AFRICAN STRUCTURAL ENGINEERING

METHODOLOGY PAPER

A Bayesian Hierarchical Model for Efficiency Diagnostics in Rwandan Manufacturing Systems (2000–2026)

Marie Claire Uwimana[1,2] | **Aimable Nsabimana**[1,3]
Jean de Dieu Niyonzima[2] | **Jean dAmour Nkurunziza**[4]

1 *Department of Sustainable Systems, Rwanda Environment Management Authority (REMA)*
2 *Department of Electrical Engineering, University of Rwanda*
3 *Department of Mechanical Engineering, African Leadership University (ALU), Kigali*
4 *University of Rwanda*

Correspondence: muwimana@yahoo.com

Received: 11 June 2009 | Accepted: 17 August 2009 | Published: 24 September 2009 | **DOI:** 10.5281/zenodo.18967443

ABSTRACT

Background: The evaluation of manufacturing system efficiency in developing economies is often constrained by limited, heterogeneous data and the need to account for plant-specific operational contexts. Traditional deterministic frontier analyses lack mechanisms to formally incorporate prior engineering knowledge and quantify uncertainty in efficiency estimates.

Purpose and objectives: This article presents a novel Bayesian hierarchical methodology to diagnose technical efficiency in manufacturing systems. The primary objective is to provide a robust framework that quantifies efficiency gains while explicitly modelling plant-level heterogeneity and parameter uncertainty.

Keywords: *Bayesian hierarchical modelling, efficiency diagnostics, manufacturing systems, Sub-Saharan Africa, data envelopment analysis, stochastic frontier analysis, industrial development*

Article Highlights

- A three-level hierarchical stochastic frontier model quantifies plant-level heterogeneity.
- Posterior credible intervals provide principled uncertainty quantification for all efficiency estimates.
- The methodology successfully pools information across plants for more robust diagnostics.
- Identifies significant latent heterogeneity in efficiency improvement rates across sub-sectors.

Methodological Contribution

Develops a novel Bayesian hierarchical stochastic frontier model that formally incorporates prior knowledge and models parameter uncertainty, addressing limitations of traditional deterministic analyses.

This article presents a statistically coherent framework for manufacturing efficiency analysis in data-constrained environments.