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Water environment collaborative governance policy in the Yangtze River Delta

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ABSTRACT

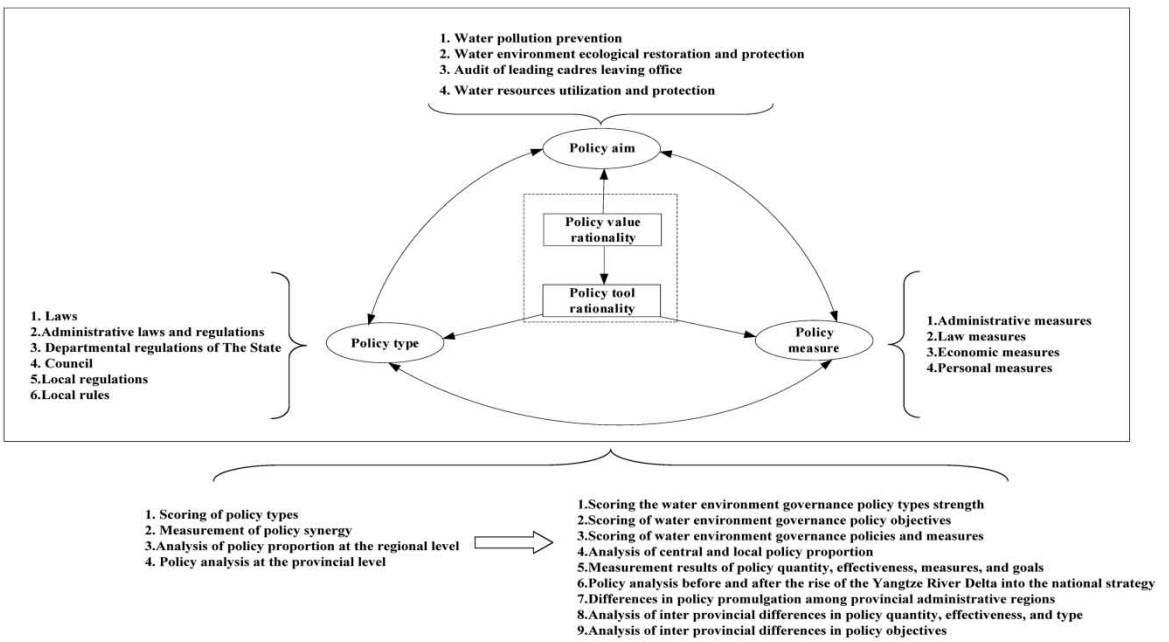
Water environment collaborative governance is an important policy agenda during the Yangtze River Delta integration. Based on collaborative theory and policy value theory, this essay finds 144 water environment collaborative governance policies in the region from 2007 to 2022. It utilizes a policy collaborative model to discuss the water environment collaborative governance state at the regional and provincial levels in this region. Results show that 87.5% of water environment collaborative governance policies are enacted by local government in the region in this period, the main policy aims of which are water resource protection and wastewater pollution control. More policy attention will need to be paid to water environment restoration and off-office auditing of cadres. While administration policies and legal interventions are the main policy levers, economic policies and personal policies are relatively underused. Policy elements are significantly diversified at the provincial level in the region. In response to the findings above, this essay offers advice to improve water environment collaborative governance in the Yangtze River Delta region on four aspects: giving local governments full discretion in wastewater pollution treatment; giving full play of the water pollution control policies' value; adopting differentiated water pollution control policies; and strategies among the local government in the region, exerting policy stability.

Key words: Collaborative measurement, Policy coordination, Water environment collaborative governance, Yangtze River Delta integration

HIGHLIGHTS

- The collaborative policy evaluation system comprehensively considers the policy value rationality and policy tool rationality, and calculates the central regional synergy, target synergy and measure synergy of policies.
- Exploring the relationship between those three policy elements in the context of collaborative governance will help to improve collaborative efficiency and achieve higher quality integration.

GRAPHICAL ABSTRACT



1. INTRODUCTION

The Yangtze River Delta region located in the lower reaches of the Yangtze River Basin, consisting of four provincial-level administrative regions, three provinces of Anhui, Jiangsu, and Zhejiang, and one municipality directly under the central government of Shanghai. The land area accounts for 3.7% of the country, the population accounts for 16.7%, and the economic output accounts for 24.1% of the country. The region has developed industries, a large population and a dense water network, which not only undertakes the transfer of some pollutants from the middle and upper reaches of the Yangtze River but also has to deal with water pollution within the region, making an adequate provision of water arduous. The contradiction and conflict of local environmental protection regulations caused by administrative divisions have led to the phenomenon of 'beggar thy neighbor' in water environment protection, which frequently occurs in the region (Figure 1).

This region has started to carry out collaborative water environment governance to break administrative boundaries' constraints and solve water pollution governance problems ever since the year 2002. The implementation of the Yangtze River Delta national integration strategy accelerates the policy procedure for promoting coordinated governance of water environment protection in the region. In March 2019, the Government Work Report of the 13th National People's Congress' second session officially upgraded the Yangtze River Delta integration into a national strategy. Afterwards, the Yangtze River Delta integration was put into practice at all levels of environmental, social, and economic development in an orderly manner. The water environment governance integration in the Yangtze River Delta is one of the challenges faced by the Yangtze River Delta integration. Looking back the water environment coordinated governance in the region since the Yangtze River Delta integration national strategy implementation is of practical significance to implement policy subjective analysis. The lessons learned from this research are not only beneficial for water environment governance integration in this region but

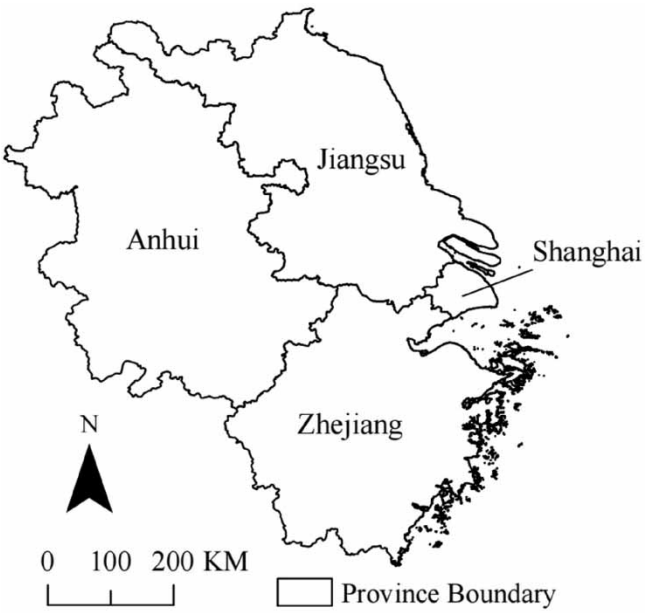


Fig. 1 | The Yangtze River Delta area.

also can be learned by other environmental governance integration such as polluted air and climate change adaptation.

The water environment governance policy is an important tool for implementing coordinated water pollution control in the Yangtze River Delta and achieving the water environment governance integration in the region. Refining the theoretical logic behind policy governance can provide a reference for collaborative governance. Policy types, policy objectives, and policy measures are the three main policy elements. From a development policy perspective, policy objectives change overtime (Wang *et al*., 2015). According to comparative policy studies, the selection of policy types and measures will affect the policy objectives' effectiveness degree, and different policy types and measures need to be selected to ensure that policy objectives are achieved (Chen & Sun, 2023). Exploring the relationship between those three policy elements in the context of collaborative governance will help to improve collaborative efficiency and achieve higher quality integration.

Policy rationality is the union of value rationality and instrumental rationality. Value rationality represents the starting point for policy formulation while instrumental rationality is the strategy and means adopted to achieve policy value rationality. Among policy elements, policy objectives represent the value rationality of policy, while policy types and measures represent policies' instrumental rationality (Wu & Guo, 2022). In the context of Chinese governance, the value rationality of water resource collaborative governance policies is to improve water environment quality and ensure water resource security. The instrumental rationality is to adopt various current policy measures to ensure the realization of the aforementioned policy mechanism rationality.

The collaborative policy evaluation system constructed by this research comprehensively considers the policy value rationality and policy tool rationality. It calculates the central regional synergy, target synergy, and measure synergy of policies in the Yangtze River Delta (see Figure 2). First, the water environment protection's central regional synergy status is explored, and the proportion of water environment protection policies issued by central and local governments is discussed. Second, we focus on policy goal synergy, which refers to the proportion of

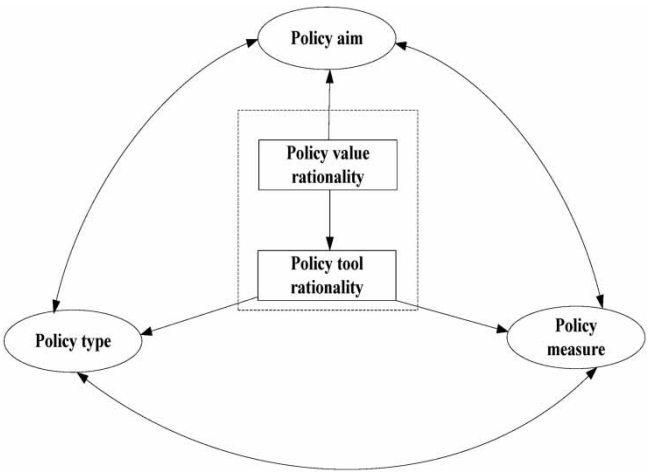


Fig. 2 | Relationship between policy rationality and policy elements.

different policy goals that reflects policy value's rational preference. Third, we attend to the synergy of policy measures currently mainly adopted, which in turn reflects the rational tendency of policy tools. The significance of this study lies in its ability to reveal the relationship between rational unity and rational unity of policy tools deployed for the Yangtze River Delta.

The policy value rationality determines the formulated policy objectives, and the rational choice of policy types and policy measures by policy tools, while the policy's value rationality is the fundamental basis for making rational choices of policy tools (Zhou & Zhang, 2023). Determining policy's value rationality based on reality plays a very important role in the policy formulation and implementation processes. Most of the current water environment protection policy value rationality focuses on water resource conservation. In fact, water resources scarcity can be alleviated through the improvement of technology, such as water pollution treatment technology, but the ecological damage caused by water pollution may affect the broader ecological balance. Therefore, the current water environment protection policy value rationality should gradually shift from water resource conservation and pollution prevention to how to support quality of life (including the provision of safe drinking water), protect the environment in its own right (which in turn helps ensure the provision of high-level aquatic ecological products), and repair damaged water ecological environments. Water resource conservation can be implemented by governments in different regions within their respective administrative authority. However, the restoration of water ecology requires coordinated governance among local governments. The shift in water environment protection policy's value rationality emphasizes the importance of water environment coordinated governance, and will trigger changes in policy tool rationality and various policy elements. Table 1 illustrates the relationship between key terms and concepts.

This study draws on the Peking University Treasure Database (www.pklaw.com) where we identified 144 water environment governance policies issued in the Yangtze River Delta region between 2007 and 2022. Eight experts and scholars from universities, research institutes, and relevant government departments in the water environment governance field have constructed a policy synergy evaluation model, three of whom are professors in universities and institutions, three of whom work in the government, two of whom work in the government agencies. The model includes three dimensions: policy strength, policy measures, and policy objectives, based on the demonstration and optimization of relevant policy synergy evaluation standards. These policies are

Table 1 | Relationships between key terms and concepts.

Policy rationality		
Policy instrument rationality		**Policy value rationality**
Policy measures	*Policy types*	*Policy aims*
1. Administrative measures	1. Laws	1. Water pollution prevention
2. Law measures	2. Administrative laws and regulations	2. Water environment ecological restoration and protection
3. Economic measures	3. Departmental regulations of the State Council	3. Audit of leading cadres leaving office
4. Personal measures	4. Local regulations	4. Water resources utilization and protection
	5. Local rules	

scored, and each policy's strength scores are obtained after consistency testing. We substituted these scores into the policy synergy evaluation model to obtain the policy synergy value between different policy-making departments, the synergy value between different policy objectives, and the synergy value between different policy measures' types. From this, we identify the policies' evolution pattern over time. On this basis, key policy factors that constrain the water environment's coordinated governance in the region are analyzed, and policy recommendations for optimizing the water environment's coordinated governance in the region are proposed. The full text is arranged as follows: The first part is a literature review. The second part presents research methods and calculation steps, followed in the third part by research results and analysis. The fourth offers conclusion and policy recommendations.

2. LITERATURE REVIEW

Policy synergy is a cutting-edge field of policy scientific research, an important entry point for watershed collaborative governance, and an important basis for promoting watershed-level environmental governance integration. It refers to the process of two or more organizations creating new rules or utilizing existing decision-making rules to jointly respond to similar task environments. In the contemporary era, policy synergy is an important support for 'good governance'. Policy synergy can not only overcome administrative barriers between cross-regional administrative units and functional departments and enhance intergovernmental cooperation, but also improve the efficiency of policy effectiveness and enhance the supply capacity of public services (Jordan & Lenschow, 2010; Yi *et al.*, 2019).

Policy synergy research involves various fields such as technology, resources, and the environment. Previous research on this topic has focused on issues such as technology talent policy synergy, service industry policy synergy, land policy synergy, elderly care service synergy, and pharmaceutical industry innovation policy synergy (Yang *et al.*, 2018; Li *et al.*, 2020a, 2020b; Cao & Du, 2021). This article reviews the existing research results from two aspects: the measurement of policy synergy and the impact of policy synergy governance on the water environment in the Yangtze River Delta.

2.1. Research on measuring policy synergy

There are two definitions of policy synergy: broad and narrow. The broad concept of policy synergy includes three connotations: first, different administrative departments achieve the same policy goal by formulating and

implementing policies; second, issuing different types of policies to achieve the same policy objectives; and third, coordinating different stakeholders in the process of policy formulation and implementation to achieve the same policy goal. Narrowly defined policy synergy refers to 'policy synergy' that uses different policy types, objectives, and measures in policy texts for synergy.

Extensive research has been conducted on narrow policy synergy, using frequency distribution methods and synergy measurement model methods. The frequency distribution method calculates the number of policies issued in a certain year and the frequency of different target and measure keywords appearing in policies. For example, using the text search, word frequency statistics, and encoding functions of Nvivo software was used to deeply mine text content, analyze the execution logic of household waste classification policies, and study-specific collaborative measures such as collaborative content and degree during the policy release, execution, supervision, and feedback stages (Ding & Zhang, 2022).

The collaborative degree measurement model method is currently a commonly used method for studying narrow policy systems. It includes direct modeling and uses the collaborative degree formula after subjective assignment. An example of the direct modeling method for measuring synergy is to construct a synergy function between the central and local government industrial policy measures based on the state synergy model, to measure the synergy status between central and local policy measures (He *et al*., 2021). Based on the composite system synergy model, taking 210 science and technology talent policies implemented by 9 cities in the Pearl River Delta in the Guangdong Hong Kong Macao Greater Bay Area as an example, the subsystem order and composite system synergy of science and technology talent policies are measured (Tang & Gao, 2022).

Using the collaborative degree formula after subjective assignment first requires us to establish a quantitative standard manual and assign policy values, invite experts and scholars to score, and construct a synergy model to calculate the three policy elements' synergy using the scoring results. Multiple scholars have constructed corresponding synergy models to measure the degree of policy synergy and quantitatively analyze the internal structural elements of policies (Li & Li, 2020; Zhang *et al*., 2020; Lan, 2021). For example, using a synergy model to measure the synergy of technological innovation policies from three dimensions, Peng *et al*. describe policy measures, goals, intensity, and the evolution of policy synergy (Peng *et al*., 2008). Based on the synergy theory, Zhang constructs a measurement model for policy effectiveness and synergy from multiple dimensions using energy conservation and emission reduction as samples. The synergy of China's resource and environmental audit policies announced from 1987 to 2016 is calculated by Mei & He (2018).

2.2. Research on the impact of policy collaboration on the water pollution environment in the Yangtze River Delta

Scholars have conducted qualitative research on the collaborative mechanisms construction and quantitative measurement of changes in pollution in the Yangtze River Delta region in response to the impact of water environment collaborative governance policies (Chen *et al*., 2018, 2019; She *et al*., 2019). For example, Tian and Ding qualitatively explored the water pollution collaborative governance mechanism in the Yangtze River Delta region under the background of a large department system, and constructed a cost-benefit accounting system for water pollution collaborative governance in the region. In quantitative analysis, Chen *et al*. used exploratory spatial data analysis (ESDA) and logarithmic mean divisia index (LMDI) methods to study wastewater discharge in the Yangtze River Delta region and found technological progress has a negative impact on wastewater discharge in the region, while industrial structure, population structure, and economic development effects have a positive impact on wastewater discharge, but not significant (Chen *et al*., 2019). She *et al*. used the DID (difference-in-differences) method to analyze the implementation effect of the river head system in various cities along the Yangtze River Economic Belt. The study found that as the level of the 'river head system'

increased, the total GDP increased, and as environmental regulations became stricter, the effect of water pollution control gradually became significant (She *et al*., 2019). Chen *et al*.'s research found that environmental policies generate economic and environmental dividends. During the 11th Five Year Plan period, the same pollution reduction policies had different effects in the upstream and downstream of the Yangtze River Basin, and the pollution industry shifted to low environmental regulation areas, that is, there was a phenomenon of 'pollution paradise' in the upstream and downstream of the Yangtze River Basin (Chen *et al*., 2018).

The aforementioned calculation of policy synergy in the fields of technology, resources, and environment provides a reference point for this study. Based on the aforementioned research results, this article is based on the recognition that in the context of integration, it is necessary to focus on exploring the policy synergy status in the coordinated governance of the water environment in the Yangtze River Delta, in order to promote the integrated implementation of regional environmental governance from the policy operation level. Therefore, this study will focus on exploring the synergy between policies issued in the field of water environment protection in the Yangtze River Delta, measuring the degree of synergy of water environment governance policies and analyzing the trend of their synergistic evolution, reflecting the synergy between different policy departments, policy objectives, and policy measures, and identifying key policy factors that constrain the synergy, providing reference for improving water environment collaborative governance effectiveness in the Yangtze River Delta.

3. RESEARCH METHODS AND CALCULATION STEPS

3.1. Scoring of policy types

Based on the research of Li *et al*., according to the different levels of policy intensity, policies in a broad sense are divided into five different types of policies: laws, administrative regulations, departmental regulations of the State Council, local regulations, and local rules (Li, 2017). For this paper, we searched the 'Peking University Treasure Database' (www.pklaw.com) using the keyword 'water' to identify water resource regulations that collaborate with the Yangtze River Delta, including multiple joint or independent water environment protection policies issued by the National People's Congress, the State Council, the Ministry of Natural Resources, the Ministry of Ecology and Environmental Protection, the Ministry of Science and Technology, as well as water environment protection policies of provincial and municipal governments. Table 2 shows various policy types and associated administrative units and quantities.

The National People's Congress issued a total of 7 laws and legal modification records related to water environment governance after 2007, the State Council issued 5 administrative regulations related to water resources, and relevant departments of the State Council such as the Ministry of Water Resources, the Ministry of Housing and Urban Rural Development, and the Ministry of Environmental Protection issued 6 rules and regulations related to water resources, and the provincial and municipal governments in the Yangtze River Delta region have issued a total of 63 local regulations, 62 local rules, and 144 policies in total.

Then this paper assessed the strength, objectives, and measures of policies.

Table 2 | Types of water environment protection policies for the Yangtze River Delta at or above the municipal level from 2007 to 2022.

Policy type	Laws	Administrative regulations	Departmental regulations of the State Council	Local regulations	Local rules
Number of policies	7	5	6	63	62

3.1.1. Scoring the water environment governance policy types strength

The scores for different types of policies vary, and the scoring criteria are shown in Table 3.

3.1.2. Scoring of water environment governance policy objectives

There are four types of policy objectives for water environment governance, namely water resource utilization and protection, water pollution prevention and control, water environment ecological restoration and protection, and leadership cadres' water resource asset departure audit. Each policy objective can be further refined into sub-objectives. The quantitative standards for sub-goals and their target scores are based on the research of Mei and He on the measurement standards for resource and environmental audit policy objectives, and Zhang's research on the measurement standards for energy conservation and emission reduction policy objectives (Zhang *et al.* 2014; Mei & He, 2018). The method defines 5, 3, and 1 point, with 4 points between 5 and 3 points, and 2 points between 3 and 1 point. If the various laws and regulations that have been sorted out earlier include the four policy objectives mentioned above, then the scores of each policy objective are quantified and added up to obtain the total score of the policy objectives.

3.1.3. Scoring of water environment governance policies and measures

The corresponding laws, administrative regulations, departmental regulations of the State Council, local regulations, and local regulations for water environment governance are divided into four categories: administrative measures, economic measures, legal measures, and personnel measures. They mainly provide support for water environment governance from the administrative, economic, legal, and personnel levels. We assign an integer between 1 and 5 based on the quantity, intensity, specific degree, scope, etc., of policy measures as the evaluation criteria, drawing on the research results of Mei & He and Zhang (Zhang *et al.* 2014; Mei & He, 2018). The scoring criteria for water environment policy measures are 5 points, 3 points, and 1 point, with 4 points and 2 points between 5 and 3 points, and 3 points and 1 point, respectively. If a measure is not included in the policy, a score of 0 will be assigned.

3.2. Measurement of policy synergy

Based on the above measurement standards, multiple rounds of scoring were conducted to obtain the strength, measures, and target data of various policies each year. Referring to Zhang's synergy measurement model (Equations (1) and (2)), the synergy values of various policies were obtained (Zhang *et al.* 2014).

$$\mathrm{PMJ}_i = \sum_{j=1}^{N} \mathrm{pe}_j \times \mathrm{pm}_{jk} \times \mathrm{pm}_{jl} \tag{1}$$

Table 3 | Policy intensity assignment standards for different policy types.

Policy strength	5	4	3	2	1
Policy type	Laws	Administrative regulations, directives, regulations, and orders issued by various ministries and commissions by the State Council	Regulations, provisional regulations, plans, decisions, opinions, and standards issued by the State Council	Local regulations, temporary regulations, opinions, plans, guidelines, detailed rules, conditions, standards	Local rules, notices, announcements, plans

$$\mathrm{PGJ}_i = \sum_{j=1}^{N} \mathrm{pe}_j \times \mathrm{pg}_{js} \times \mathrm{pg}_{jt} \tag{2}$$

Among them, PMJ_i represents water environment governance policy synergy in the year i, PGJ_i represents the goal synergy of water environment governance policy in the year j, N represents the number of policies issued in the year i, pe_j represents the strength score of policy j, pm_{jk} and pm_{jl} represent the score of policy measures k and l in policy j, k and l ($k \neq 1$) represent the selection of two of four measures: administrative measures, economic measures, legal measures, and personnel measures to calculate measure synergy. pg_{js} and pg_{jt} represent the score of policy objectives in item s and t of policy j, where s and t ($s \neq t$) represent two selected from four policy objectives, namely water resource utilization and protection, water pollution prevention and control, water environment ecological restoration and protection, and leader water resource asset departure audit, to calculate goal synergy. This is followed by the calculation on the synergy of policy measures (Formula (3)) and the policy objectives' synergy (Formula (4)).

$$\mathrm{YTPE}_i = \sum_{j=1}^{N} \mathrm{pe}_j \times \mathrm{pm}_j \times \mathrm{pg}_j \tag{3}$$

$$\mathrm{YPE}_i = \frac{\sum_{j=1}^{N} \mathrm{pe}_j \times \mathrm{pm}_j \times \mathrm{pg}_j}{N} \tag{4}$$

Among them, YTPE_i represents the total effectiveness of the policy in the year i, YPE_i represents the average effectiveness of the policy in the year i, N represents the number of policies in the year i, pe_j, pm_j, and pg_j represent the policy strength score, policy measure score, and total policy goal score of the policy in the year, respectively. Based on the above measurement standards, multiple rounds of scoring were conducted to obtain the strength, measures, and target data of various policies each year. Referring to Zhang *et al.*'s collaborative measurement model, the collaborative values of various policies were obtained (Zhang *et al.*, 2014). Through the above calculations, it is possible to solve the synergy between different policy departments in the Yangtze River Delta, the synergy between different types of collaborative development policy measures, and the synergistic evolution of policy objectives in the Yangtze River Delta.

4. CALCULATION RESULTS AND ANALYSIS

4.1. Analysis of policy proportion at the regional level

4.1.1. Analysis of central and local policy proportion

From 2007 to 2022, a small portion of the water environment governance policies in the Yangtze River Delta region were issued by the central government, with a total of 18 policies, accounting for approximately 12.5%. From 2007 to 2011, the country maintained the frequency of issuing two water environment governance policies annually, with the highest number of policies issued by the country in the year 2017, reaching four. In 2012, 2014, and 2018–2022, no water environment governance policies were issued at the national level. The water environment governance policies introduced by the central government are programmatic documents, such as the Water Law of the People's Republic of China (2016 Amendment) and the Water Pollution Prevention and Control Law of the People's Republic of China (2017 Amendment). The majority of water environment governance policies in the region come from local governments, with a total of 125 items, accounting for approximately 87.5%. Local governments have issued corresponding plans and detailed rules and implemented them as the main body

implementing water environment governance. The proportion of water environment governance policies introduced by central governments from 2007 to 2022 is shown in Figure 3.

4.1.2. Measurement results of policy quantity, effectiveness, measures, and goals

The number of policies is a key factor determining the overall effectiveness of policies, with the highest policy effectiveness occurring in 2012, at 268. The minimum value of policy effectiveness is only 1, which occurred in 2021. The distribution pattern is similar to the number of policy issuances. In 2018, only nine policies were issued, but the average effectiveness of each policy reached its maximum. The strength, measures, and goals of water environment governance policies issued that year were significantly improved, and both the central and local governments increased their efforts in regional water environment governance. After 2020, the number of water environment governance measures in the Yangtze River Delta has decreased, and policies have shown stability (Figure 4).

Utilization and protection of water resources are the most important policy objectives for the region's water resources, followed by water pollution prevention and control, the water environment ecological restoration and protection, and finally, the departure audit of leading cadres. The water pollution control in the Yangtze River Delta region places greater emphasis on source prevention. After 2015, with the introduction of the strictest environmental assessment system in China, the main body responsible for environmental protection implemented a 'one vote veto system' for ecological environment protection. For regions and units that are subject to the 'one vote veto system', their qualifications for leading cadres, responsible leading cadres, and responsible leading cadres to be selected, awarded, promoted, and promoted shall be revoked within 1 year. The achievements in water environment governance to some extent determined the promotion of officials and the retention of personnel. Therefore, the proportion of audit for leaders leaving office in the overall policy goal has slightly increased. The water pollution control policies' value rationality emphasizes prevention at the source.

From the perspective of policy measures, administrative orders are still the most commonly used measure in current water environment governance. Next are legal measures, then economic measures, and finally personnel measures. The current pollution control in the Yangtze River Delta region is still in the stage of relying on

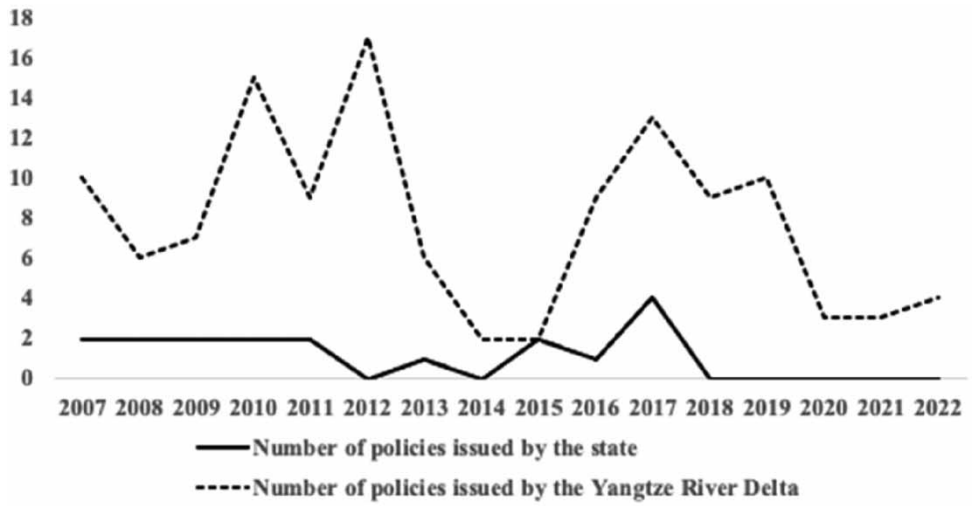


Fig. 3 | Analysis of policies' quantity issued by central government offices.

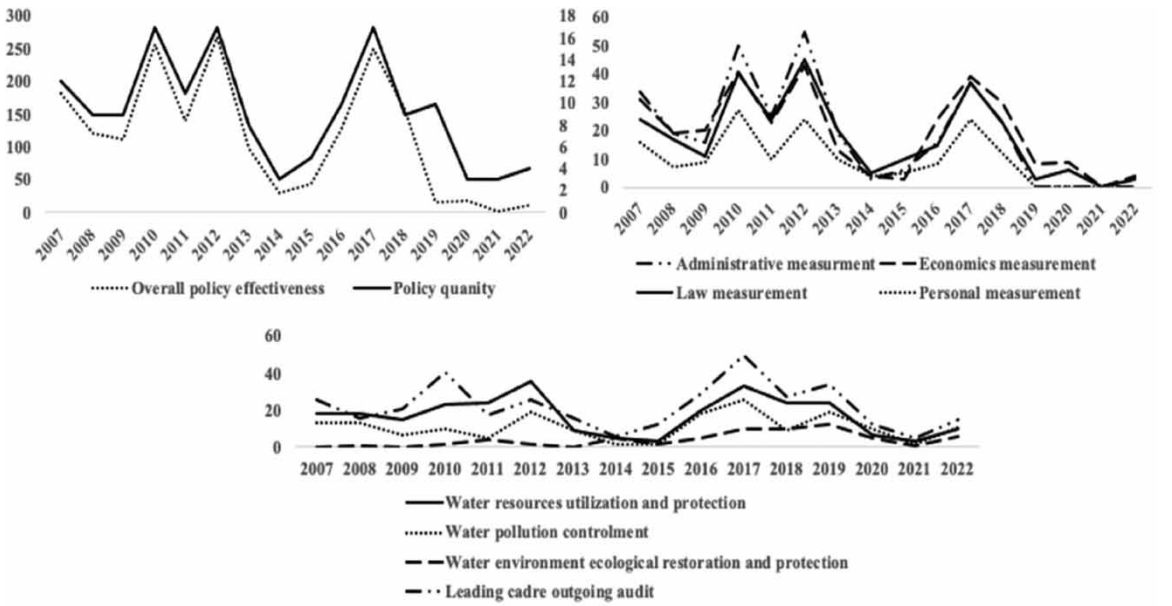


Fig. 4 | Number, objectives, and measures of water environment governance policies from 2007 to 2022.

administrative and legal measures, and the rational value tools of water environment governance policies tend to be more toward mandatory administrative command strategies. Due to the region's developed economy, economic measures are also widely applied. However, the use of personnel measures is relatively limited. Due to personnel changes caused by the tenure of officials, the personnel strategies' value rationality is not fully reflected, and there is room for its improvement in the future.

4.1.3. Policy analysis before and after the rise of the Yangtze River Delta into the national strategy

From 2019 to 2022, after the Yangtze River Delta policy integration became national strategy, a total of 16 policies were issued, with an average of 4 policies issued per year. The number of policies issued was lower than that of 2007–2019 before the Yangtze River Delta became the national policy, with an average of nearly 10 policies issued per year, which was a sharp decrease in government publications. The reason may be that the focus of the country's work has shifted to the field of public health since 2020, diluting the administrative power of water environment governance and affecting the formulation and promulgation of water resource governance policies.

After the Yangtze River Delta rose to the national strategy, the main policy measures in the region shifted from administrative and legal measures to legal and economic measures. The main policy objectives have shifted toward water resource utilization and protection, water environment ecological restoration and protection, which was different from the policy objectives of water pollution prevention and control when the Yangtze River Delta has not yet become a national strategy. At present, the focus of water resource management in the Yangtze River Delta region has shifted from end to source prevention.

4.2. Policy analysis at the provincial level

4.2.1. Differences in policy promulgation among provincial administrative regions

Between 2007 and 2022, among the water resource governance policies in the Yangtze River Delta region, 66 provincial-level administrative units issued 66 policies and 59 municipal administrative units issued 59 policies.

Among them, there are 20 provincial-level and 34 municipal-level projects in Jiangsu Province, 21 provincial-level and 13 municipal-level projects in Zhejiang Province. Anhui Province has 8 provincial-level projects and 12 municipal-level projects, 17 provincial-level projects in Shanghai. In provincial-level administrative regions such as Jiangsu and Anhui, water resource governance rights have further declined, and prefecture-level cities play a more important role in policy formulation. Compared with other provinces, Zhejiang Province is better at unified action across the province, formulating water pollution control policies at the provincial level, and then implementing them separately by each prefecture level city. These two methods have their own advantages and disadvantages. The former can mobilize the policy enthusiasm of various prefecture level cities to a greater extent, but the latter helps to implement coordinated water resource governance at the provincial level. Therefore, Zhejiang Province has specially formulated the 'Zhejiang Province Cross administrative Region River Intersection Section Water Quality Monitoring and Protection Measures (Revised in 2021)' to coordinate water resources' coordinated management across administrative regions within the province. In other administrative regions, there has been no cross-regional water resource governance policy, which belongs to Zhejiang's own water resource governance characteristics.

4.2.2. Analysis of inter-provincial differences in policy quantity, effectiveness, and type

In Anhui Province, the number of policies issued each year is less than 4. These policies are mainly administrative orders, followed by legal measures, and personnel and economic measures are not commonly used (Figure 5). This is related to the underdeveloped economy and relatively outdated management in the region. Economic measures cannot effectively stimulate water pollution control in the region, so they are less used. In terms of per capita GDP, Anhui is 56.1 thousand RMB per year per person in 2018 and 72.9 thousand RMB per year

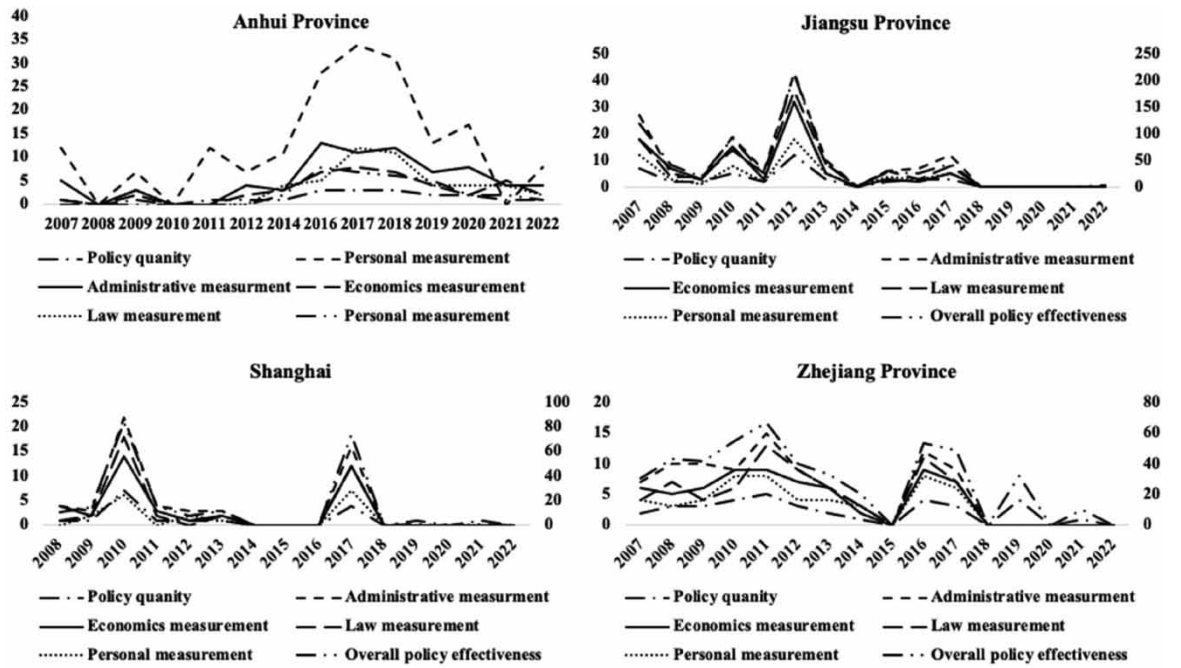


Fig. 5 | Number, effectiveness, and types of water environment governance policies in four inter-provincial administrative regions of the Yangtze River Delta region.

per person in 2022, which has increased by 30% in 4 years, the GDP growth rate of which has been relatively fast. With the enhancement of economic activity, the utilization rate of economic strategies in water environment governance in Anhui Province has increased.

Jiangsu Province has issued the most water environment governance policies. Before 2012, the number of water environment governance policies was in a state of alternating high and low, with a higher number of policies issued in the previous year and a corresponding decrease in the number of policies issued in the following year. In 2012, 12 policies were issued, which was the peak year for the number of policies between 2007 and 2022. However, in the following years, the number of policies issued, the strength of policy measures, and the overall strength of policies remained relatively low. Administrative measures are the most commonly adopted water environment governance measures in Jiangsu Province, followed by legal measures, economic measures, and personnel measures subsequently.

In Shanghai City, the number of policies and the effectiveness of various policy measures reached a peak of 7 in 2010 and 2017. In other years, the number of policies issued is relatively small and the policy intensity is relatively weak. Except for the relatively weak strength of personnel measures in Shanghai, the other three measures have been used to a large extent. Compared with other provinces, Shanghai is particularly skilled in the use of economic measures, which cannot be separated from its developed economic background. In 2018, Shanghai's per capita GDP was 135,000 yuan, ranking second among the 32 provincial-level administrative regions in the country, meeting the standards of developed country economies, and possessing the economic foundation to use economic measures to promote water environment governance.

In Zhejiang Province, the coordination of policies and measures remains at a high level, making it the provincial-level administrative region that pays the most attention to details in policy formulation in the Yangtze River Delta region. The basis is that the number of policies issued by Zhejiang Province each year is not large, maintaining a level of around 3, with a maximum of 5 in the year 2011. However, the overall effectiveness of its policies is significant, and each policy in the province maximizes the use of four policy measures to ensure the maximum implementation and execution of policies. In the province's 'Five Water Co-governance', the objectives of sewage treatment, flood prevention, waterlogging drainage, water supply guarantee, and water saving are efficiently combined and implemented together. The comprehensive application of collaborative governance policies has successfully prompted its policy effectiveness.

4.2.3. Analysis of inter-provincial differences in policy objectives

This section compares differences in policy objectives among the four provinces. The most important goal for Anhui Province is the utilization and protection of water resources, followed by water ecological restoration and protection, leader departure audit, and water pollution prevention and control. The policy goal of water pollution prevention and control has been ignored, and it can be further strengthened in the future to improve water pollution control effectiveness (Figure 6).

The policy objectives of Jiangsu Province are stronger than those of other provincial administrative regions in the Yangtze River Delta, and their water environment governance policies are detailed and characterized by strong implementation. Before 2021, water pollution prevention and control are the most important policy goals in the province, followed by water resource utilization and protection, water environment ecological restoration and protection, and leadership cadres' departure audit. After 2021, the key goals of water environment governance policies in Jiangsu Province have gradually shifted toward water resource utilization and protection, followed by ecological restoration and protection of the water environment, followed by water pollution prevention and control, and the final policy goal is the audit after the departure of leading cadres. This indicates that

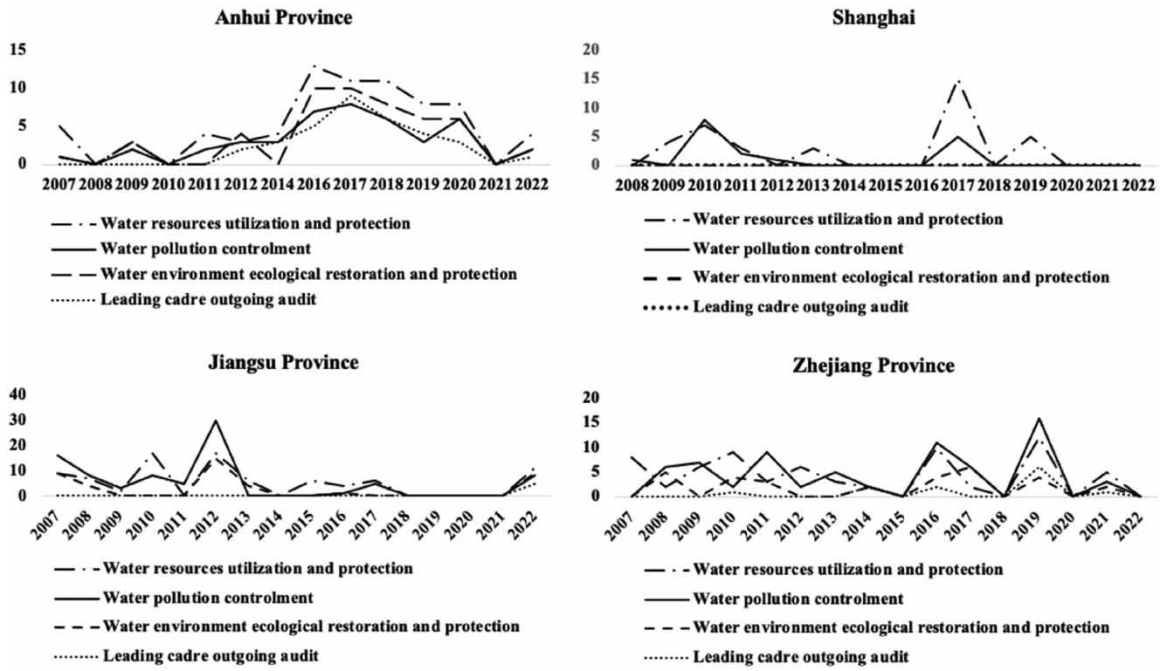


Fig. 6 | Evolution of the number, intensity, and effectiveness of water environment governance policies in different provinces.

after long-term efforts, the water quality in the province has significantly improved, and the rational value of policies has shifted from end to source prevention.

The water resource governance policy in Shanghai only lists two key goals, namely water resource utilization and protection, and water pollution prevention and control. The strength of the policy goals is not significant, and there is a lack of two policy goals, namely water environment ecological restoration and leader departure audit. In the future, the implementation of these lacked two policy goals can become the focus to improve water resource governance in Shanghai.

The characteristic of the water resource governance policy goals in Zhejiang Province, which differ from other provinces in the region, is that the three major policy goals of water resource utilization and protection, water pollution prevention and control, and water environment ecological restoration and protection are very balanced, and all the three policy goals are implemented in its 'Five Water Governance'. However, the audit system for the departure of its leading cadres is relatively weak, and this policy goal can be applied to improve the effectiveness of water resource governance in the future.

5. CONCLUSION AND POLICY RECOMMENDATIONS

5.1. Research conclusion

This study uses a policy synergy model to calculate the synergy of 144 water environment governance policies issued by the country and the Yangtze River Delta region from 2007 to 2022. We find that, firstly, the water resource governance policies issued by local governments account for 87.5% of the total policy volume, making them the main decision-makers of water resource governance policies. Second, the main water resources management policy objectives in the Yangtze River Delta are water resources protection and water pollution

prevention, and the policy attention paid to water environmental remediation and the leaving audit of leading cadres is insufficient. Thirdly, administrative and legal measures are the most important policy measures for water resource management in the Yangtze River Delta, and the use of economic and personnel measures is relatively insufficient. Fourthly, there are significant differences in the goals, dynamics, and measures of water resource governance policies among various provincial administrative regions in the Yangtze River Delta. Based on the above findings, we close our paper with policy recommendations for improving the collaborative governance of the water environment in the region.

5.2. Policy recommendations

The central government needs to create conditions for local governments to play a leading role in water governance. Local governments are the main force in regional water environment governance, and the central government should give them full discretion. According to the policy objectives and needs of water environment governance in different provincial administrative regions, they should be empowered to maximize the administrative potential of local governments in water environment governance and ensure the healthy and sustainable water environment governance in the Yangtze River Delta region. This will require us to fully leverage the rationality of water environment governance policies.

The current water environment governance in the Yangtze River Delta deserves recognition for its value rational approach of 'focusing on source prevention'. However, considering the historical accumulation of water pollution in the region, the equal emphasis on 'prevention and governance' is sufficient to effectively improve water pollution governance efficiency. The rational utility of policy tools in the current region has not been fully utilized, and there is significant room for improvement in economic and personnel measures. The implementation cost of administrative and legal measures is high, and water environment governance is difficult to form a virtuous cycle in the long term. It is necessary to strengthen the use of economic and personnel measures to enhance the sustainability of water resource governance – effectively linking the value rationality of water resource governance with the instrumental rationality, such as integrating the value rationality of 'emphasizing source prevention' into the instrumental rationality of administrative and legal measures, and combining the value rationality of 'water resource governance' with economic and personnel measures to maximize the effectiveness of water pollution governance.

Each provincial-level administrative region in the Yangtze River Delta needs to improve its water resource governance policy system based on its own characteristics. There is significant room for improvement in the policy system of Anhui Province in terms of policy quantity, policy effectiveness, policy measures, and other policy elements. Jiangsu Province is necessary to improve the implemented policies' continuity to ensure their continued effectiveness. For Shanghai, the number and intensity of its water resource governance policies need to be increased. Zhejiang Province has room for improvement in the number of policies.

There is a need for policy stability to enhance policy effectiveness. In 2019, the integration of the Yangtze River Delta became a national strategy, but the number of water resource governance policies in the Yangtze River Delta region did not increase but decreased between 2020 and 2022. On the other hand, it may also be because the region is committed to implementing previously formulated policies, forming policy stability, and continuously exerting the effectiveness of existing policies, with policy effects greater than sudden termination or opening new policies. How to measure the stability of water resource governance policies in the region and evaluate their impact provides further research direction.

This study also has policy implications for other watersheds as listed below. First, in the watershed collaborative governance field, rational thinking should be given to the logical relationship between policy elements and policy rationality, and reasonable policy tools should be utilized to reflect policy value to accelerate the

comprehensive watershed governance framework construction. Second, basin collaborative governance should examine the policy governance characteristics of each independent unit, analyze the internal causal relationship between the governance unit's own basin water resource governance tasks and governance policy choices, and explore using the differentiated governance models within the basin under the collaborative governance framework to achieve better basin governance effects.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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