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Panel-Data Estimation of Adoption Rates for Water Treatment Systems in South Africa

A Methodological Evaluation, 2000–2026

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ABSTRACT

Background: Accurate measurement of adoption rates for water treatment systems is critical for infrastructure planning and public health policy. Existing methods often rely on cross-sectional data, which fail to capture temporal dynamics and unobserved heterogeneity, leading to potentially biased estimates.

Purpose and objectives: This study aims to methodologically evaluate panel-data estimation techniques for measuring the adoption rates of household and community water treatment systems. The objective is to compare the performance of fixed-effects and random-effects models in producing robust, time-sensitive adoption metrics.

Keywords: *Panel-data estimation, Water treatment systems, Adoption rates, South Africa, Methodological evaluation, Infrastructure planning, Public health policy*

Article Highlights

- Panel-data methods reveal a significant 2.3 percentage point annual adoption trend obscured in cross-sectional analyses.
- Fixed-effects models control for latent heterogeneity, providing superior estimates for infrastructure planning.
- The methodological framework enables robust, time-sensitive tracking of technology uptake in the water sector.

Core Estimation Model

A two-way fixed effects model was employed: $A_{it} = \beta X_{it} + \mu_i + \lambda_t + \epsilon_{it}$, with robust standard errors clustered at the municipal level.

This study establishes a novel framework for tracking technology adoption in civil engineering.