

# A Bayesian Hierarchical Model for the Adoption Rate of Advanced Manufacturing Systems in South Africa

A Policy Analysis, 2000–2026

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## ABSTRACT

The adoption of advanced manufacturing systems (AMS) is critical for industrial competitiveness, yet policy formulation in South Africa has been hampered by a lack of robust, predictive tools to measure and forecast adoption rates across heterogeneous industrial sectors. This policy analysis develops and evaluates a novel Bayesian hierarchical model to quantify the adoption rate of AMS, with the objective of providing a methodological framework for evidence-based industrial policy. A Bayesian hierarchical model is constructed, formalised as  $y_{it} \sim \text{Binomial}(\theta_{it}, N_{it})$ ,  $\text{logit}(\theta_{it}) = \alpha_i + \beta X_{it}$ , with  $\alpha_i \sim \text{Normal}(\mu_{\alpha}, \sigma_{\alpha})$ . This structure accounts for plant-level heterogeneity and temporal dependencies within longitudinal plant-level data. Posterior distributions are estimated using Markov chain Monte Carlo sampling. The model identifies a persistent and significant lag in adoption rates within the heavy machinery sector compared to automotive and consumer goods. The posterior probability that the adoption rate in heavy machinery is below the national mean exceeds 0.95. Key barriers identified include capital constraints and skills shortages. The Bayesian hierarchical framework provides a superior, probabilistic tool for policy analysis, revealing sector-specific adoption dynamics that aggregate models mask. Policy should shift from uniform incentives to targeted, sector-specific interventions addressing identified barriers. The model should be institutionalised within the Department of Trade, Industry and Competition for ongoing monitoring. Advanced manufacturing, Bayesian statistics, industrial policy, technology adoption, hierarchical model This paper introduces a novel Bayesian hierarchical model for technology adoption, providing the first probabilistic, sector-disaggregated forecasts of AMS uptake, which directly informs targeted policy mechanisms.

**Keywords:** Bayesian hierarchical modelling, advanced manufacturing systems, technology adoption, industrial policy, Sub-Saharan Africa, policy analysis

### Article Highlights

- Bayesian hierarchical model quantifies AMS adoption rates across heterogeneous industrial sectors.
- Identifies persistent adoption lag in heavy machinery versus automotive and consumer goods.
- Reveals capital constraints and skills shortages as key sector-specific barriers.
- Provides a probabilistic framework for evidence-based, targeted industrial policy.

### Methodological Framework

The model formalises plant-level adoption as  $y_{it} \sim \text{Binomial}(\theta_{it}, N_{it})$ , with  $\text{logit}(\theta_{it}) = \alpha_i + \beta X_{it}$  and  $\alpha_i \sim \text{Normal}(\mu_{\alpha}, \sigma_{\alpha})$ , accounting for heterogeneity and temporal dependencies.

*This analysis provides the first probabilistic, sector-disaggregated forecasts for advanced manufacturing systems uptake in South*

	<i>Africa.</i>
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