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Methodological Diagnostics for Smallholder Farm System Efficiency

A Systematic Review of Panel Data Estimation in South Africa, 2021–2026

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ABSTRACT

Smallholder farm system efficiency is critical for food security and rural livelihoods. Panel data estimation offers robust methodological advantages for capturing dynamic efficiency gains, yet a systematic assessment of its application and diagnostic rigour in this specific context is lacking. This systematic review aims to critically evaluate the methodological application of panel data models in estimating technical efficiency for smallholder farm systems, identifying prevalent practices, diagnostic checks, and inferential limitations within the recent literature. A systematic search of peer-reviewed journal articles was conducted following PRISMA guidelines. Studies were screened for relevance, with data extracted on model specification, efficiency estimation technique (e.g., stochastic frontier analysis), and diagnostic reporting. Quality appraisal focused on methodological transparency and robustness checks. A dominant theme was the prevalent use of the true fixed-effects stochastic frontier model, $ln\, y\{it\} = alphai + \beta^{prime} x\{it\} + v\{it\} - u_{it}$, though fewer than 30% of studies reported tests for key assumptions like time-invariant inefficiency. Inference was frequently compromised by a lack of reporting on robust standard errors or bootstrapped confidence intervals

for efficiency scores. While panel methods are widely adopted, methodological diagnostics are inconsistently applied, undermining the reliability of efficiency estimates and subsequent policy inferences. Greater rigour in model validation is required. Future research should mandate reporting of diagnostic tests for panel model assumptions and incorporate bootstrapping for uncertainty quantification. Journals should enforce stricter methodological reporting standards. technical efficiency, stochastic frontier analysis, panel data, model diagnostics, agricultural productivity, robustness This review provides the first structured methodological critique of panel data efficiency estimation for smallholder systems, establishing a benchmark for diagnostic reporting and identifying a critical gap in uncertainty quantification for policy-relevant parameters.

Keywords: *Smallholder agriculture, Panel data analysis, Technical efficiency, Sub-Saharan Africa, Stochastic frontier analysis, Agricultural productivity, Farm system modelling*

Article Highlights

- True fixed-effects SFA dominates but key assumption tests rarely reported
- Fewer than 30% of studies test time-invariant inefficiency
- Inference compromised by lack of robust standard error reporting
- Critical gap in bootstrapped uncertainty quantification for policy parameters

Methodological Imperative

This review establishes the first benchmark for diagnostic reporting in panel data efficiency estimation for smallholder systems.

A structured critique identifying reporting gaps with policy implications.