mobilization and immediate decision-making, collaborative governance participants tend to adopt informal collaborative governance methods. In emergency situations, such informal collaborative governance methods enable rapid exchange and sharing of crisis event information, which is crucial for formulating response strategies and subsequent resource coordination and allocation. In practice, the regional heavy pollution weather emergency response mechanism established in the BTH region to address heavy pollution weather is a typical example of this informal collaborative behavior model. This emergency response mechanism effectively reduces the degree of air pollution and its impact on public health through unified planning and coordinated cooperation when heavy pollution weather occurs. Clearly, the effects produced by such highly flexible and autonomous collaborative behavior models in addressing sudden and urgent environmental issues are incomparable to those of formal collaborative behavior models characterized by institutionalization and standardization.

5.2. Policy Recommendations

The findings of this study indicate that, for inter-governmental collaborative governance, formal collaborative governance behaviors realized through formal cooperation agreements and work plans can achieve governance objectives. On the contrary, informal collaborative governance behaviors such as symposiums and joint meetings can sometimes yield twice the result with half the effort. Based on this, this study argues that for

policymakers, adopting a one-size-fits-all formal coordination framework is not the optimal choice; instead, they should grant greater autonomy to policy implementers. On the one hand, a resilient framework that integrates both formal agreements and informal “rapid response” network attributes should be designed. Higher-level authorities should avoid mandatory formal mandates for horizontal or diagonal collaborations, allowing local governments to leverage flexible informal networks to achieve sustainability goals more rapidly. On the other hand, investments should be made in constructing institutional trust and knowledge-sharing platforms among local governments so as to realize the benefits of informal collaboration. Regional platforms should document and archive informal working meetings, actively transforming spontaneous interactions into long-term organizational memories. Furthermore, policymakers need to recognize that for cross-provincial issues, establishing binding formal agreements is crucial to mitigate risks and ensure accountability.

5.3. Limitations and Future Directions

This study has several limitations. First, the analysis is confined to the BTH region, which has a unique political and economic context. The generalizability of our findings to other regions in China or other countries with different governance systems requires future cross-cultural research. Second, the binary classification of collaborative behaviors, while offering clarity, may oversimplify reality. Future studies could use a categorical or continuous measure of formality/informality for greater nuance. Finally, although this study has established the logic underlying the choice of governance tools, it has not quantitatively calculated the ultimate ecological outcomes through specific purification values of water or soil. Future longitudinal panel data should merge these behavioral choices with concrete spatial–environmental metrics to fully map the efficiency of regional environmental sustainability.

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