Global NEST Journal, **28** (XX), pp 1-13
Available online: 07/06/2026

Do River Chiefs Deliver? Political, Environmental, and Fiscal Dimensions of Water Governance Effectiveness

Wan Sun[1], Shi Chen[2, 3], Xue Lei[4]*

[1]School of Medical Humanities, Hubei University of Chinese Medicine, Wuhan, China
[2]School of Public Administration and Policy, Shanghai University of Finance and Economics, Shanghai, China
[3]Department of Computer, Control, and Management Engineering "Antonio Ruberti", Sapienza University of Rome, Italy
[4]School of Management, Shanghai University, Shanghai, China

*Correspondence e-mail: leixue_work@shu.edu.cn

Abstract

Industrial wastewater discharge remains a critical threat to sustainable water resource management, yet how institutional accountability arrangements constrain urban pollution behavior under decentralized governance systems is insufficiently understood. This paper exploits the staggered provincial rollout of China's River Chief System to construct a staggered difference-in-differences model using panel data covering 285 prefecture-level cities from 2013 to 2020. The results show that River Chief System implementation reduces urban industrial wastewater discharge intensity by approximately 7%, a finding that holds across parallel trends tests, placebo tests, and alternative estimators including the Callaway–Sant'Anna and Sun–Abraham approaches. The reduction is also visible in the discharge of chemical oxygen demand and ammonia nitrogen, the two pollutants targeted by China's water quality assessment. Policy effects, however, vary systematically across cities: a higher political rank of the provincial chief river official strengthens downward accountability transmission; greater water resource scarcity raises local officials' implementation initiative; and higher fiscal self-sufficiency enables more effective translation of institutional mandates into enforcement actions. The policy works in part by raising local environmental enforcement effort and encouraging a shift toward cleaner industrial activity. These findings suggest that embedding water quality targets within political career structures, combined with differentiated fiscal support matched to city-level resource endowments and capacities, offers a more robust pathway toward sustainable water governance than relying on short-term policy shocks alone, with implications for decentralized water management in other developing economies.

Keywords: River Chief System; Industrial wastewater discharge; Decentralized governance; Water resource endowment; Fiscal self-sufficiency; Political accountability.

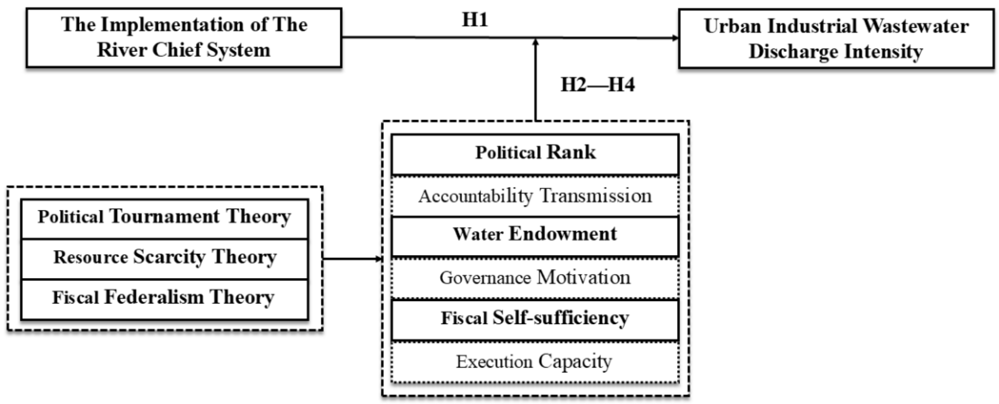
OPEN ACCESS

Received: 04/03/2026,

Accepted: 03/06/2026,

Available online: 07/06/2026

Graphical abstract



1. Introduction

Industrial wastewater discharge has been identified as a key threat to global freshwater systems. As industrialization deepens, rivers and lakes have absorbed growing volumes of pollutants, including organic compounds, heavy metals, and excess nitrogen and phosphorus, while their natural self-purification capacity has continued to decline under increasing environmental pressure and more frequent extreme weather events. The threats posed by industrial pollution to sustainable water use have therefore intensified along both quantitative and qualitative dimensions (Liang *et al.*, 2025). As a major manufacturing economy, China has long recognized that severe contamination at many river headwaters originates primarily from poor industrial pollution control. Where industrial pollutants and domestic wastewater accumulate together, their combined impact poses a substantial risk to water resource security. At the city level, the intensity of industrial wastewater discharge reflects both the trade-offs that local governments confront between economic growth and environmental protection and the practical effectiveness of water pollution control policies. How institutional design can constrain urban industrial pollution behavior is therefore a central question in water resource economics and public policy research.

Under a decentralized governance system in which the central government sets regulations and local governments implement them, policy effectiveness depends more on local incentive arrangements than on the formal allocation of fiscal authority. Although fiscal decentralization and environmental decentralization can in some respects strengthen a region's capacity to manage resources, they do not automatically translate into reductions in pollutant emissions (Xu, 2022). Targeted policies have at times been more effective in improving specific aspects of pollution within short time horizons; for instance, empirical evidence indicates that initiatives such as the "Water Ten Plan" have improved urban water quality and reduced wastewater discharge (Chen, 2024; Zheng *et al.*, 2022). Yet such one-time policy shocks rarely alter the underlying incentive constraints that shape local officials' day-to-day behavior, and emission levels often rebound once external pressure subsides. Through unified central deployment in 2016, the River Chief System linked water environmental quality vertically to local officials' political careers, thereby generating sustained upward accountability pressure. In institutional design, it directly addresses the core problem of weak incentive mechanisms in decentralized governance (Liu & Bai, 2022; She *et al.*, 2019). It is worth situating the River Chief System within the broader range of water governance arrangements at this point, because the choice of this institution as the analytical object is substantively motivated. Decentralized water governance elsewhere has been organized around at least three alternative designs: independent environmental regulatory agencies that concentrate enforcement authority in a specialized bureaucracy, integrated river basin commissions that align jurisdiction with hydrological rather than administrative boundaries, and market-based instruments such as tradable discharge permits that price pollution directly. Each addresses the fragmentation problem from a different angle. What distinguishes the River Chief System is that it leaves the existing administrative map intact while attaching personal, named responsibility for specific water bodies to individual leading officials and embedding water quality outcomes within the political career evaluation those officials already face. Its distinctive feature is therefore not a new enforcement agency or a new market, but a re-engineering of the incentive structure surrounding officials who were already in place. Studying this design speaks to a general question in the governance literature, namely whether decentralized accountability that works through career incentives rather than through institutional redesign can deliver environmental improvement, and under what conditions it does so.

Existing research on the policy effects of the River Chief System has taken several different approaches. The system has shown some restraining effect on agricultural non-point source pollution, although its effectiveness against pollutants such as chemical oxygen demand remains contested (Li *et al.*, 2020; Li & Huang, 2021). Firm-level analyses have identified time lags and even short-term increases in pollutant concentrations following the reform (Zuo *et al.*, 2026). Promotion incentives and the personal characteristics of local officials shape the depth of policy implementation to varying degrees (Li *et al.*, 2024; Tang *et al.*, 2025), and some cities exhibit weak compliance behavior in which non-assessed pollutants are effectively ignored (Wang & Zhao, 2025). In sum, although the literature has examined how the effects of the River Chief System vary across spatial scales, the city-specific conditions that drive such variation, particularly how the transmission intensity of political pressure, north–south differences in water resource endowment, and disparities in fiscal implementation capacity jointly shape policy effectiveness, remain largely unexplored.

Does the River Chief System reduce urban industrial wastewater discharge intensity? Does the political rank of the provincial chief river official strengthen the downward transmission of policy pressure? Do regional differences in water resources lead to systematic variation in implementation? And are cities with greater fiscal autonomy more effective in achieving emission reductions in practice?

Drawing on an unbalanced panel dataset of 285 prefecture-level cities from 2013 to 2020, this paper constructs a staggered difference-in-differences model that exploits cross-provincial variation in the timing of policy implementation to address these questions systematically.

The contributions are threefold, and the central one concerns not whether the River Chief System reduces discharge but the conditions under which a decentralized accountability arrangement is translated into compliance. The first contribution reframes the question of policy effectiveness. Rather than asking in binary terms whether institutional accountability works, this study advances the view that the effectiveness of the River Chief System is contingent on the joint configuration of political, ecological, and fiscal conditions, and it documents how each condition shapes the strength of the response. This moves the discussion from a question about average effects toward one about institutional and environmental complementarities, namely which combinations of downward political pressure, resource-driven governance motivation, and fiscal execution capacity allow a paper mandate to become enforced behavior. The second contribution is empirical. The study targets urban industrial wastewater discharge intensity, complements it with the discharge of chemical oxygen demand and ammonia nitrogen, and exploits exogenous provincial variation in policy rollout to construct a quasi-experimental design, providing robust evidence through systematic checks using the Callaway–Sant'Anna and Sun–Abraham estimators. The third contribution is to trace how the policy operates, with the accountability arrangement raising local environmental enforcement effort and encouraging a shift toward cleaner industrial activity, which offers evidence on the channels through which decentralized environmental policy works rather than treating the effect as a black box. From a policy standpoint, the findings provide direct guidance for institutional reform and incentive design in jurisdictions seeking to enhance water environmental governance under decentralized arrangements, with broader relevance for other developing and transition economies.

2. Literature Review and Hypothesis Development

2.1. *Literature Review*

The governance of water environments in China lies at the heart of ecological civilization construction, and industrial wastewater, the principal source of surface water pollution, has long attracted attention regarding both its emission reduction pathways and the policy responses available. The literature on factors influencing industrial wastewater discharge is now relatively comprehensive. With respect to pollution sources, industrial activity remains the central driver of water body pollution in China, reflecting both firm-level discharge behavior and the strength of regional regulatory capacity; the combined pressure of agricultural non-point source pollution, domestic sewage, and industrial discharge poses an increasingly severe challenge for water quality protection. With respect to the institutional environment, fiscal decentralization significantly shapes local governments' willingness to invest in environmental protection and their actual governance performance. Areas with greater fiscal capacity tend to exhibit higher implementation standards but do not necessarily achieve lower aggregate emissions simply by gaining more autonomy (Xu, 2022). The literature on technological pathways has also identified threshold effects: the suppressive effect of technological progress on water pollution intensity becomes more pronounced under sufficiently strong regulatory pressure (Ma *et al.*, 2020). Although most studies describe mechanisms that may influence industrial wastewater discharge, detailed assessment of how specific policies and regulatory measures translate into emission outcomes remains limited.

Empirical evaluations of China's water environmental governance policies have grown rapidly. Among the institutional reforms whose effects on water quality are now relatively well established, several findings stand out. Evidence from cities in the Yangtze River Economic Belt indicates that the River Chief System produces a substantial reduction in surface water pollution, with effects more pronounced in smaller cities and in those with weaker baseline regulation and lower economic capacity (She *et al.*, 2019). Dynamic firm-level analysis suggests a delayed emission-reduction effect: it typically takes two to three years before chemical oxygen demand declines noticeably, and certain pollutants exhibit short-term spikes following policy introduction (Zuo *et al.*, 2026). County-level evidence shows that the River Chief System reduces water pollution from livestock and poultry wastewater shocks but cannot fully restrain non-point source pollution from fertilizer use (Li & Huang, 2021). Other research based on provincial monitoring data identifies signs of surface-level governance and notes that path dependence favoring economic development can undermine the system's expected effects across all pollutants (Li *et al.*, 2020). Beyond the River Chief System, work on other elements of China's ecological civilization framework suggests that linking officials' performance evaluation directly to environmental quality targets can improve implementation, though weak local execution capacity continues to generate substantial regional variation in policy outcomes (Chen, 2024; Li *et al.*, 2024; Zheng *et al.*, 2022). The divergence among these findings is itself informative rather than a set of contradictions to be averaged away. Firm-level studies capture immediate adjustment costs and the lumpy timing of abatement investment, which can register as a transitory rise in measured concentration, whereas city-level studies observe the net behavioral response once adjustment has occurred; results tend to be stronger for assessed pollutants that enter official evaluation than for those outside the assessment scope; and studies that end early or rely on a conventional two-way fixed effects specification under staggered adoption may understate effects that accumulate over time. Reading the prior evidence in this light clarifies the gap this study addresses, since working at the city level, examining an intensity measure alongside the discharge of the two assessed pollutants, and relying on estimators designed for heterogeneous and staggered treatment together recover a behavioral response that is comparable across the conflicting prior findings.

Building on these contributions, the existing literature has accumulated empirical evidence on the effects of the River Chief System at the city, firm, and county levels but has not systematically examined how policy effects vary across regions under a unified institutional framework. In particular, few studies investigate how the strength of political pressure transmission, regional differences in water resource endowment, and disparities in urban fiscal capacity jointly shape the spatial structure of the system's emission-reduction effects. Political incentives determine whether accountability pressure can be transmitted effectively to municipal-level executive bodies; resource scarcity shapes the intensity with which local officials pursue implementation; and fiscal capacity ensures that institutional deployment is backed by adequate resources and enforcement strength. These three factors operate through distinct channels but jointly determine ultimate policy effectiveness. Without explicit attention to these conditioning factors, the underlying drivers of cross-city variation in River Chief System outcomes remain obscured, and it is difficult to design targeted policies suitable for different urban governance contexts. Drawing on an unbalanced panel of 285 prefecture-level cities from 2013 to 2020, this paper applies a staggered difference-in-differences approach to integrate these three categories of city-level characteristics into a unified analytical framework, providing a more nuanced understanding of the spatial heterogeneity of the River Chief System's emission-reduction performance.

2.2. *Hypothesis Development*

According to environmental federalism theory, the central government sets general environmental improvement goals while local governments adopt specific strategies appropriate to their circumstances under the relevant incentives and constraints. The River Chief System ties leadership accountability directly to environmental protection objectives at every level and transmits responsibility downward through the administrative hierarchy when water pollution control fails to meet expectations. Industrial wastewater is now a major contributor to water pollution across prefectures, reflecting both firm operating behavior and the strength of government regulation (Hong *et al.*, 2020). Prior to the implementation of the River Chief System, the principal problems in river protection were diffuse responsibility, fragmented management, and weak incentive mechanisms (Wang & Chen, 2020). According to the principal–agent model, as monitoring costs fall and incentive-compatibility constraints tighten, agents' actions increasingly reflect the principal's interests (Levačić, 2009; Miller & Whitford, 2007). Through mechanisms such as the "one-vote veto" and annual performance appraisal of river chiefs, the new incentive structure makes it infeasible for local officials to evade responsibility for polluted water bodies in their jurisdictions, generating tangible regulatory pressure on enterprises that discharge wastewater. This leads to the following hypothesis:

H1: Implementation of the River Chief System decreases the intensity of urban industrial wastewater discharge.

Effectiveness can vary substantially across localities under the same institutional framework, and the strength of political pressure transmission is one important conditioning factor. Political incentive theory offers a specific expectation here, but its application to the River Chief System depends on a feature of the Chinese cadre system that deserves to be stated explicitly rather than assumed. In a promotion-tournament setting, the behavior of a subordinate official responds most strongly to signals that originate from the level with authority over that official's advancement, and the credibility of such a signal rises with the rank of the official who issues it (Chen *et al.*, 2017). When the provincial chief river official is the provincial party secretary or governor, water environmental performance is no longer one objective among many delegated to a functional department; it becomes a priority owned by the leader who controls the evaluation of every city-level official in the province. The mechanism therefore runs through the structure of the cadre evaluation system rather than through any change in formal regulatory authority. The scope condition is that this expectation applies where promotion is centrally managed and where a higher-ranked principal can credibly attach career consequences to a specific outcome, which is the situation of provincial leadership in China. When the provincial chief river official is the provincial party secretary or governor, environmental management becomes a high-salience responsibility at the provincial level, the risk of regulatory laxity at city and county levels declines, and local officials become more strongly motivated to strengthen pollution prevention within their jurisdictions. This pattern is particularly pronounced in China's governance model, where direct supervision by senior officials can rapidly translate written policy plans into on-the-ground action (Kornreich, 2025; Schubert & Alpermann, 2019). Conversely, when the chief river official holds a relatively low rank, command authority is weaker, local enforcement enjoys more discretion, and policy effectiveness is correspondingly diminished. Hence:

H2: The higher the political rank of the river chief, the greater the emission-reduction effect of the River Chief System.

Beyond political motivation, the natural environment of a city can also shape officials' governance behavior. Resource scarcity theory holds that the effort an actor devotes to safeguarding a resource rises with the scarcity of that resource (Hassani-Mahmooei & Parris, 2013). The theory was originally developed for private resource users facing the prospect of depletion, so its transfer to the behavior of bureaucratic officials calls for a bridging argument rather than a direct transplant. That bridge is the political salience of scarcity. In northern Chinese cities, low per capita water availability raises the cost of water supply, tightens the carrying capacity of local water environments, and turns water shortage into a visible source of public concern and potential social instability. Under these conditions, water becomes a resource whose mismanagement carries political risk for the official, so the official internalizes the scarcity that residents face and treats water environmental governance as a higher priority. The scope condition for applying the theory to officials is thus that scarcity is politically salient enough to enter the official's own objective function, which holds where water shortage is severe and locally visible. Northern Chinese cities generally have far lower per capita water resources than their southern counterparts, face greater pressure on water environmental carrying capacity, and contend not only with higher water supply costs but also with potential social stability concerns associated with water scarcity. These conditions give local officials in the north stronger incentives to advance River Chief System implementation. In the south, where water environmental constraints are typically less severe, officials retain more flexibility in policy execution, and full institutionalization is harder to ensure. Studies of local government behavior find that officials tend to allocate administrative resources toward the points of greatest governance pressure (Agranoff, 2014); the scarcer a region's water resources, the stronger the actual governance pressure, and the greater the deterrent effect of policy. Accordingly:

H3: Cities with scarcer water resources exhibit a larger emission-reduction effect under the River Chief System.

Governance motivation must be matched by governance capacity to produce results. Fiscal federalism theory in its classical form assumes autonomous subnational jurisdictions that set their own taxes and tailor public goods provision to local preferences, and it links the quality of that provision to local fiscal capacity (Zhuravskaya, 2000). The Chinese fiscal system departs from this benchmark in an important respect, because local governments operate under substantial central constraints on both revenue authority and expenditure mandates, so they cannot freely adjust taxation to fund local priorities. The relevant insight from the theory survives this departure once it is framed in terms of fiscal capacity rather than fiscal autonomy. What matters for the River Chief System is whether a city can mobilize the resources required to give the policy effect, and a city with a higher ratio of own revenue to expenditure has greater discretionary room to finance environmental infrastructure and enforcement even within a centrally constrained system. The theory is therefore applied here in its capacity formulation, which suits a setting where jurisdictions lack tax-setting power but still differ markedly in the fiscal slack available for discretionary policy implementation. The River Chief System requires the construction and maintenance of online monitoring equipment, upgrading of wastewater treatment facilities, and strengthening of environmental enforcement capacity, all of which depend on sustained fiscal support. Cities with greater fiscal capacity are better positioned to convert high-quality development standards into binding rules on enterprise wastewater discharge through environmental funds, improved enforcement efficiency, and related instruments. Fiscally constrained cities, by contrast, often confine implementation to formal documents without the supporting measures needed to give policy effect. Classic studies of public policy implementation likewise emphasize that implementation capacity is a key determinant of whether policy goals are ultimately achieved (O'Toole Jr, 2000; Williams, 2021). This leads to:

H4: Cities with higher fiscal self-sufficiency achieve larger emission reductions under the River Chief System.

3. Methodology

3.1. *Data Sources*

This study constructs an unbalanced panel dataset of 285 prefecture-level cities in China from 2013 to 2020. Information on the timing of River Chief System implementation was hand-collected from official documents and government work reports, including the year in which each prefecture-level city's province formally issued a comprehensive plan for advancing the system, which is treated as the policy implementation year. Data on industrial wastewater discharge volumes and related water pollution indicators are drawn from the China Environmental Statistics Yearbook and the China Urban Statistical Yearbook; regional economic and social regulatory variables come from the China Urban Statistical Yearbook and provincial statistical yearbooks. City-level discharge of chemical oxygen demand and ammonia nitrogen in industrial wastewater is obtained from the China Economic Information Network statistical database, whose figures derive from data published by local statistical bureaus. The count of green patent authorizations at the city level is drawn from the China National Intellectual Property Administration records. Data on the personal characteristics of officials are obtained from a comprehensive database of provincial, municipal, and county-level officials in China provided by CnDataSeed, which is used to construct measures of the political rank of river chiefs.

3.2. *Variable Definitions*

Industrial wastewater discharge intensity (WINT): the annual industrial wastewater discharge volume of each city divided by total industrial output value in the same year, expressed in logarithmic form to mitigate heteroskedasticity. As an alternative measure, log (WASTE) is also used.

The core explanatory variable is the River Chief System implementation dummy (RIVER), which equals 1 if the province in which the prefecture-level city is located has officially issued a comprehensive plan for implementing the River Chief System and the system is in effect during the corresponding year, and 0 otherwise. Because the central government issued a unified deployment plan at the end of 2016 and provinces completed implementation between 2017 and 2018, the staggered timing of provincial rollouts provides exogenous variation suitable for a staggered difference-in-differences design.

The study further examines interaction effects between three city-level characteristics and the River Chief System policy. River chief political rank (RANK) equals 1 when the provincial party secretary or governor personally serves as the provincial chief river official; a higher political rank implies stronger downward transmission of accountability pressure, and the interaction with RIVER is expected to be significantly negative. Water resource endowment (WATER) measures per capita water resources at the city level; in water-scarce northern regions, the urgency of environmental governance is greater, and the River Chief System's effect on industrial wastewater control is expected to be more pronounced. Fiscal self-sufficiency (FISCAL) is defined as the ratio of local general public budget revenue to expenditure; cities with higher fiscal autonomy possess greater capacity to support environmental infrastructure construction. These three variables capture, respectively, political pressure transmission, natural condition constraints, and fiscal execution capacity.

Two mechanism variables are used to characterize how the policy operates. Environmental enforcement intensity (ENV) is measured as completed investment in industrial pollution control projects divided by industrial output, capturing the effort that local governments devote to enforcement and abatement. Green patent intensity (GPAT) is the logarithm of one plus the annual number of authorized green patents in each city, capturing the extent to which the local economy is shifting toward cleaner production.

The control variables include per capita GDP (PGDP) to capture scale effects of economic growth on emissions; the share of industrial output in GDP (IND) to account for differences in industrial structure; the logarithm of actual utilized foreign direct investment (FDI); and the logarithm of population density (POP).

3.3. *Empirical Strategy*

Variation in the timing of formal River Chief System adoption across provinces is used to construct a staggered difference-in-differences (SDD) model. Because deployment was directed centrally, the staggered rollout offers a favorable setting for estimating the net policy effect while ruling out most forms of self-selection bias by provinces. The baseline specification is given below:

$$WINT_{it} = \alpha + \beta RIVER_{it} + \gamma X_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

where $WINT_{it}$ is the industrial wastewater discharge intensity of city i in year t; $RIVER_{it}$ is the core explanatory variable; X_{it} is a set of time-varying control variables; μ_i is the city fixed effect, absorbing time-invariant city-level differences; λ_t is the year fixed effect, controlling for common time trends; and ε_{it} is the random error term.

4. Results

4.1. *Descriptive Statistics*

Table 1 reports descriptive statistics for the main variables. The mean industrial wastewater discharge intensity (WINT) is 1.352, with a standard deviation of 0.824, indicating substantial cross-city variation in wastewater discharge performance and providing sufficient cross-sectional contrast for comparison. The mean of the River Chief System dummy (RIVER) is 0.423, indicating that about four-tenths of the city–year observations correspond to post-implementation periods, with provinces gradually rolling out the system during 2017 and 2018. The distribution of control variables is broadly consistent with expectations: the mean of per capita GDP (PGDP) is 10.682, corresponding to typical prefecture-level per capita output; the mean industrial output share (IND) is 0.412, reflecting a manufacturing-oriented industrial structure across the sample. All variables fall within reasonable empirical ranges, with no extreme outliers attributable to observational bias.

4.2. *Benchmark Results*

Table 2 reports the baseline regression estimates. Column (1) includes only city and year fixed effects, while column (2) additionally incorporates the full set of control variables. Both columns indicate that River Chief System implementation produces an identifiable suppressive effect on industrial wastewater discharge intensity. In the absence of control variables, the coefficient on RIVER is −0.087, significant at the 5% level; because WINT is log-transformed, this coefficient implies that industrial wastewater discharge intensity declines by approximately 8.3% following implementation. With control variables included, the coefficient narrows to −0.074, remaining significant at the 5% level and corresponding to a reduction of approximately 7.1%. This moderate contraction suggests that part of the unconditional estimate is confounded by systematic city-level characteristics, but the direction and magnitude of the policy effect remain stable, leaving the core conclusion substantively unchanged.

Several control variables, including fiscal self-sufficiency, per capita GDP, industrial structure, and foreign direct investment, are plausibly related to one another, so it is useful to check that this overlap does not distort the estimates. **Table 3** reports variance inflation factors for the baseline specification. The values are uniformly low, with a maximum of 2.41 for PGDP and a mean of 1.87 across the regressors, comfortably below both the conventional threshold of 10 and the more demanding threshold of 5.

4.3. *Robustness Checks*

The validity of staggered difference-in-differences estimation rests on the parallel trends assumption: treated and control cities should display similar pre-implementation trajectories of industrial wastewater discharge intensity. To assess this assumption, an event study model is estimated to obtain period-specific policy coefficients, and the corresponding patterns are presented in **Figure 1**. The estimated coefficients for all four pre-implementation periods are close to zero, with confidence intervals that comfortably contain zero, providing reasonable empirical support for the parallel trends assumption. From the implementation year onward, the coefficients move steadily in a negative direction over the next three periods before stabilizing. This pattern indicates that the emission-reduction effect of the River Chief System is not a one-time impulse but accumulates gradually with the depth of implementation, consistent with the practical reality that the system typically requires several adjustment phases before generating clearly observable effects. The figure plots the event study coefficients together with their 95% confidence intervals, with the period immediately preceding implementation serving as the base period; the horizontal axis measures event time in years relative to implementation and the vertical axis measures the estimated coefficient on WINT.

Table 1. Descriptive Statistics.

Variable	N	Mean	SD	Min	Max
WINT	1,986	1.352	0.824	−1.203	3.847
WASTE	1,986	7.218	1.134	3.562	10.241
COD	1,986	9.864	1.057	5.913	12.736
NH_3N	1,986	7.142	1.218	3.047	10.358
RIVER	1,986	0.423	0.494	0.000	1.000
PGDP	1,986	10.682	0.512	9.143	12.084
IND	1,986	0.412	0.112	0.108	0.692
FDI	1,986	11.243	1.876	5.234	15.682
POP	1,986	5.847	0.734	3.621	8.143
ENV	1,986	0.012	0.008	0.001	0.063
GPAT	1,986	3.964	1.472	0.000	8.216
FISCAL	1,986	0.487	0.213	0.092	1.058

Table 2. Baseline Results.

Variable	(1)	(2)
	WINT	WINT
RIVER	−0.087**	−0.074**
	(−2.34)	(−1.98)
PGDP		−0.312***
		(−4.21)
IND		0.643**
		(2.47)
FDI		−0.031
		(−1.12)
POP		0.124*
		(1.87)
City FE	Yes	Yes
Year FE	Yes	Yes
N	1,986	1,986
R^2	0.689	0.708

Note: t-statistics in parentheses; ***, **, * indicate significance at the 1%, 5%, and 10% levels, respectively. Standard errors are clustered at the city level. All the subsequent tables are consistent with the current table.

Table 3. Variance Inflation Factors.

Variable	VIF
PGDP	2.41
FDI	2.13
FISCAL	2.06
IND	1.78
POP	1.52
ENV	1.34
Mean	1.87

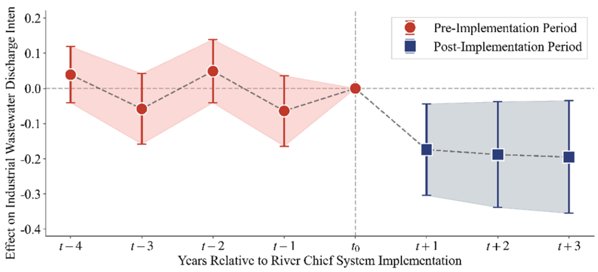


Figure 1. Parallel Trends Test

A placebo test is also conducted by randomizing treatment timing across the sample. Policy implementation years are assigned randomly to sampled cities, and 500 simulated regressions are used to construct the empirical distribution of placebo RIVER coefficients. As shown in **Figure 2**, the empirical distribution is concentrated around zero, while the actual baseline coefficient of −0.074 lies in the left tail, far from the center of the placebo distribution. This pattern indicates that the estimated policy effect is unlikely to arise from chance variation or omitted variable bias. The figure note records that the distribution is constructed from 500 random reassignments of treatment timing, and the actual estimated coefficient of −0.074 is marked against this distribution, lying far below the bulk of the simulated coefficients.

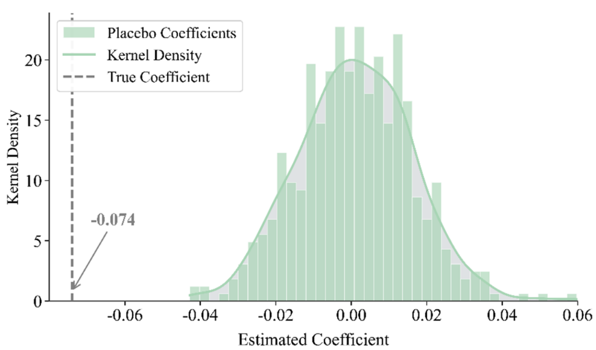


Figure 2. Placebo Test

Additional robustness checks reported in **Table 4** reinforce the baseline conclusion. Column (1) employs propensity score matching combined with difference-in-differences (PSM-DID), using city-level 2013 control variables as matching covariates and applying one-to-one nearest-neighbor matching before re-estimation; the RIVER coefficient is −0.069, significant at the 10% level, with a sign and magnitude broadly consistent with the baseline. Column (2) replaces the dependent variable with the logarithm of industrial wastewater discharge volume (WASTE); the coefficient is −0.091, significant at the 5% level, indicating that the River Chief System's compression of industrial wastewater discharge behavior is robust across alternative measurement choices. Column (3) further includes the number of pollutant discharge permits issued (the logarithm of the annual number of enterprises in each city receiving a discharge permit) and an environmental protection tax dummy (equal to 1 from the year in which the provincial government completes local rate filing and officially begins collection, generally from 2018 onward) in order to absorb potential confounding from concurrent reforms in the discharge permit system and the environmental protection tax. After these adjustments, the RIVER coefficient is −0.071, significant at the 10% level and close in magnitude to the original estimate; the policy effect remains identifiable once concurrent reforms are accounted for. The coefficients on the discharge permit count and the environmental protection tax dummy are both significant at conventional levels and consistent with their expected emission-reducing effects, but their inclusion does not materially alter the main result. Column (4) re-estimates the model after excluding provincial capitals and cities with independent planning status; the coefficient is −0.078, still significant at the 10% level and close to the baseline, suggesting that the inclusion of a small number of politically and economically prominent cities does not drive the overall conclusion.

Table 4. Robustness Checks.

Variable	(1) PSM-DID	(2) WASTE	(3) Concurrent Policies	(4) Excl. Capitals
RIVER	−0.069*	−0.091**	−0.071*	−0.078*
	(−1.89)	(−2.16)	(−1.91)	(−1.94)
Permit (log)			−0.134**	
			(−2.08)	
ENVTAX			−0.056*	
			(−1.72)	
Controls	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	1,724	1,986	1,986	1,742
R^2	0.701	0.681	0.715	0.705

Because staggered implementation can produce heterogeneous treatment dynamics across cohorts, **Table 5** reports aggregated average treatment effects estimated using the Callaway–Sant'Anna and Sun–Abraham methods, respectively (Callaway & Sant'Anna, 2021; Sun & Abraham, 2021). The first method constructs clean comparison cohorts for each treatment period and aggregates cohort-specific average treatment effects; the second decomposes the two-way fixed effects coefficient into a weighted sum of period-specific contributions through an interaction-weighted procedure. Both methods provide unbiased aggregate estimates under heterogeneous treatment effects. The two estimators yield ATTs of −0.068 and −0.071, both significant at the 5% level and very close to the TWFE estimate of −0.074. The joint significance test for the pre-treatment period yields a p-value of 0.331 and does not reject pre-treatment parallelism, in line with the visual evidence in **Figure 1**; overall robustness is therefore satisfactory.

4.4. *Pollutant-Specific Outcomes*

The intensity measure used so far captures discharge per unit of industrial output, which reflects firm behavior and the administrative effort behind it. It is natural to ask whether the same effect appears in the pollutants that the water quality assessment system actually targets, since chemical oxygen demand and ammonia nitrogen are the two pollutants written into China's binding water quality evaluation. A policy that tightens water governance, rather than merely compressing aggregate wastewater volume, should leave a mark on the discharge of these two substances in particular. **Table 6** re-estimates the baseline specification with the logarithm of industrial chemical oxygen demand discharge (COD) and the logarithm of industrial ammonia nitrogen discharge (NH3N) as outcomes, keeping the full set of controls and fixed effects.

The results are in line with the baseline finding. In column (1), the coefficient on RIVER for chemical oxygen demand is −0.083, significant at the 5% level, implying a reduction of roughly 8.0% following implementation. In column (2), the coefficient for ammonia nitrogen is −0.078, significant at the 10% level, corresponding to a reduction of roughly 7.5%. The response is somewhat sharper for chemical oxygen demand than for ammonia nitrogen, which fits the greater prominence of chemical oxygen demand in the assessment framework, and the broad similarity in magnitude across the two assessed pollutants and the intensity measure suggests that the reduction reflects a real change in pollution behavior.

Table 5. Callaway–Sant'Anna & Sun–Abraham.

Variable	Callaway–Sant'Anna	Sun–Abraham
	WINT	WINT
Overall ATT	−0.068**	−0.071**
	(−2.19)	(−2.08)
Pre-test p-value	0.331	
Controls	Yes	Yes
City FE	Yes	Yes
Year FE	Yes	Yes
N	1,986	1,986

Table 6. Pollutant-Specific Outcomes.

Variable	(1)	(2)
	COD	NH3N
RIVER	−0.083**	−0.078*
	(−2.02)	(−1.86)
Controls	Yes	Yes
City FE	Yes	Yes
Year FE	Yes	Yes
N	1,986	1,986
R^2	0.727	0.703

4.5. *How the Policy Operates*

Establishing that the River Chief System lowers discharge raises the question of how the effect comes about. Among the channels that the institutional logic of the system suggests, two can be examined with the data at hand. The accountability arrangement operates first on local government, which may respond to heightened evaluation pressure by raising its enforcement and abatement effort, and this enforcement effort may in turn press the local economy toward cleaner production, which lowers discharge per unit of output. **Table 7** examines these two channels in turn, using environmental enforcement intensity (ENV) and green patent intensity (GPAT). For each channel, columns report the association of the policy with the channel and then the joint association of the policy and the channel with discharge, so that the portion of the effect running through the channel and the portion remaining direct can be read together.

Columns (1) and (2) trace the enforcement channel. In column (1), the policy is associated with an increase in ENV of 0.002, significant at the 5% level. In column (2), where both RIVER and ENV enter the discharge regression, ENV carries a coefficient of −3.200 on WINT, significant at the 5% level, and the direct coefficient on RIVER is −0.068, also significant at the 5% level, so the portion of the effect running through enforcement is close to −0.006 and the two pieces together recover the baseline estimate of approximately −0.074. Columns (3) and (4) trace the cleaner-production channel. In column (3), the policy is associated with an increase in GPAT of 0.094, significant at the 5% level. In column (4), GPAT carries a coefficient of −0.170 on WINT, significant at the 5% level, and the direct coefficient on RIVER is −0.058, significant at the 10% level, so the portion running through cleaner production is close to −0.016 and again the two pieces together return the baseline estimate. These patterns indicate that stronger enforcement effort and a shift toward cleaner production each account for part of the headline effect while a direct association remains, which fits the technology literature, in which the pollution-reducing role of innovation is stronger under heavier regulatory pressure (Ma *et al.*, 2020), and evidence that performance assessment under the River Chief System encourages green innovation by enterprises (Tang *et al.*, 2025).

4.6. *Further Investigation*

Building on the baseline results, interaction terms between three city-level characteristics and the River Chief System are introduced to examine whether policy effects vary systematically across cities, as specified below:

$$WINT_{it} = \alpha + \beta_1 RIVER_{it} + \beta_2 RIVER_{it} \times M_{it} + \beta_3 M_{it} + \gamma X_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

Where M_{it} is replaced in turn by RANK, WATER, and FISCAL, and β_2 captures the strengthening or weakening effect of each city characteristic on the system's emission-reduction performance. The results are reported in **Table 8**, with the three columns examining how policy effects diverge along the dimensions of political pressure transmission, water resource endowment, and fiscal execution capacity.

Column (1) presents the interaction between RIVER and river chief political rank (RANK). The interaction coefficient is −0.089 and significant at the 5% level, while the main effect of RIVER is −0.052 and statistically insignificant. This suggests that in cities whose provincial chief river official is not the principal provincial leader, the direct emission-reduction effect of the River Chief System is comparatively modest, whereas a higher political rank can substantially amplify this effect. When the provincial party secretary or governor takes the lead, accountability pressure is transmitted directly downward to municipal and county governments, regulation of polluting enterprises within their jurisdictions is strengthened, and enforcement intensity rises accordingly, a pattern that resonates strongly with the "top-leader effect" repeatedly observed in China's water environmental governance experience.

Table 7. How the Policy Operates.

Variable	(1)	(2)	(3)	(4)
	ENV	WINT	GPAT	WINT
RIVER	0.002**	−0.068**	0.094**	−0.058*
	(2.31)	(−1.99)	(2.18)	(−1.71)
ENV		−3.200**		
		(−2.27)		
GPAT				−0.170**
				(−2.05)
Controls	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	1,986	1,986	1,986	1,986
R^2	0.682	0.719	0.747	0.717

Table 8. Further Investigation.

Variable	(1)	(2)	(3)
	WINT	WINT	WINT
RIVER	−0.052	−0.083	−0.043
	(−1.24)	(−1.53)	(−1.02)
RIVER × RANK	−0.089**		
	(−2.18)		
RANK	0.034		
	(0.87)		
RIVER × WATER		0.023*	
		(1.87)	
WATER		−0.018**	
		(−2.14)	
RIVER × FISCAL			−0.124**
			(−2.03)
FISCAL			−0.087
			(−1.43)
Controls	Yes	Yes	Yes
City FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N	1,986	1,986	1,986
R^2	0.716	0.714	0.718

Column (2) reports the interaction between RIVER and per capita water resources. The interaction coefficient is 0.023 and significant at the 10% level, indicating that the suppressive effect of the River Chief System on industrial wastewater discharge weakens as water resource availability increases. The main effect of WATER is −0.018

and the coefficient on RIVER alone is statistically insignificant, implying that the policy's emission-reduction effect operates substantially through resource-endowment conditions. Water-stressed northern cities face heavier pressure on water environments, generating stronger official enthusiasm for implementing the River Chief System and correspondingly more rigorous enforcement, whereas in water-rich southern regions where governance demand is weaker, implementation is comparatively relaxed and policy effectiveness is reduced. The pronounced regional imbalance in China's water resources is therefore reflected directly in spatial differences in policy outcomes.

Column (3) reports the interaction between RIVER and fiscal self-sufficiency (FISCAL). The interaction coefficient is −0.124, significant at the 5% level, while the main effect of RIVER is −0.043 and statistically insignificant. This pattern indicates that fiscal capacity substantially conditions the magnitude of the system's emission-reduction effect. Fiscally stronger cities can provide robust financial support for the institutional infrastructure of the River Chief System, including online monitoring equipment, supporting wastewater treatment facilities, and complementary regulatory capacity, and can sustain incentive and accountability arrangements that anchor environmental enforcement, thereby reinforcing the durability of emission-reduction effects. In fiscally constrained cities, by contrast, the system risks remaining a paper exercise that fails to generate genuine governance pressure. Taken together, the three columns demonstrate that the policy effects of the River Chief System are not uniform across cities: whether political pressure is effectively transmitted downward, whether water resource scarcity provides strong governance motivation, and whether fiscal capacity supports institutional implementation jointly shape the spatial heterogeneity of the system's emission-reduction performance.

5. Discussion

The findings of this study extend the existing literature in two connected respects. With respect to the principal direction of policy effects, prior quasi-experimental work has generally concluded that the institutional accountability arrangement introduced by the River Chief System constrains industrial wastewater discharge, while the literature has repeatedly noted a pattern that warrants careful consideration, namely that under path dependence favoring economic development local officials often confine institutional implementation to visible compliance indicators and tacitly tolerate certain forms of discharge that satisfy headline criteria (Li *et al.*, 2020; Wang & Zhao, 2025). This study focuses on emissions per unit of output, which more directly reflects an administrative intent to advance cleaner production, whereas other studies that examine aggregate emissions are more susceptible to confounding from industrial structural adjustment, so that observed declines may partly reflect production constraints rather than pollution control. The pollutant-specific results add to this picture, since the reduction appears in chemical oxygen demand and ammonia nitrogen, the two pollutants that enter the assessment system, which speaks to a response in the pollutants officials have the strongest reason to address.

With respect to the conditions and channels that shape policy effects, this study moves the discussion beyond the binary question of whether the system works toward the more policy-relevant question of which urban conditions translate institutional constraints into actual emission reductions, and how the translation occurs. As the political rank of the provincial chief river official rises, the scope for city-level officials to evade accountability narrows, a conclusion consistent with research on government behavior grounded in promotion tournament logic (Li *et al.*, 2024). Regional differences in water resource endowment reflect the geographical roots of city-level governance motivation, since cities with lower per capita water resources face greater environmental carrying capacity risks and exhibit stronger internal incentives to strengthen institutional construction, whereas relatively water-rich cities retain considerable flexibility in implementation. The role of fiscal capacity points to the material foundations of implementation, since monitoring equipment, treatment infrastructure, and sustained enforcement expenditures all depend on stable fiscal support. These conditions connect naturally to the channels documented above, in that political pressure governs how forcefully enforcement effort is activated while fiscal capacity governs whether a city can finance the enforcement that the first channel requires, so that the conditions for effectiveness and the channels of effectiveness are two aspects of the same process. The River Chief System works well not because of the rigor of its design alone but because that design interacts with a specific configuration of political, ecological, and fiscal conditions, and because the accountability pressure it creates is carried through government enforcement and a shift toward cleaner production.

6. Conclusion

Drawing on a panel dataset of 285 prefecture-level cities from 2013 to 2020, this paper shows that the River Chief System reduces urban industrial wastewater discharge intensity, with a magnitude and stability that hold across alternative estimation strategies, and that the reduction is also present in the discharge of chemical oxygen demand and ammonia nitrogen. Policy effectiveness varies systematically, being greater where political accountability pressure is strongly transmitted downward, where water resource scarcity reinforces local officials' sense of mission, and where fiscal autonomy provides the financial foundation needed to translate institutional responsibilities into enforceable behavior. The policy works in part through a process that begins with stronger local environmental enforcement and continues with a shift toward cleaner industrial activity, so that political pressure, resource endowment, and fiscal capacity together shape the spatial pattern of emission-reduction performance across Chinese cities.

These findings carry concrete implications for institutional design. The first concerns who is placed in charge. Because the response is concentrated in cities where the provincial party secretary or governor personally serves as the chief river official, the practical lesson is to assign the lead role at the level of principal provincial leadership rather than delegating it to a functional department head, since it is the rank of the responsible official that determines how forcefully accountability pressure reaches city and county governments. The second concerns the form of fiscal support. A uniform transfer leaves the cities that most need help underserved, whereas a transfer formula that grants larger support to cities combining high environmental need with weak fiscal capacity directs resources where implementation would otherwise stall; in operational terms, such a formula would weight per capita water resources so that water-scarce cities receive more, weight the ratio of fiscal self-sufficiency so that fiscally constrained cities receive more, and use baseline pollution as a supplementary criterion. The third concerns the mix of instruments. Because the policy works through enforcement effort and a shift toward cleaner production rather than through a single lever, monitoring infrastructure, enforcement funding, and innovation support are best deployed together as complementary parts of one package. For other emerging economies confronting industrial water pollution under decentralized governance, the broader lesson is that incentive-compatible institutional design, paired with fiscal support differentiated by need, is more likely to deliver durable improvements in water resource management than repeated short-term policy shocks whose effects fade as external pressure subsides. The qualification is that the system works through the cadre evaluation structure, so transferring the approach calls for identifying the locally available mechanism, whether electoral accountability, statutory enforcement authority, or fiscal conditionality, through which responsibility for a named outcome can be made to carry real consequences for the responsible official.

Several features of the data mark out promising directions for further work. The sample runs through 2020, so a natural next step is to extend the panel as later data become available and examine how the effect matures over a longer horizon, which would speak directly to the durability of accountability-based governance. The treatment is dated by provincial rollout and applied at the provincial level, so the estimates are best read as the average response to provincial onset, and richer local implementation records would allow future research to distinguish the speed and depth of adoption across cities within a province. The pollutant-specific outcomes measure discharge of chemical oxygen demand and ammonia nitrogen, which speaks closely to firm behavior and administrative effort, and pairing these series with ambient monitoring records in future work would connect discharge behavior to realized in-stream quality, since ambient conditions are additionally shaped by hydrology, upstream sources, and non-industrial activity. On the empirical side, the centrally mandated and staggered rollout is what makes the design informative, and although a credible external instrument is difficult to construct in this setting because plausible candidates would themselves be related to the conditions that influence discharge, the combination of event-study evidence, placebo testing, heterogeneity-robust estimators, and matching addresses the principal concerns within the available design and provides a solid foundation that finer-grained local data can build upon.

Disclosure of Interest

The authors report there are no competing interests to declare.

Funding

This work received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Data Availability Statement

The data presented in this study are available on request from the corresponding author due to third-party restrictions.

References

Agranoff, R. (2014). Local governments in multilevel systems: Emergent public administration challenges. *The American Review of Public Administration*, *44*(4_suppl), 47S–62S.

Callaway, B., & Sant'Anna, P. H. (2021). Difference-in-differences with multiple time periods. *Journal of Econometrics*, *225*(2), 200–230.

Chen, J., Luo, D., She, G., & Ying, Q. (2017). Incentive or selection? A new investigation of local leaders' political turnover in China. *Social Science Quarterly*, *98*(1), 341–359.

Chen, P. (2024). Unlocking policy effects: Water resources management plans and urban water pollution. *Journal of Environmental Management*, *365*, 121642.

Hassani-Mahmooei, B., & Parris, B. W. (2013). Resource scarcity, effort allocation and environmental security: An agent-based theoretical approach. *Economic Modelling*, *30*, 183–192.

Hong, Y., Lyu, X., Chen, Y., & Li, W. (2020). Industrial agglomeration externalities, local governments' competition and environmental pollution: Evidence from Chinese prefecture-level cities. *JOURNAL OF CLEANER PRODUCTION*, *277*, 123455.

Kornreich, Y. (2025). Navigating Uncertainty: The Use of Expert Deliberation in China's Policymaking. *Journal of Contemporary China*, 1–18.

Levačić, R. (2009). Teacher incentives and performance: An application of principal–agent theory. *Oxford Development Studies*, *37*(1), 33–46.

Li, B., Tang, S. Y., Wang, F., & Yin, H. (2024). Policy implementation through performance measurement: A study of water pollution remediation in China's Huai River Basin. *Review of Policy Research*, *41*(1), 210–238.

Li, J., Shi, X., Wu, H., & Liu, L. (2020). Trade-off between economic development and environmental governance in China: An analysis based on the effect of river chief system. *China Economic Review*, *60*, 101403.

Li, Z., & Huang, J. (2021). The river chief system and agricultural non-point source water pollution control in China. *Journal of Integrative Agriculture*, *20*(5), 1382–1395.

Liang, K., Hu, L., Ma, Z., Huang, S., Liu, M., Fang, W., Yang, J., & Bi, J. (2025). Non-linear relationships between air temperature and river water quality revealed by a panel dataset of 276 Chinese cities. *Communications Earth & Environment*.

Liu, L., & Bai, C. (2022). Environmental regulation and economic development: evidence from the river chief system in China. *Water Economics and Policy*, *8*(04), 2240010.

Ma, Y., Cao, H., Ma, Y., & Wu, S. (2020). Does technological innovation reduce water pollution intensity in the context of informal environmental regulation? *Asia-Pacific Journal of Chemical Engineering*, *15*, e2493.

Miller, G. J., & Whitford, A. B. (2007). The principal's moral hazard: Constraints on the use of incentives in hierarchy. *Journal of Public Administration Research and Theory*, *17*(2), 213–233.

O'Toole Jr, L. J. (2000). Research on policy implementation: Assessment and prospects. *Journal of Public Administration Research and Theory*, *10*(2), 263–288.

Schubert, G., & Alpermann, B. (2019). Studying the Chinese policy process in the era of 'top-level design': The contribution of 'political steering'theory. *Journal of Chinese Political Science*, *24*(2), 199–224.

She, Y., Liu, Y., Jiang, L., & Yuan, H. (2019). Is China's river chief policy effective? Evidence from a quasi-natural experiment in the Yangtze River economic belt, China. *JOURNAL OF CLEANER PRODUCTION*, *220*, 919–930.

Sun, L., & Abraham, S. (2021). Estimating dynamic treatment effects in event studies with heterogeneous treatment effects. *Journal of Econometrics*, *225*(2), 175–199. https://doi.org/10.1016/j.jeconom.2020.09.006

Tang, Y., Yang, Q., Cui, X., & Ma, X. (2025). The impact of the implementation and assessment of China's river chief system on sustainable green innovation of enterprises. *Economic Change and Restructuring*, *58*(5), 88.

Wang, J., & Zhao, X. (2025). Goal orientation and effectiveness of water environment governance in China. *Ecohydrology & Hydrobiology*, 100673.

Wang, Y., & Chen, X. (2020). River chief system as a collaborative water governance approach in China. *International journal of water resources development*, *36*(4), 610–630.

Williams, M. J. (2021). Beyond state capacity: bureaucratic performance, policy implementation and reform. *Journal of Institutional Economics*, *17*(2), 339–357.

Xu, F. (2022). Explaining provincial variation in implementation of China's clean water policies. *Water Economics and Policy*, *8*(02), 2250009.

Zheng, P., Wang, H., Wei, D., Pu, C., & He, Z. (2022). Environmental governance capability and water quality: A quasi-natural experiment based on the Ten-point Water Plan. *Urban Climate*, *41*, 101050.

Zhuravskaya, E. V. (2000). Incentives to provide local public goods: fiscal federalism, Russian style. *Journal of Public Economics*, *76*(3), 337–368.

Zuo, X., Huang, C., Du, Y., Tian, Z., Yang, G., & Yue, S. (2026). Institutional accountability for water governance: firm-level evidence from the Yangtze River economic belt. *Water Policy*, *28*(1), 132–147.