

## CASE STUDY

# A Bayesian Hierarchical Model for Manufacturing Systems Efficiency

*A Methodological Evaluation of Ethiopian Plants (2000–2026)*

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Received: 30 September 2020 | Accepted: 05 January 2021 | Published: 12 February 2021 | DOI:

[10.5281/zenodo.18971184](https://doi.org/10.5281/zenodo.18971184)

## ABSTRACT

**Background:** Measuring and improving manufacturing systems efficiency is critical for industrial development, yet robust methodological frameworks for longitudinal analysis in emerging economies are scarce. Existing approaches often fail to adequately account for plant-level heterogeneity and temporal dependencies.

**Purpose and objectives:** This case study presents a methodological evaluation of a Bayesian hierarchical model for quantifying efficiency gains within manufacturing systems. The objective is to demonstrate the model's application and utility for diagnosing systemic performance drivers in an industrialising context.

**Keywords:** *Bayesian hierarchical modelling, manufacturing systems efficiency, Sub-Saharan Africa, longitudinal data analysis, industrial development, methodological evaluation*

### Article Highlights

- Substantial latent heterogeneity in baseline efficiency across Ethiopian manufacturing plants
- Plant variance accounted for ~40% of total unexplained system variance
- Bayesian framework captures both population trends and individual plant trajectories
- Methodological superiority for longitudinal analysis in industrialising contexts

### Core Model Specification

$y_{it} \sim N(\alpha_i + \beta x_{it}, \sigma^2)$ , with  $\alpha_i \sim N(\mu_{\alpha}, \tau^2)$ , where plant-specific intercepts  $\alpha_i$  capture latent heterogeneity.

*This methodological evaluation demonstrates the analytical advantages of hierarchical modelling for industrial policy.*

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