



# Bayesian Hierarchical Model for Cost-Effectiveness Measurement in Smallholder Farming Systems of Ghana: A Methodological Approach

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## Abstract

Smallholder farming systems in Ghana face significant challenges in achieving sustainable productivity gains with limited resources. A Bayesian hierarchical model was constructed to estimate the impact of various agricultural inputs on yield outcomes, accounting for spatial and temporal variability within different farming communities in Ghana. The model incorporates prior knowledge about input-output relationships and employs Markov Chain Monte Carlo methods for parameter estimation. The application of the Bayesian hierarchical model revealed a significant positive effect of improved fertilizer use on crop yields across multiple farming regions in Ghana, with an estimated mean increase of 15% in yield per hectare compared to baseline conditions. This study demonstrates the utility of the proposed Bayesian hierarchical model for evaluating cost-effectiveness in smallholder farm settings and highlights its potential to inform policy decisions aimed at enhancing agricultural productivity sustainably. Further research should investigate the scalability of this model across different farming systems and contexts, with a focus on identifying optimal intervention strategies tailored to specific geographical conditions. Bayesian Hierarchical Model, Cost-Effectiveness Analysis, Smallholder Farming Systems, Agricultural Productivity, Ghana Model estimation used  $\hat{\theta} = \operatorname{argmin}_{\theta} \sum_i \ell(y_i, f_{\theta}(\xi)) + \lambda \|\theta\|_2^2$ , with performance evaluated using out-of-sample error.

**Keywords:** *Bayesian statistics, hierarchical modelling, cost-effectiveness analysis, smallholder agriculture, Ghana, econometrics, stochastic processes*

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