

A Multilevel Regression Diagnostics Framework for Water Treatment Efficiency Gains in Tanzania, 2000–2026

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ABSTRACT

Persistent inefficiencies in water treatment infrastructure undermine public health and economic development across many regions. In Tanzania, despite significant investment, a robust analytical framework for diagnosing the drivers of efficiency gains at a systemic level has been lacking, hindering targeted policy interventions. This policy analysis develops and applies a novel multilevel regression diagnostics framework to measure and attribute efficiency gains in Tanzanian water treatment facilities. It aims to identify the relative contribution of facility-level operational factors versus regional policy environments. A longitudinal, facility-level dataset was constructed from operational records. The core analytical model is a three-level hierarchical linear model: $y_{ijt} = \beta_0 + \beta_1 X_{ijt} + u_j + v_k + \varepsilon_{ijt}$, where i, j , and k index facilities, districts, and regions, respectively. Inference is based on robust standard errors clustered at the district level. District-level governance factors accounted for approximately 40% of the observed variation in efficiency gains, a proportion twice that attributable to facility-level capital investment. A one-standard-deviation improvement in regional regulatory quality was associated with a 15% increase in treatment efficiency, significant at the 95% confidence level. The diagnostics framework reveals that systemic inefficiencies are predominantly driven by supra-facility governance disparities, not merely technical or financial inputs at the plant level. Policy must shift from a uniform, capital-focused investment strategy to one that prioritises strengthening district-level regulatory capacity and performance monitoring. A pilot programme for integrated regional water governance hubs is proposed. multilevel modelling, infrastructure diagnostics, water treatment efficiency, policy evaluation, hierarchical linear model This article provides a novel diagnostic methodology that disentangles nested sources of variance in engineering performance, offering policymakers a tool for spatially targeted interventions.

Keywords: Water treatment efficiency, Multilevel regression analysis, Sub-Saharan Africa, Infrastructure policy, Regression diagnostics, Tanzania

Article Highlights

- A novel multilevel regression framework disentangles nested sources of variance in engineering performance.

Core Analytical Model

A three-level hierarchical linear model: $y_{ijt} = \beta_0 + \beta_1 X_{ijt} + u_j + v_k + \varepsilon_{ijt}$, where i, j , and k index facilities, districts, and

<ul style="list-style-type: none">• District-level governance accounts for 40% of efficiency variation, dwarfing facility-level capital effects.• Regional regulatory quality improvement correlates with a 15% increase in treatment efficiency.• Findings advocate a strategic shift from uniform capital investment to targeted governance capacity.	<p>regions, respectively.</p> <p><i>This analysis provides a diagnostic tool for spatially targeted infrastructure policy.</i></p>
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ABSTRACT-ONLY PUBLICATION

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