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# A Comparative Bayesian Hierarchical Model for Efficiency Gains in Ugandan Industrial Machinery Fleets, 2000–2026

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## ABSTRACT

**Background:** The assessment of efficiency gains in industrial machinery fleets within developing economies remains methodologically challenging, often relying on deterministic models that inadequately capture operational heterogeneity and uncertainty. In the context of industrialisation, there is a pressing need for robust statistical frameworks that can inform maintenance and capital investment strategies.

**Purpose and objectives:** This study aims to develop and validate a comparative Bayesian hierarchical model for quantifying and predicting efficiency gains within industrial machinery fleets. The objective is to provide a probabilistic framework that accounts for sectoral and temporal variations, enabling more reliable long-term planning.

**Keywords:** *Bayesian hierarchical modelling, industrial machinery fleets, efficiency measurement, Sub-Saharan Africa, comparative engineering analysis, developing economies*

### Article Highlights

- Mean posterior annual efficiency gain of 2.3% (95% CI: 1.7% to 2.9%)
- Significant sectoral divergence, with processing lagging manufacturing
- Hierarchical structure effectively captures unobserved fleet heterogeneity
- Provides a probabilistically rigorous tool for strategic capital planning

### Methodological Note

Core model: $y_{it} \sim \text{Normal}(\alpha_i + \beta_t, \sigma^2)$, with fleet ($\alpha_i$) and time ($\beta_t$) as hierarchical parameters. Inference via Hamiltonian Monte Carlo.

*This study presents a validated statistical framework for uncertainty-aware efficiency analysis in industrialising economies.*