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The Efficiency Gap in Nigerian Cassava Farming: A Stochastic Frontier Analysis

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Abstract **Case Studies**

This study examines resource use efficiency among smallholder cassava farmers in Edo State, Nigeria, using a stochastic frontier analysis framework. Data were collected from 240 farmers through a multi-stage sampling technique and analysed using maximum likelihood estimation. The results reveal substantial inefficiency in input use, with a gamma (γ) value of 0.552 indicating that over half of the deviation from optimal production is attributable to managerial factors rather than random shocks. Fertilizer exhibited the highest level of waste at 31.2 per cent, followed by land (24.5 per cent) and labour (18.7 per cent). Key determinants of efficiency included formal education and participation in group-based extension services, which significantly reduced inefficiency across all inputs. Conversely, reliance on informal credit sources increased land use inefficiency, while age showed a small but positive effect on inefficiency. These findings suggest that policy interventions focused solely on input access are insufficient. Instead, complementary investments in farmer education, collective learning institutions, and financial inclusion are necessary to address the allocative inefficiencies that constrain profitability in smallholder cassava systems.

Keywords: Stochastic frontier analysis, input efficiency, smallholder agriculture, cassava, Nigeria, resource allocation.

Introduction

Nigeria's position as the world's largest cassava producer masks a persistent productivity paradox. Despite the crop's importance for food security and rural livelihoods, smallholder farmers continue to achieve yields substantially below potential, with average productivity remaining at just 30-50 per cent of what is technically feasible (FAO, 2022). This gap represents not only lost agricultural output but also foregone income for millions of farm households. While technical constraints such as poor seed quality and pest pressures have received considerable attention, the economic dimension of resource allocation remains comparatively underexplored.

The efficient allocation of scarce resources, land, labour, capital, and fertilizer is fundamental to farm profitability and sustainable intensification. In theory, profit-maximising farmers should employ inputs up to the point where the value of their marginal product equals their marginal cost. In practice, smallholder farmers in developing countries often deviate from this optimum due to imperfect information, market failures, credit constraints, and risk aversion (Barrett, 2022). These deviations, collectively termed allocative inefficiency, result in higher production costs and lower returns to investment.

In Nigeria, the cassava sector presents a compelling case for examining these allocative challenges. As a staple crop with both subsistence and commercial importance, cassava occupies a central role in rural economies. However, persistent low profitability raises questions about how farmers combine and apply their resources. Are they using too much fertilizer relative to labour? Are they cultivating more land than they can manage optimally? Understanding these allocation patterns is crucial for designing interventions that move beyond input provision to address the underlying economic logic of farm decision-making.

This study employs a stochastic frontier analysis framework to investigate input-specific inefficiencies among cassava farmers in Edo State, southern Nigeria. Unlike conventional approaches that generate a single efficiency measure, our methodology allows for the estimation of distinct inefficiency levels for different inputs within a unified analytical framework. By separating systematic managerial failure from random shocks, and by identifying the socio-economic and institutional factors that influence input use, we provide a granular diagnosis of the efficiency constraints facing smallholder cassava producers.

Literature Review

The theoretical foundation for analysing production efficiency dates to Farrell's (1957) seminal decomposition of economic efficiency into technical and allocative components. While technical efficiency concerns the physical transformation of inputs into outputs, allocative efficiency addresses the economic optimisation of input combinations given prevailing prices. In developing country agriculture, empirical studies consistently find that allocative inefficiency constitutes a more significant barrier to optimal performance than technical limitations (Bravo-Ureta & Pinheiro, 1997).

Research on Nigerian agriculture has documented pervasive allocative inefficiencies across various crop systems. Ogundari and Ojo (2007), examining cassava farmers in Osun State, found that allocative inefficiency accounted for a larger share of overall economic inefficiency than technical shortcomings. Similarly, Idiong (2007) reported that while rice farmers in Cross River State achieved reasonable technical efficiency, their allocative performance was substantially poorer. These patterns suggest that improving farmers' economic decision-making may yield greater returns than focusing exclusively on production techniques.

The stochastic frontier analysis (SFA) methodology, developed independently by Aigner et al. (1977) and Meeusen and van den Broeck (1977), provides a robust framework for efficiency measurement. Its key innovation lies in the decomposition of the error term into two components: random statistical noise and systematic inefficiency. This distinction is particularly valuable in agricultural applications, where production is subject to weather shocks, measurement errors, and other stochastic factors beyond farmers' control.

Recent methodological advances have extended SFA to model input-specific inefficiencies through input requirement frontier specifications (Kumbhakar & Wang, 2005). This approach, less commonly applied in developing country contexts, enables researchers to identify which inputs are used inefficiently and to what extent. Such granular analysis offers practical advantages for policy design, as interventions can be targeted to address specific resource misallocations rather than generic inefficiency.

Determinants of allocative efficiency in smallholder systems have been extensively studied. Human capital, typically measured through formal education, consistently emerges as a significant factor enhancing efficiency by improving information processing and optimisation capabilities (Lockheed et al., 2020). Institutional factors such as access to formal credit and extension services also play important roles, though their effectiveness depends on design and implementation (Anderson & Feder, 2004). Social capital and participation in farmer groups facilitate knowledge sharing and collective learning, which can improve allocative decisions (Wossen et al., 2021).

Despite this substantial literature, few studies have applied input-specific frontier models to Nigerian cassava systems. Most efficiency analyses in this context rely on output-oriented models that generate composite efficiency scores, obscuring the particular inputs that are mismanaged. Our study addresses this gap by employing an input requirement stochastic frontier model to quantify and explain inefficiencies in land, labour, and fertilizer use among cassava farmers. This approach provides novel insights into the specific nature of resource misallocation and its drivers in a major staple crop sector.

Methodology

Study Area and Sampling

The research was conducted in Edo State, located in Nigeria's humid forest zone and divided into three agro-ecological zones: Edo North, Edo Central, and Edo South. These zones represent the state's primary cassava-producing regions. We employed a two-stage sampling procedure to select participants. In the first stage, two Local Government Areas (LGAs) were purposively selected from each agro-ecological zone based on cassava production intensity and the presence of active farmer organisations under the FADAMA III development programme. This yielded a total of six LGAs.

In the second stage, we randomly selected two FADAMA User Groups (FUGs) from each LGA. From the membership registers of these twelve FUGs, 240 cassava farmers were randomly selected for inclusion in the study. This sampling strategy ensured representation across ecological zones while focusing on farmers with some degree of organisational affiliation, which facilitated data collection and provided contextual relevance for examining institutional determinants of efficiency.

Data Collection

Primary data were collected through structured questionnaires administered via face-to-face interviews during the 2025 agricultural season. The survey instrument gathered detailed information on farm production, input use, and socio-economic characteristics. Production data included cassava yield (measured in kilograms per hectare), cultivated area (hectares), labour input (man-days per hectare), fertilizer quantity (kilograms per hectare), and other variable costs. We also collected data on input prices, including local market prices for fertilizer, hired labour wages, and land rental rates.

Farmer characteristics encompassed age, education level (years of formal schooling), farming experience, household size, access to credit (distinguishing between formal and informal sources), and engagement with extension services (with particular attention to whether contact occurred primarily through individual visits or group meetings). The use of improved cassava varieties was recorded as a binary variable.

Analytical Framework

We employed a stochastic frontier analysis model configured as an input requirement frontier. This approach models the minimum input requirement conditional on output level and input prices, providing direct estimates of input-specific technical inefficiency. For farmer i and input k (where k represents land, labour, or fertilizer), the model is specified as:

$$x_{k_i} = f(y_i, w_i; \beta) + v_{k_i} + u_{k_i} \text{-----------(1)}$$

where x_{k_i} is the observed quantity of input k used, y_i is cassava output, w_i is a vector of normalised input prices, and β represents parameters to be estimated. The error term comprises two components: v_{k_i} , a symmetric random error capturing statistical noise and assumed to be normally distributed with zero mean and variance σ_v^2 *and* u_{k_i} , a non-negative random variable representing input-specific technical inefficiency, assumed to follow a half-normal distribution.

A key parameter is $\gamma = \sigma_u^2/(\sigma_v^2 + \sigma_u^2)$, which measures the proportion of total error variance attributable to inefficiency. A γ value close to 1 indicates that deviations from the frontier are dominated by inefficiency, while a value close to 0 suggests they are mostly random.

To examine determinants of inefficiency, we adopted a one-step estimation procedure (Battese & Coelli,

1995) where the mean of the inefficiency term u_{k_i} is modelled as a function of observable farmer characteristics:

$$\mu_{k_i} = \delta_0 + z_i'\delta \text{----------(2)}$$

where z_i is a vector of farmer characteristics including age, education, access to formal credit, primary mode of extension contact, use of improved varieties, and reliance on informal credit. This specification allows for simultaneous estimation of the frontier parameters (β) and inefficiency determinants (δ) using maximum likelihood estimation in STATA 17.

Results

Descriptive Statistics

Table 1 presents summary statistics for key variables. The average farmer cultivated 1.5 hectares of cassava, achieving a yield of 12.4 metric tons per hectare. Labour input averaged 85 man-days per hectare, while fertilizer application averaged 250 kilograms per hectare. Farmers had an average of 8 years of formal education and 15 years of farming experience. Only 35 per cent had accessed formal credit in the previous season, while 60 per cent reported that their primary extension contact occurred through farmer group meetings rather than individual visits. Approximately 65 per cent used improved cassava varieties.

Table 1: Descriptive Statistics of Sample Farmers (N=240)

Variable	Mean	Standard Deviation	Minimum	Maximum
Production Variables				
Cassava yield (kg/ha)	12,400	3,150	4,800	21,500
Land cultivated (ha)	1.5	0.8	0.5	5.0
Labour (man-days/ha)	85	22	40	150
Fertilizer (kg/ha)	250	95	0	500
Farmer Characteristics				
Age (years)	48	11.2	25	72
Education (years)	8	4.5	0	16
Access to formal credit (% yes)	35	-	0	1
Group-based extension (% yes)	60	-	0	1
Use improved varieties (% yes)	65	-	0	1

Frontier Estimates

Table 2 presents the maximum likelihood estimates of the stochastic input requirement frontier. The estimated coefficients for output and price ratios were statistically significant and carried expected signs, supporting the model specification. The gamma (γ) parameter of 0.552 was significant at the 1 per cent level, indicating that 55.2 per cent of the deviation from the optimal input frontier is attributable to systematic inefficiency rather than random factors. This finding underscores the importance of managerial factors in explaining suboptimal resource use.

Table 2: Stochastic Input Requirement Frontier Estimates

Parameter	Coefficient	Standard Error	p-value
Frontier Function			
Constant	1.205	0.321	0.000
Ln(Output)	0.352	0.045	0.000
Price ratio 1	-0.184	0.087	0.034
Price ratio 2	0.267	0.062	0.000
Variance Parameters			
Sigma-squared	0.418	0.102	0.000
Gamma (γ)	0.552	0.098	0.000
Log-likelihood	-285.42		
LR test of one-sided error	86.51		0.000

Input-Specific Inefficiency

The model revealed substantial variation in inefficiency across inputs (Eqn.1). Fertilizer exhibited the highest level of waste at 31.2 per cent, meaning farmers used approximately one-third more fertilizer than the technically efficient benchmark for their output level. Land use showed 24.5 per cent inefficiency, while labour was relatively less inefficient at 18.7 per cent. This hierarchy suggests that knowledge- and capital-intensive inputs like fertilizer are particularly susceptible to mismanagement, possibly due to complex application requirements and timing considerations.

Determinants of Inefficiency

Table 3 presents estimates of factors influencing input-specific inefficiency. Formal education significantly reduced inefficiency for all three inputs, with the strongest effect on fertilizer use. Each additional year of schooling reduced fertilizer inefficiency by approximately 2.9 percentage points. Group-based extension services also proved effective, particularly for reducing labour and land inefficiencies. Access to formal credit specifically lowered fertilizer inefficiency, likely by enabling timely purchase and application.

Table 3: Determinants of Input-Specific Technical Inefficiency

Determinant	Land	Labour	Fertilizer
Education (years)	-0.021***	-0.018**	-0.029***
Group-based extension	-0.085**	-0.112***	-0.067*
Access to formal credit	-0.041	-0.055	-0.098**
Reliance on informal credit	0.102**	0.031	0.047
Use of improved varieties	-0.076*	-0.038	-0.089**
Age (years)	0.002*	0.001	0.003**

*Note: Coefficients represent marginal effects on inefficiency. *** $p<0.01$, ** $p<0.05$, * $p<0.10$*

Notably, reliance on informal credit sources was associated with increased land use inefficiency. This finding suggests that high-interest, short-term loans may compel farmers to make suboptimal land allocation decisions, such as expanding cultivation beyond manageable scale or planting low-value crops for quick returns. Age showed a small but positive effect on land and fertilizer inefficiency, indicating that older farmers may be less efficient in using these inputs, possibly due to greater adherence to traditional practices.

Discussion

The finding that systematic inefficiency explains over half of the deviation from optimal input use has important implications for agricultural policy in Nigeria. For decades, policy has emphasised input access through subsidy programmes and credit schemes. While these interventions address real constraints, our results suggest they are incomplete. The substantial waste of fertilizer (31.2 per cent), land (24.5 per cent), and labour (18.7 per cent) represents a significant leakage of potential farm income. Closing these efficiency gaps could substantially improve profitability without requiring additional external inputs.

The hierarchy of inefficiency across inputs offers practical guidance for intervention design. Fertilizer's position as the most wasted input points to specific knowledge gaps in its management. Farmers may lack understanding of appropriate application rates, timing, and methods for different soil types and cassava varieties. This suggests that fertilizer subsidy programmes should be complemented with targeted extension on integrated soil fertility management rather than focusing solely on distribution.

The effectiveness of group-based extension in reducing inefficiency, particularly for labour and land use, underscores the value of collective learning institutions. Farmer groups facilitate knowledge sharing, peer monitoring, and economies of scale in service delivery. Policy should therefore strengthen these organisations rather than relying predominantly on individual extension visits. The positive association between formal education and efficiency across all inputs reinforces the long-term value of human capital development in agriculture. This extends beyond basic literacy to include numeracy and problem-solving skills relevant to farm management.

The contrasting effects of formal and informal credit on efficiency highlight the importance of financial product design. While formal credit enabled better fertilizer management, informal credit distorted land use decisions. This suggests that agricultural credit programmes should prioritise affordable, appropriately structured products that align with farming cycles rather than forcing distress sales or suboptimal cropping patterns.

Several limitations warrant consideration. First, the study's focus on organised farmers within FADAMA groups may limit generalisability to entirely unorganised producers. Second, cross-sectional data preclude analysis of efficiency dynamics over time. Third, while we control for major socio-economic factors, unobserved heterogeneity may still influence results. Future research employing panel data and mixed methods could provide deeper insights into efficiency trajectories and the qualitative dimensions of decision-making.

Conclusion

This study provides empirical evidence that input-specific inefficiency constitutes a major constraint to profitability in Nigerian cassava farming. The finding that systematic managerial factors explain more than half of the deviation from optimal input use challenges policy approaches focused predominantly on input access. Instead, complementary investments in farmer capability and institutional support are needed to address the allocative inefficiencies that currently undermine farm incomes.

Specifically, we recommend a reorientation of extension services toward input-specific management training, with particular emphasis on fertilizer use efficiency. Farmer organisations should be strengthened as platforms for collective learning and service delivery. Education policies should recognise the agricultural value of basic schooling and incorporate farm management content into curricula. Financial inclusion efforts should develop products that support rather than distort productive decision-making.

By shifting from an input-access paradigm to an efficiency-enhancement approach, policymakers can help cassava farmers achieve greater returns from their existing resources. This not only improves household welfare but also contributes to more sustainable agricultural intensification. As Nigeria seeks to transform its agricultural sector, addressing the allocative inefficiencies documented in this study represents a crucial step toward realising the full potential of smallholder cassava production.

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