

Economic Analysis of Rural Wastewater Governance in Chongqing from the Public Goods Supply Perspective: A Study on Challenges, Approaches, and Enduring Mechanisms

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Abstract: Rural domestic sewage treatment is a crucial component in building beautiful villages and promoting integrated urban-rural development. It yields significant ecological, environmental, and social benefits, making it a typical quasi-public good in rural areas. Taking Chongqing's rural sewage treatment as the research subject, this paper systematically analyzes the core economic challenges faced in Chongqing's rural sewage treatment. These challenges include inaccurate design and planning, insufficient capital investment, lack of operation and maintenance mechanisms, and low technology adaptability. The analysis integrates theoretical tools from public goods theory, externalities theory, cost-benefit analysis, institutional economics, and information economics, combined with recent policy documents, statistical data, and field research information. Building on this, the paper proposes establishing a five-pronged long-term governance mechanism integrating "planning-investment-technology-operation-supervision": emphasizing scientific planning and precise design to reduce sunk costs; innovating a sustainable funding model featuring "government leadership, diversified financing, and shared villager responsibility"; promoting a cost-saving and efficiency-enhancing combination of "appropriate technology and smart management"; establishing a localized and professionalized operation and maintenance system with clear rights and responsibilities; and improving performance-based supervision, assessment, and digitally empowered oversight. This study aims to provide theoretical references and practical guidance for addressing the economic challenges of rural wastewater treatment, enhancing the efficiency of public goods supply, and supporting comprehensive rural revitalization in Chongqing and the broader central-western regions.

Keywords: Rural wastewater treatment, Public goods supply, Cost-benefit analysis, Transaction costs, Long-term mechanism.

1. Introduction: The Economics of Rural Environmental Governance in the Context of Rural Revitalization

The 19th CPC National Congress proposed implementing the rural revitalization strategy, emphasizing ecological livability as a key priority. As one of the "Three Major Revolutions" in rural living environment improvement, rural domestic sewage treatment directly impacts farmers' health and well-being, the ecological foundation of villages, and the development potential of cultural tourism industries. It serves as a crucial cornerstone for advancing equalization of urban-rural public services and achieving sustainable rural development. From an economic perspective, rural wastewater treatment services exhibit non-exclusivity and non-rivalry, making them typical "quasi-public goods" or "club goods." Their provision involves significant market failures and necessitates government intervention. However, compared to urban sewage treatment systems characterized by high concentration and pronounced economies of scale, rural sewage treatment presents distinct challenges: dispersed discharge points, significant fluctuations in water quality and quantity, pronounced population mobility and seasonal patterns, weak payment capacity, and high regulatory complexity. This makes the direct application of urban treatment models often ill-suited and unsustainable, fundamentally stemming from distorted public resource allocation and sharply increased transaction costs within the urban-rural dual structure.

Chongqing, a unique blend of large cities, vast rural areas,

extensive mountainous regions, and expansive reservoir zones, exhibits pronounced urban-rural disparities. The challenges it faces in rural wastewater treatment are highly representative of those in China's central and western provinces. In recent years, Chongqing has made phased progress in improving rural living environments, achieving an 87.8% coverage rate for flush toilets/latrines, 100% coverage for waste collection and disposal systems, and a 75% treatment rate for domestic sewage. However, deep-seated structural and economic contradictions remain prominent. Recent policy discussions indicate that fundamental solutions are still lacking for issues such as the mismatch between urban sewage treatment capacity and actual rural demand, structural funding gaps in governance, and inadequate long-term operational and maintenance mechanisms for facilities. This reflects persistent inefficiencies in the allocation of environmental governance resources across urban-rural divides and different governance stages.

Therefore, systematically deconstructing Chongqing's rural sewage treatment practices from an economic perspective is not only a technical and managerial analysis of specific environmental issues but also a profound exploration of how to efficiently, equitably, and sustainably supply quasi-public goods to rural areas under/within resource constraints. This paper integrates recent policy documents, statistical data, and case materials. Employing analytical frameworks such as public goods theory, externalities theory, cost-benefit analysis, and new institutional economics, it systematically dissects the economic logic and practical constraints of Chongqing's rural sewage treatment. It further attempts to construct a long-term, incentive-compatible governance framework.

2. Economic Characteristics and Practical Challenges of Chongqing's Rural Sewage Treatment: An Empirical Analysis

2.1 High Transaction Costs and Diseconomies of Scale: Inherent Supply Disadvantages from Spatial Dispersion

Chongqing's rural terrain is predominantly mountainous and hilly, with settlements exhibiting a typical pattern of "high dispersion and low concentration." This highly fragmented spatial layout first results in exceptionally high construction costs for sewage collection networks. Laying pipelines in mountainous and hilly areas requires navigating complex terrain, posing significant construction challenges and driving up labor costs, making it difficult to achieve the economies of scale seen in urban pipeline networks. Research indicates that in some villages with complex topography, the unit cost of sewage collection systems far exceeds that in flatland areas, sometimes accounting for an extremely high proportion of the total project investment. Second, small-scale and micro wastewater treatment facilities built to accommodate dispersed settlements generally suffer from diseconomies of scale. The limited processing capacity per facility results in persistently high construction and operational costs per ton of treated water. Even when employing relatively low-cost technologies like constructed wetlands or stabilization ponds, their lifecycle costs often lose their advantage due to fragmented deployment. This geographically determined high initial cost represents a fundamental economic constraint in rural wastewater management.

2.2 Information Asymmetry and Planning Failure: The Conflict Between Dynamic Demand and Static Supply

Rural populations exhibit migratory patterns and seasonal clustering, resulting in significant tidal fluctuations in sewage generation. However, traditional treatment planning often relies on static household registration data or fixed per capita discharge coefficients, frequently causing mismatches between facility capacity and actual demand. Recent case studies continue to reveal instances where existing rural wastewater treatment facilities suffer from either underutilization (excessively low load rates) or short-term overload. Consequently, substantial investments become sunk costs, with facilities either idle or operating inefficiently. The economic root cause lies in severe information asymmetry between the supply side (government and design entities) and the demand side (dynamically changing rural communities). Failure to adequately obtain and effectively process key information during the planning phase—such as permanent population size, seasonal variation patterns, and actual water usage habits—has led to investment decisions deviating from optimal paths, resulting in inefficient capital allocation.

2.3 Challenges in Internalizing Negative Externalities and Structural Funding Constraints

The direct discharge of untreated rural domestic sewage poses significant negative externalities to aquatic environments and public health. Addressing sewage pollution entails internalizing these external costs, yet this process demands sustained and stable financial investment. Currently, funding constraints exhibit dual characteristics: First, overall

investment remains insufficient, with excessive reliance on central and municipal fiscal transfers, placing immense pressure on district/county and township-level matching funds. Second, investment structure is severely imbalanced, with the persistent issue of "prioritizing construction over operation and maintenance." Dedicated funding is typically secured for the construction phase of projects. However, there are no institutionalized funding channels for long-term operational costs, including pipeline maintenance, equipment operation, consumption of electricity and chemicals, and professional management personnel. For instance, some districts and counties in Chongqing Municipality report a significant funding gap in the annual operation and maintenance budgets for rural sewage facilities, leading to a situation where many facilities are "in use but out of maintenance" after their warranty periods expire.

While charging villagers sewage fees is theoretically feasible, practical implementation faces multiple challenges: a small fee base (due to low per capita water consumption in rural areas), low collection rates, and limited willingness and ability to pay among households, making it difficult to cover operational costs.

2.4 Agency Issues in Technology Selection and Neglect of Full Life-Cycle Costs

Different wastewater treatment technologies exhibit significant variations in initial construction investment, long-term operational expenses, management complexity, and land requirements. While technology selection should be a rational decision-making process grounded in cost-effectiveness analysis, deviations frequently occur in practice. On one hand, there is a tendency toward "over-engineering," where blind pursuit of excessively stringent discharge standards leads to direct adoption of urban wastewater treatment processes. This results in prohibitively high construction and operational costs that local finances struggle to sustain. On the other hand, there is a tendency to "prioritize construction costs over operational and maintenance costs," selecting technologies with low initial investment but high operational demands and poor stability. Such facilities often fail shortly after completion due to lack of professional maintenance. This reflects a classic principal-agent problem: decision-makers (agents) may prioritize visible construction achievements during their tenure while shifting high long-term operational costs and risks to future administrations or subordinate units. There is a lack of mechanisms for scientifically evaluating and constraining the total life-cycle cost (LCC) of projects.

2.5 Regulatory Failure and Incentive Mismatch Among Multiple Stakeholders

Rural sewage facilities are numerous, widely dispersed, and highly specialized. Traditional direct government oversight incurs extremely high costs with limited effectiveness, leading to superficial regulation and persistent neglect of maintenance. The economic root lies in the misalignment of incentives and the mismatch between responsibilities and benefits among stakeholders in the governance chain: higher-level departments allocate funds and assign tasks, while county-level departments oversee project construction.

Yet the long-term operation and maintenance responsibilities after facility completion primarily fall on financially weak townships or village collectives lacking professional capacity. Villagers, as direct beneficiaries, lack both effective payment incentives and channels or motivation for oversight participation. Such a misalignment of rights, responsibilities, and benefits results in severely weakened incentives for maintenance at the end of the public goods supply chain, ultimately facilitating the “tragedy of the commons”-style deterioration of facility assets.

3. Economic Approaches and Policy Recommendations for Building a Long-Term Governance Mechanism

Resolving the above challenges requires systematically constructing a comprehensive governance framework that aligns with economic principles, effectively reduces transaction costs, achieves incentive compatibility, and ensures long-term sustainability.

3.1 Planning Leadership and Targeted Investment: Optimizing Capital Allocation Through Dynamic Models

First, implement dynamic demand assessment and flexible planning. Radically reform static planning methods by establishing a dynamic wastewater volume analysis model that integrates permanent resident big data, seasonal mobility patterns (e.g., holidays, peak tourism seasons), village development types, and trend forecasts. Advocate a flexible infrastructure model featuring “reserved planning, phased construction, and modular integration,” gradually expanding treatment capacity based on actual demand growth to avoid capital stagnation from excessive upfront investment. Second, strengthen life-cycle cost-benefit analysis. Mandate LCCA implementation during project initiation and scheme review phases. This requires not only calculating initial construction costs but also discounting future operational, maintenance, major repair, and even renewal and replacement costs over the next 20-30 years for comprehensive economic comparison. Use LCCA outcomes as the core basis for technical solution selection and fiscal funding approval, curbing short-term decision-making tendencies at the source. Third, deepen targeted measures through classification and zoning. Based on Chongqing’s “One Zone, Two Clusters” regional development strategy, formulate and dynamically update differentiated technical guidelines, discharge standards, construction standards, and investment subsidy criteria. These should account for varying socioeconomic development levels, population concentration patterns, topographical conditions, and environmental sensitivity across Western Chongqing, Northeastern Chongqing, Southeastern Chongqing, and new urban districts. This approach enhances the marginal benefits of public funds and policy tools.

3.2 Innovative Financing and Shared Responsibility: Establishing a Sustainable Investment Guarantee Mechanism

First, clearly delineate intergovernmental responsibilities and expenditure obligations. Through local legislation or government regulations, define the division of responsibilities and corresponding expenditure obligations among the

municipal, district, county, and township levels for each stage of rural wastewater governance. The municipal level may focus on cross-regional major infrastructure, key technology R&D and promotion, citywide smart supervision platform construction, and inter-regional coordination. District and county levels shall bear fiscal responsibility for constructing trunk systems and core operation and maintenance within their jurisdictions. Township and village levels primarily maintain household systems, conduct routine inspections, and organize villagers to participate and share costs through mechanisms like “one matter, one discussion.” Second, vigorously expand market-oriented and socialized financing channels. In areas with relatively concentrated populations and sufficient economic conditions—such as townships and key rural tourism villages—prudently promote Public-Private Partnership (PPP) models. Introduce professional environmental enterprises through competitive processes to handle investment, construction, and long-term operations. Actively explore the Ecologically Oriented Development (EOD) model, deeply integrating wastewater treatment with operational projects like land remediation, ecological agriculture, rural tourism, and wellness industries. Use revenues generated by associated industries to cover environmental management investments, achieving internalization of value. For example, EOD pilot projects in some districts and counties of Chongqing are attempting to integrate river basin governance with the realization of the value of ecological products. Third, design incentive-compatible “beneficiary-pays” and compensation mechanisms. Explore establishing a wastewater treatment charging system that matches farmers’ affordability and keeps collection costs controllable. Consider integrating wastewater treatment fees into water bills with a low initial rate, while offering exemptions or subsidies for low-income groups. Simultaneously, vigorously promote non-economic incentives—such as the “rural governance points system” piloted in some Chongqing districts—where farmers earn points for environmental actions like maintaining pipelines, compliant discharges, and water conservation. These points can be redeemed for goods and services or credit rewards, transforming passive fee collection into proactive guidance and positive incentives.

3.3 Technology Adaptation and Smart Empowerment: Pursuing Optimal Lifecycle Costs

First, promote the “appropriate technology +” combination model. Adhere to the principles of “local adaptation, cost-effectiveness, and simplified operation and maintenance” in technology selection. In hilly and mountainous areas with relatively ample land, prioritize the promotion of ecological combined processes such as “anaerobic pretreatment plus constructed wetlands/stabilization ponds”, enhanced by simple power-driven devices. In densely populated villages with limited land, deploy proven, highly automated, remotely controllable integrated biological treatment units. Simultaneously, actively promote wastewater resource utilization, divert standard-compliant tail water to agricultural irrigation, landscape water replenishment and municipal miscellaneous use, turn the “treatment burden” into a “second water source”, and create direct and indirect economic value. Second, digitalization-driven management for cost reduction and efficiency enhancement accelerate the construction and

refinement of a three-tiered digital supervision platform for rural wastewater treatment, covering municipal, district/county, and township levels. By deploying IoT sensors at critical nodes, real-time data on facility operation status, water quality, and flow rates can be collected. Leverage big data and artificial intelligence for intelligent diagnostics, early warning and predictions, performance evaluations, and optimized scheduling. This significantly reduces the frequency and cost of manual inspections, accelerates fault response and improves repair efficiency, enhances the precision and intelligence of operations and maintenance management, and effectively mitigates management failures caused by information asymmetry.

3.4 Strengthen Operations, Maintenance, and Supervision Systems: Reconstruct Incentive Constraints and Governance Structures

First, implement a “localized management + specialized services” model. Clearly designate township governments as the primary responsible entities for overseeing the operation and maintenance of rural wastewater facilities within their jurisdictions. Encourage districts, counties, or larger regions to bundle dispersed facilities and commission qualified, experienced specialized environmental companies or regional state-owned environmental platforms for unified operation and maintenance through government procurement of services. Leverage the scale efficiency and technical advantages of specialized companies to reduce average operation and maintenance costs while ensuring service quality. Second, establish a performance-based payment mechanism based on key performance indicators (KPIs). Reform payment methods for maintenance service providers by shifting from fixed fees to performance-based payments tied to core KPIs. Contract payments should be closely linked to KPIs such as facility operational uptime, effluent quality compliance rates, timely fault response rates, energy and material consumption levels, and villager satisfaction. Through carefully designed performance contracts, align the government’s pursuit of public environmental benefits with corporate economic interests to achieve incentive compatibility. Third, establish a collaborative oversight network featuring multi-stakeholder governance. Leverage village self-governance bodies, rural elites and villager representatives to incorporate wastewater treatment requirements into village regulations. Regularly disclose facility operation data, financial receipts and expenditures, and assessment results to safeguard villagers’ right to know. Establish accessible supervision and reporting channels, exploring incentive-based whistleblower programs. Develop a four-pronged supervision system integrating “government administrative oversight, third-party professional monitoring, routine village-level inspections, and villager social supervision.” This approach reduces the marginal costs of single-entity oversight and enhances regulatory effectiveness.

4. Conclusions and Outlook

The practice of rural wastewater treatment in Chongqing profoundly reveals the economic complexities of effectively supplying quasi-public goods in rural areas within an urban-rural dual structure. While government leadership remains indispensable, relying solely on unilateral fiscal

investment and engineering projects—while neglecting issues such as high transaction costs, information asymmetry, and distorted incentives among multiple stakeholders inherent to rural socio-economic characteristics like spatial dispersion, population mobility, and limited payment capacity—will hinder long-term sustainability.

This study argues that advancing Chongqing’s rural wastewater treatment from “intensive remediation” to “long-term management” hinges on a fundamental shift from an “engineering-oriented” approach to one focused on “modernizing governance capabilities.” This requires deeply integrating economic thinking throughout public policy formulation and implementation: in planning decisions, strengthening dynamic forecasting and cost-benefit analysis to optimize public capital allocation; In funding mobilization, clarify intergovernmental fiscal responsibilities, innovate market-based financing instruments, and design incentive-compatible user-fee mechanisms; In technical pathways, adhere to the principle of optimizing full-lifecycle costs, select appropriate technologies, and embrace digital transformation; In institutional design, establish incentive-constraint structures with balanced rights, responsibilities, and benefits through contract governance, performance management, and social co-governance.

Ultimately, by systematically constructing and effectively implementing a five-pronged long-term governance mechanism encompassing “planning - investment - technology - operation - regulation,” rural wastewater treatment can be transformed from a persistent fiscal burden into foundational investment and strategic assets that significantly improve living environments, enhance rural ecological value, and empower green industrial development. This will lay a solid ecological foundation and economic institutional basis for Chongqing’s comprehensive advancement of rural revitalization and the realization of high-quality integrated urban-rural development.

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