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PRODUCTION RISK AND TECHNICAL EFFICIENCY IN INTERNAL AND EXTERNAL INPUTS USE AMONG CASSAVA FARMERS IN BAYELSA STATE, NIGERIA

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ABSTRACT

This study assessed production risk and technical efficiency among cassava farmers in Bayelsa State, Nigeria, with a focus on the use of internal (organic) and external (synthetic) inputs. Using a multistage sampling technique, 334 farmers were surveyed, including 173 internal input users and 161 external input users. Socio-economic analysis revealed that internal input users were older (mean age: 49.2 years) and had more farming experience (25.3 years). In comparison, external input users had higher educational attainment (10 years vs. 8 years) and operated larger farms (3.95 ha vs. 1.32 ha). Household sizes were similar across groups (8 persons), and annual income per hectare showed Internal (₦579,900) and external (₦570,570). The technical efficiency analysis, based on stochastic frontier modelling, indicated that both groups operated inefficiently, with internal input users showing 46.5% inefficiency and decreasing returns to scale, while external input users showed 78.9% inefficiency but increasing returns to scale. These findings highlight significant inefficiencies and suggest the need for targeted interventions to improve resource use and reduce production risks in cassava farming.

Keywords: Cassava farming, Technical efficiency, Internal and external inputs, Socio-economic characteristics

INTRODUCTION

Nigeria's agricultural sector has witnessed low productivity and inefficiency, especially in cassava farming, despite the country being the world's top producer. Cassava output remains insufficient

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due to poor mechanization, suboptimal agronomic practices, and inefficient input use. Cassava, being a staple for millions, is at the heart of food security and rural livelihoods. Despite having abundant arable land and a significant portion of its population engaged in farming, the country still depends heavily on food imports to meet domestic demand. Between 2018 and 2022, Nigeria's food import bill rose from ₦857 billion to over ₦1.9 trillion, showing a growth dependency on foreign food sources (NBS, 2022). This situation underscores the pressing need to enhance local food production capacity and sustainability. Cassava, a staple crop consumed by over 600 million people globally, plays a critical role in Nigeria's food security and rural economy. Nigeria is the largest producer of cassava in the world, accounting for over 20% of global production (FAOSTAT, 2022). Yet, the country's average yield per hectare remains significantly lower than potential levels due to factors such as limited mechanization, poor agronomic practices, fragmented landholdings, and inefficient input use (Akinola *et al*., 2020).

Inputs used in cassava farming are broadly categorized into internal (organic) and external (synthetic) inputs. Internal inputs include compost, manure, and crop residues, which are locally sourced and affordable. External inputs such as chemical fertilizers, herbicides, and pesticides are often imported, expensive, and less accessible to resource-poor farmers (Arthur *et al*., 2022). These inputs influence not only yield levels but also the risks and sustainability associated with cassava production.

Production risk is a critical issue in agricultural systems and is influenced by factors such as weather variability, pest and disease outbreaks, and market fluctuations. These uncertainties affect both the quantity and quality of output and may threaten the livelihoods of smallholder farmers (Emenyonu *et al*., 2020; Ajah *et al*., 2022). Farmers' responses to risk, such as their choice of inputs and production strategies, can significantly influence their technical efficiency and resilience.

Numerous studies have examined technical efficiency in cassava farming and the impact of different input types on productivity (Akinola *et al*., 2020; Zubairu *et al*., 2020; Onu and Echebiri, 2020). However, these studies often focus on either internal or external input use in isolation and fail to model the influence of production risk on output levels. While a few studies (Alabi *et al*., 2020; Ohajianya *et al*., 2020) have explored risk attitudes in cassava farming, they do not compare how internal and external input systems interact with production risks to influence yields. This gap is particularly significant given the growing concerns around the cost, availability, and health implications of synthetic inputs (Olowogbon *et al*., 2021).

Therefore, this study aims to fill this gap by analyzing and comparing the effects of internal and external input use on production risk and technical efficiency among internal and external input cassava farmers users in Bayelsa State, Nigeria. Specifically, the study seeks to (i) describe the

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socioeconomic characteristics of the farmers under internal and external input users and (ii) estimate and compare the levels of technical efficiency among cassava farmers that use internal and external inputs.

MATERIALS AND METHODS

The study was conducted in Bayelsa State, Nigeria. Bayelsa State is in the South–South part of Nigeria, with an area of about 10,773 square kilometres and a population of 1,950,000 people (NPC, 2015). The state is geographically located between Latitudes 04° 15' North and 05° 23' North and Longitudes 05° 22' East and 06 ° 45' East. It shares boundaries with Delta State on the North, Rivers State on the East, and the Atlantic Ocean on the West and South. Bayelsa State is a picturesque tropical rain forest, and more than three-quarters of its area is covered by water, with a moderately low land stretching from Ekeremor to Nembe. The area lies almost entirely below sea level, with a maze of meandering creeks and mangrove swamps. The network of several creeks and rivers in the South flows into the Atlantic Ocean via the major rivers such as San Bartholomew, Brass, Nun, Ramos, Santa Barbara, St. Nicholas, Sangana, Fishtown, Ikebiri Creek, Middleton, Digatoro Creek, Pennington and Dobo. The vegetation is characterized by the mangrove forest. It has a thick forest with arable lands for cultivation of various food and cash crops. The State is endowed with rich and diversified marine life and an abundant forestry. Some of the agricultural resources include Food Crops, Timber Trees and Non-timber Forest Products. The food crops include; Rice, Bananas, Plantain, Yam, Cassava, Cocoyam, Sweet Potatoes, and Maize.

Most of the agricultural land in the state has the problem of Oil Pollution and gas flares pollution that affects agricultural productivity. Cassava, maize, cocoyam, and plantain are the major food crops engaged in by farmers in the area, while many others engage in fishery, timber trees, and non-timber forest products. Some cassava farmers use organic inputs such as animal manure, kitchen wastes, compost, poultry droppings, etc, while others use external inputs such as inorganic fertilizers, pesticides, herbicides, etc.

Multi-stage sampling procedure was used in this study. In the first stage, two (2) LGAs were purposively selected in each of the three Agricultural Zones of Bayelsa State based on some farmlands that were not seriously affected by oil spillages and pollution.

In the second stage, three (3) communities were randomly selected from the two LGAs, making a total of six (6) communities.

In the third stage, four (4) villages were selected randomly from the six communities, making a total of twenty-four (24) villages.

In the fourth stage, the list of registered cassava farmers was used to stratify the farmers into external input and internal input users, and a random sampling technique was used to select 173

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internal input users of cassava farmers and 161 external input users of cassava farmers. making a total of 334 cassava farmers, which was used as the sample size for the study. The internal inputs are the organic manure, poultry droppings, and many more, and the external inputs are the inorganic fertilizer and pesticides, and many more. primary data were collected through a well-structured questionnaire, interview, and focal group discussion. Practical field measurement of plots was done through the global positioning system (GPS). A combination of analytical tools, including descriptive statistical and econometric procedures, was utilized in data analyses.

The levels of technical efficiency among cassava farmers who use internal and external inputs was determined using the Stochastic frontier production function. The model is specified as follows;

$Y_i = f(X_i; \beta) \times \exp(V_i - U_i)$ --- (1)

Where:

i = 1 for cassava farmers that use internal inputs and 2 for cassava farmers that use external inputs

$X_{i =}$ Depreciation on capital inputs (₦)

X_2 = Planting material (bundles)

X_j =Labour (Mandays)

X_4 =Manure or fertilizer (Kg)

X_5= Cost of crop residue or pesticides (₦)

X_6 =Farm size (Ha)

X_7= Chemical inputs (litres)

X_8 = Interest rate (percentage)

The technical efficiency of the two farm types was compared to determine the farm type that has higher production risk.

The inefficiency model (U_i) is defined by:

$U_i = a_0+a_1z_{1i} +a_2z_{2i} + a_3z_{3i} + a_4z_{4i} +a_5z_{5i}$ --- (2)

Where Z_1, Z_2, Z_3, Z_4 and Z_5 represent education, experience, farm size, membership of cooperative and access to credit, respectively. These socio-economic variables are included in the model to indicate their possible influence on the technical efficiencies of the cassava farmers. The ßs and as are scalar parameters to be estimated.

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RESULTS AND DISCUSSIONS

Socio-economic Characteristics of Cassava farmers that used Internal and External Inputs

The results of the socioeconomic characteristics of the cassava farmers, such the age, educational attainment, marital status, household size, farming experience, marital status, and income, are presented in Table 1.

Table 1: Socioeconomic Characteristics of Respondents

Internal Input User			External Input User			Pooled Input Users		
Age	**Frequency**	**%**	**Age**	**Frequency**	**%**	**Age**	**Frequency**	**%**
32 – 41	18	10.40	22 -31	39	24.22	32 – 41	57	17.07
42 – 51	107	61.84	32 – 41	35	21.74	42 – 51	142	42.51
51 – 61	32	18.50	41 – 51	72	44.72	51 - 61	104	31.14
62 – 71	16	9.26	52 – 61	15	9.32	62 - 71	31	9.28
Total	**173**		**Total**	**161**			**334**	
Mean	**49.2 years**			**39.8years**			**49.8 years**	
Internal Input User			**External Input User**			**Pooled Input Users**		
Edu	**Frequency**	**%**	**Edu**	**Frequency**	**%**	**Edu**	**Frequency**	**%**
0 – 6	80	46.24	0 – 6	32	19.87	0 – 6	112	33.53
7 – 13	77	44.51	7 – 13	106	65.84	7 – 13	183	54.79
14 – 20	15	8.67	14 – 20	21	13.04	14 – 20	36	10.78
21 – 27	1	9.26	21 - 27	2	1.25	21 - 27	3	0.90
Total	**173**	**0.58**	**Total**	**161**			**334**	
Mean	**7.5 years**			**9.7years**			**8.5 years**	
Internal Input User			**External Input User**			**Pooled Input Users**		
FE	**Frequency**	**%**	**FE**	**Frequency**	**%**	**FE**	**Frequency**	**%**
0 – 15	24	13.87	0 – 15	35	21.74	0 – 15	59	17.66
16 – 31	106	61.27	16 – 31	101	62.73	16 – 31	207	61.98
32 – 47	43	24.86	32 – 47	25	15.53	32 – 47	68	20.36
Total	**173**		**Total**	**161**			**334**	
Mean	**25.3 years**			**22.5years**			**23.9 years**	
Internal Input User			**External Input User**			**Pooled Input Users**		
FI (‘000)	**Frequency**	**%**	**FI (‘000)**	**Frequency**	**%**	**FI(‘000)**	**Frequency**	**%**
50 – 275	13	7.51	50 – 275	13	8.07	50 – 275	26	7.78
275 – 500	44	25.43	275 – 500	44	27.33	275 – 500	88	26.35
501 – 726	71	40.04	501 – 726	64	39.75	501 – 726	135	40.42
727 – 952	45	26.01	727 - 952	40	24.84	727 - 952	85	25.45
Total	**173**	**100**	**Total**	**161**	**100**		**334**	**100**
Mean	**₦579,990**			**₦570,570**			**₦575,450**	
Internal Input User			**External Input User**			**Pooled Input Users**		
FS (Ha)	**Frequency**	**%**	**FS (Ha)**	**Frequency**	**%**	**FS(Ha)**	**Frequency**	**%**

0.2 – 1.2	110	63.58	0.1 – 3.0	39	24.22	0.1 – 3.0	149	44.61
1.3 – 2.3	23	13.29	3.1 – 4.0	31	19.25	3.1 – 4.0	54	16.17
2.4 – 3.4	29	16.76	4.1 – 5.0	78	48.45	4.1 – 5.0	107	32.04
3.5 – 4.5	8	4.62	5.1 – 6.0	8	4.97	5.1 – 6.0	16	4.79
4.6 – 5.6	3	1.73	6.1 – 7.0	5	3.11	6.1 – 7.0	8	2.39
Total	**173**	**100**	**Total**	**161**	**100**		**334**	**100**
Mean	**1.32ha**			**3.95h**			**2.59ha**	
Internal Input User			**External Input User**			**Pooled Input Users**		
HHS	**Frequency**	**%**	**HHS**	**Frequency**	**%**	**HHS**	**Frequency**	**%**
1 – 5	10	5.78	1 – 5	18	11.18	1 – 5	28	8.38
6 – 10	145	83.82	6 – 10	137	85.09	6 – 10	282	84.43
11 – 15	18	10.40	11 – 15	6	3.73	11 – 15	24	7.19
Total	**173**	**100**	**Total**	**161**	**100**		**334**	**100**
Mean	**8 persons**			**8 persons**			**8 persons**	

Source: Field Survey Data Analysis 2024 EDU (Education in years), FS (Farm Size in hectare), FI (Farm Income in naira), HHS (Household Size in Number of persons)

Table 1 presents the mean age of farmers based on their usage of internal versus external inputs: 49.2 years for those using internal inputs, 39.8 years for those using external inputs, and 49.8 years for the entire pooled sample. These findings suggest that farmers in the study area are predominantly within their productive age range, which likely enhances their potential for efficient production. This age distribution is particularly significant as it indicates the farmers' ability to adapt to technological innovations, an essential factor in improving agricultural practices. The finding is consistent with the study by Elum and Snijder (2023), who reported a mean age of 47 years for farmers in coastal communities of Bayelsa State, aligning with the productive age profile observed in this study. Moreover, age is a critical factor in labour decision-making within agricultural households. As Tong *et al*. (2024) assert, the ageing of farmers negatively impacts total factor productivity. They argue that an ageing labour force hinders agricultural productivity by slowing the adoption of new technologies and reducing the efficiency of resource allocation. Thus, the age distribution of the labour force in the study area is important for making informed labour and production decisions. By focusing on the productive age bracket, policies and interventions can be better tailored to address labour-related challenges and enhance agricultural output.

Table 1 also shows that farmers who used internal, external, and pooled inputs had mean years of educational attainment of 7.5 years, 9.7 years, and 8.5 years, respectively. These results indicate that farmers using external inputs have more years of schooling than those using internal inputs. This finding is expected, since internal inputs are typically basic, low-cost resources that are easily accessible and affordable to resource-constrained farmers. In contrast, external inputs often require a higher level of financial investment, which may correlate with a higher educational attainment, as more educated individuals tend to seek out and utilize more advanced inputs in production. The relationship between education and the adoption of advanced farming techniques is well established. Higher educational attainment reduces the conservatism that is often observed among rural farmers, increasing their capacity to embrace modern agricultural practices. Therefore, the higher education attainment among external input users aligns with the a priori expectation that educated farmers are more likely to adopt innovative production techniques.

This finding corroborates Nwaiwu *et al*. (2009), who found that farmers using external inputs were more literate than those relying on internal inputs, with mean educational attainments of 13 and 7 years, respectively. Furthermore, education is known to enhance technical efficiency. Consequently, farmers using external inputs and possessing higher educational attainment are expected to exhibit greater technical efficiency in cassava production than their counterparts who use internal inputs. As a result, the production risk, measured by the deviation from expected mean production, is anticipated to be lower among external input farmers than internal input farmers. This assertion is consistent with Njeru (2010), who argued that higher education reduces technical inefficiencies among wheat farmers in Uasin Gishu District, Kenya. Similarly, Abimbola *et al*. (2024) found that secondary and tertiary education positively and significantly influenced technical efficiency, with a 1% significance level. These findings further underscore the importance of education in enhancing agricultural productivity and reducing inefficiency.

Table 1 further shows that the mean farming experience of cassava farmers is based on their input usage. Farmers utilizing internal inputs reported an average of 25.3 years of farming experience, while those relying on external inputs averaged 22.5 years. The pooled sample showed a mean farming experience of 23.9 years. These figures suggest that cassava farmers in the study area possess substantial practical farming experience, equipping them with the skills and techniques necessary for the effective and efficient application of both internal and external production inputs.

Furthermore, when cross-tabulating their farming experience with their mean ages (49.2 years for internal input users and 39.8 years for external input users), it indicates that many farmers have been involved in cassava production for a significant portion of their lifetimes, potentially over half of their lifespan. This extensive experience is expected to positively influence technical efficiency by reducing production costs and minimizing associated risks, such as input wastage and yield variability. The importance of farming experience in enhancing technical efficiency is well supported by previous studies. Ali *et al*. (2022) demonstrated that farming experience significantly decreased technical inefficiency among rice growers in Pakistan. Similarly, Mohammad and Showkat (2014) identified farming experience, alongside factors like household size and farm size, as key determinants of variations in technical efficiency among farm households. These findings further reinforce the notion that accumulated farming experience is a critical asset for improving production outcomes and promoting more sustainable cassava farming practices.

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The mean annual farm income per hectare for cassava farmers in the study area. Farmers who utilized internal inputs (such as farmyard manure, compost, and family labour) recorded a mean income of ₦579,900/ha, while those employing external inputs (including synthetic fertilizers, hired labour, and improved planting materials) reported a slightly lower mean income of ₦570,570/ha. The pooled mean income across both groups was ₦558,320.96/ha. This result indicates that, regardless of the input source, cassava farmers in the study area achieved relatively high-income levels per hectare. This level of income is not just survival money, it is strong enough to enable reinvestment into higher-quality inputs, facilitate technology adoption, and potentially scale operations for the next planting season. This finding aligns with recent studies emphasizing the economic viability of cassava farming when proper input management strategies are deployed. For instance, Okoro *et al*. (2023) found that cassava farmers who diversified their input use achieved a 15–20% higher net income compared to those who depended solely on traditional practices. Similarly, Adebayo and Chukwu (2021) observed that a balance between internal and external input use significantly enhances productivity and profitability among smallholder cassava farmers.

Moreover, the slight difference between internal and external input users suggests that local resource mobilization strategies for internal inputs may be just as economically viable as externally sourced inputs, a finding supported by Nwachukwu *et al*. (2022), who reported that internal input use could boost farmers' resilience against price shocks in the input market. In terms of sustainable agricultural development, these results point towards a promising pathway where farmers can maximize income while minimizing dependency on costly external inputs. This is crucial, especially in an era of global input price volatility (World Bank, 2022), making it imperative for farmers to optimize resource use efficiency.

Table 1 also shows that the farm sizes of cassava farmers in Bayelsa State, based on their input usage, had a mean farm size of 1.32 hectares, while those relying on external inputs operated on a significantly larger mean of 3.95 hectares. The overall pooled mean stood at 2.59 hectares, which situates most of these farmers firmly within the smallholder category, typically defined as those managing less than 10 hectares (FAO, 2021). These results align with the recent findings of Chiaka *et al*. (2022), who observed that the average farm size in Nigeria ranges between 1–3 hectares, with larger holdings in the North than in the South. The data thus reinforces the structural pattern of small-scale agriculture prevalent across the Nigerian South, particularly in root and tuber production systems.

The difference in mean farm sizes between internal and external input users has significant implications. Larger farm sizes among external input users suggest a higher likelihood of achieving technical efficiency through economies of scale, especially when mechanization and purchased inputs such as synthetic fertilizers and herbicides are utilized (Adebisi and Fawole, 2023). This operational scale facilitates the adoption of cost-reducing technologies, which ultimately boost productivity and profitability.

Conversely, internal input users, with significantly smaller hectares, are more likely to depend on family labour, rudimentary tools, and locally available organic inputs, a strategy often adopted to minimize cash outflows and maintain sustainability (Okorie *et al*., 2021). This group may face greater constraints in expanding operations or transitioning to mechanized farming due to capital and input limitations. Moreover, the larger landholdings among external input users may necessitate greater investment in production technologies, which often come with higher upfront costs. As observed by Umeh and Eze (2022), farmers managing larger cassava farms in Nigeria exhibit a stronger dependency on market-sourced inputs, including agrochemicals and tractor services, to maintain yield levels. Thus, the disparity in farm sizes reflects not just differences in land ownership or access, but also varying production philosophies and input ecosystems. While internal input systems offer a low-cost, sustainable model, they may struggle to keep up with the efficiency gains offered by external input-based, scale-driven models, particularly in an era where climate variability and input prices are rapidly evolving (World Bank, 2022).

Table 1 also reveals that most cassava farming households in the study area have household sizes ranging between 6 to 10 persons, with a mean household size of 8 persons across internal input users, external input users, and the pooled sample. This suggests that farming households in Bayelsa State typically have large family sizes, reflecting a demographic pattern common in rural sub-Saharan Africa. These findings align with recent global demographic data. According to United Nations DESA (2023), average household sizes remain relatively high across Africa, ranging between 5 to 8 persons. The results in this study therefore reinforce the idea that cassava farming households in Nigeria reflect the typical African extended family structure, where agricultural labour is often sourced from within the household.

Large household sizes in rural agrarian settings are frequently linked to labour availability, especially in smallholder farming systems where mechanization is limited, and farming tasks are labour-intensive. This supports findings by Ogunniyi *et al*. (2022), who reported that in regions like the Niger Delta, households with more members are better positioned to leverage family labour, reducing the need for hired labour and lowering production costs. Moreover, larger household sizes may contribute positively to technical efficiency if household members are productively engaged in farming activities. Ojo *et al*. (2021) found that among smallholder cassava farmers in Nigeria, labour availability from within the household significantly improved input utilization efficiency, especially for those using internal inputs like composting and manual weeding. However, it is important to note that household size alone does not automatically equate to higher efficiency. Akinrinde and Lawal (2020) cautioned that household size becomes a drag on

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productivity when dependency ratios are high, that is, when non-working members like children and the elderly outnumber the active labour force.

Levels of Technical Efficiency and Effects of Internal and External Inputs Use in Cassava Production

The result of the maximum likelihood estimation of the effects of Internal and External inputs on cassava production in Bayelsa is presented in Table 2.

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Table 2: Maximum Likelihood Estimation of Effects of Internal and External Inputs on Cassava Production in Bayelsa State

Internal Sourced Inputs (n = 173)				External Sourced Inputs (n = 161)			
		Parameter Estimates				Parameter Estimates	
Variable	**Units**	**Coefficient**	**/t/-values**	**Variable**	**Units**	**Coefficient**	**/t/-values**
Constant		10.00***		Constant		8.673***	
(std. error)		0.070	136.00	(std. error)	-	0.238	36.44
lnLabour		0.019**		lnLabour		-0.007***	
(std. error)	Man-day	0.009	2.12	(std. error)	Man-day	0.002	3.50
lnManure		1.330***		lnFertilizers		-0.391***	
(std. error)	Kilogramme	0.430	3.08	(std. error)	Kilogramme	0.114	3.43
lnFarm Size		-1.050***		lnFarm Size		0.726	
(std. error)	Hectares	0.120	9.11	(std. error)	Hectares	0.460	1.58
lnPlant Material		0.778***		lnPlant materials		0.138***	
(std. error)	Bundles	0.220	3.54	(std. error)	Bundles	0.041	3.37
lnDepreciation		-0.671		lnAgro-Chemicals		-1.336	
(std. error)	Naira	0.511	1.31	(std. error)	Liters	0.449	0.316
				lnDepreciation		1.539**	
				(std. error)	Naira	0.776	1.983
				lnInterest		0.623***	
				(std. error)	Percentage	0.185	3.368
Returns To Scale		**0.106**		**Returns To Scale**		**1.292**	
		Diagnostic Statistics/Functional Parameters					
Variable		**Coefficient**	**/t-Value/**	**Variable**	**Coefficient**	**Standard Error**	**/t-Value/**
Sigma Squared	$\delta^2 = \partial_u^2 + \partial_v^2$	**0.250**	**6.32**	**Sigma Squared**	$\delta^2 = \partial_u^2 + \partial_v^2$	**0.303**	**2.51**
Gamma	$(\lambda^2 / (1+\lambda^2) = \partial_u^2 / \partial_z^2)$	**0.465**	**27.69**	**Gamma**	$(\lambda^2 / (1+\lambda^2) = \partial_u^2 / \partial_z^2)$	**0.789**	**94.49**
Lambda	$\partial_u^2 / \partial_z^2$	**0.301**	**1.92**	**Lambda**	$\partial_u^2 / \partial_z^2$	**0.553**	
Log likelihood Ratio		**-191.70**		**Log likelihood Ratio**		**-179.67**	
LR		**18.143**		**LR**		**39.99**	

Source: Frontier 4.0 2024 Production

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The Maximum Likelihood Estimates (MLE) of Cobb-Douglas production functions for two categories of cassava input users, internal and external, are presented in Table 9. These functional parameters, which include variance parameters, indicate a lambda (λ) value of 0.301 (30.1%) for internal inputs and 0.553 (55.3%) for external inputs. Lambda, the ratio of the standard error of the one-sided error term (u) to that of the two-sided error term (v), serves as a proxy for the goodness of fit and the appropriateness of the distributional assumptions of the stochastic frontier model.

Both estimates are significantly different from zero at the 5% level ($P < 0.05$), demonstrating that the model fits the data well and is statistically valid for explaining the influence of input types on cassava output. The external input system's lambda of 0.553 reflects a stronger one-sided error component, indicating more pronounced technical inefficiency and, potentially, more room for performance improvement under external input use. This also suggests that the stochastic frontier model is more effective in capturing the performance of external input users than internal input users.

The slope coefficients (elasticities of production) deviate from unity, implying the presence of either increasing or decreasing returns to scale. Internal input systems exhibited a total return to scale of 0.106, indicating decreasing returns to scale, while external inputs produced a return to scale of 1.292, reflecting increasing returns to scale. These findings show that the marginal productivity of external inputs increases as usage increases, whereas the internal inputs become less productive beyond a certain point.

This differential in scale elasticity means that internal and external input systems have distinct impacts on cassava productivity. Internal users should consider reducing input levels to improve efficiency, while external users may benefit from scaling up inputs. Specifically, a unit reduction in internal input usage would increase cassava tuber output by 0.806 units, whereas a unit increase in external inputs would increase output by 1.292 units—an output gain of 0.292 units over the inputs added.

According to Ehirim *et al*. (2020), operations with increasing returns to scale should scale up input use for higher productivity, while decreasing returns to scale necessitate a reduction in input use to optimize outcomes and minimize costs. This study supports that principle, internal input users should streamline their input use, while external users should scale up for better productivity outcomes.

The functional parameters in Table 2 show that the internal input system presented a left-sided residual error of 18.143 and a log-likelihood estimate of -191.70. Similarly, the external input system showed residuals of 33.99 and a log-likelihood estimate of -179.67. Although negative, both log-likelihood values are significant at the 1% level ($P < 0.01$), exceeding the critical value thresholds. This confirms the robustness and consistency of the stochastic production frontier model for both internal and external input systems in cassava production in the study area.

Levels of Technical Inefficiency in Cassava Production under Internal and External Inputs Use in Bayelsa State

The result of the levels of technical inefficiency in cassava production under internal and external inputs use in Bayelsa State is presented in Table 3.

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Table 3: Farmers' Levels of Technical Inefficiency in the Use of Internal and External Input for Cassava Production in Bayelsa State

	Internal Input	Farmers Technical Inefficiency levels			External Input		
Efficiency Limits	**Class Boundaries**	**Frequency**	**Percentage**	**Efficiency Limits**	**Class Boundaries**	**Frequency**	**Percentage**
0.00 – 10.0	0 – 10.5	6	3.47	0 – 10.0	0 – 10.5	30	18.63
11.0 – 20.0	10.5 – 20.5	5	2.89	11.0 – 20.0	10.5 – 20.5	26	16.15
21.0 – 30.0	20.5 – 30.5	9	5.20	21.0 – 30.0	20.5 – 30.5	36	22.36
31.0 – 40.0	30.5 – 40.5	17	9.83	31.0 – 40.0	30.5 – 40.5	19	11.87
41.0 – 50.0	40.5 – 50.5	22	12.72	41.0 – 50.0	40.5 – 50.5	16	9.94
51.0 – 60.0	50.5 – 60.5	48	27.75	51.0 – 60.0	50.5 – 60.5	8	4.97
61.0 – 70.0	60.5 – 70.5	28	16.18	61.0 – 70.0	60.5 – 70.5	11	6.83
71.0 – 80.0	70.5 – 80.5	18	10.40	71.0 – 80.0	70.5 – 80.5	11	6.83
81.0 – 90.0	80.5 – 90.5	11	6.36	81.0 – 90.0	80.5 – 90.5	3	1.86
91.0 – 100.0	90.5 – 100.0	9	5.20	91.0 – 100.0	90.5 – 100.0	1	0.62
Maximum			88.91	Maximum			63.62
Minimum			9.02	Minimum			06.23
Mean			55.25	Mean			31.27

Diagnostic Statistics/Functional Parameters

Variable		**Coefficient**	**/t-Value/**	**Variable**	**Coefficient**	**Standard Error**	**/t-Value/**
Sigma Squared	$\delta^2 = \partial_u^2 + \partial_v^2$	**0.250**	**6.32**	**Sigma Squared**	$\delta^2 = \partial_u^2 + \partial_v^2$	**0.303**	**2.51**
Gamma	$(\lambda^2 / (1+\lambda^2) = \partial_u^2 / \partial_z^2)$	**0.465**	**27.69**	**Gamma**	$(\lambda^2 / (1+\lambda^2) = \partial_u^2 / \partial_z^2)$	**0.789**	**4.499**
Lambda	$\partial_u^2 / \partial_z^2$	**0.301**	**1.989**	**Lambda**	$\partial_u^2 / \partial_z^2$	**0.553**	**2.53**
Log likelihood Ratio		**-191.70**		**Log likelihood Ratio**		**-179.67**	
LR		**18.143**		**LR**		**39.99**	

Source: Frontier 4.0 2024 Production

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Technical inefficiency level of farmers in the use of internal and external farm inputs for cassava production is shown in Table 10 below. Technical inefficiency of farmers using internal input ranges between 0.0902 and 0.8891 or (9.02 to 88.91 percent), with a mean of 0.5525 (55.25 percent) in the area. It could be seen that majority (27.75 percent) of the farmers have between 50.5 percent to 60.5 percent technical inefficiency while only 2.89 percent of them are within 10.5 to 20.5 percent technical inefficient in the area. It is therefore, deduced that farmers with internal input in cassava production have relatively higher technical inefficiency of above 50 percent because while 38.14 percent of farmers with internal input use have more than 60 percent technical efficiency only 28.91 percent of them are below 50 percent technical efficient. Internal inputs use is locally sourced, and farmers are expected to be more careful in their usage to avoid waste. Their ability to combine the internally sourced farm inputs to attain maximum productivity in the area is organized around the farmers' subsistence outlook or features which can only allow them make use of what is available within their local environment at optimum level. Their high inefficiency in the use of internal cassava production inputs may be explained by the easy availability of such inputs around their locality as their farms can always generate the needed inputs easily. Hence a lot of waste may be sustained. This finding is contrasted with Bansard and Schroder (2021) who report that peasant farmers are careful when it comes to resource management as they avoided waste of resources in other to attain optimum resource use.

The result shows that the least technical efficient farmers with internal farm inputs for cassava production is 9.02 percent can be technically efficient if they observe cost saving device in the use of these internal farm inputs in production. Hence it is expected that they can attain maximum technical efficiency by making a total cost savings of about {1 - (0.0902/0.8891)}, which is 0.8985 (89.85) of the internal inputs use to become the highest technical efficient farmers. In the same way, the farmers who are within average technical efficiency can attain highest technical efficiency by saving the waste of internal farm inputs for cassava production. Hence a reduction in waste of internal farm inputs by {1 - (0.5525/0.8985)}, which is about 38.51 percent cost saving to become the most technically efficient cassava farmers in the use of internal inputs.

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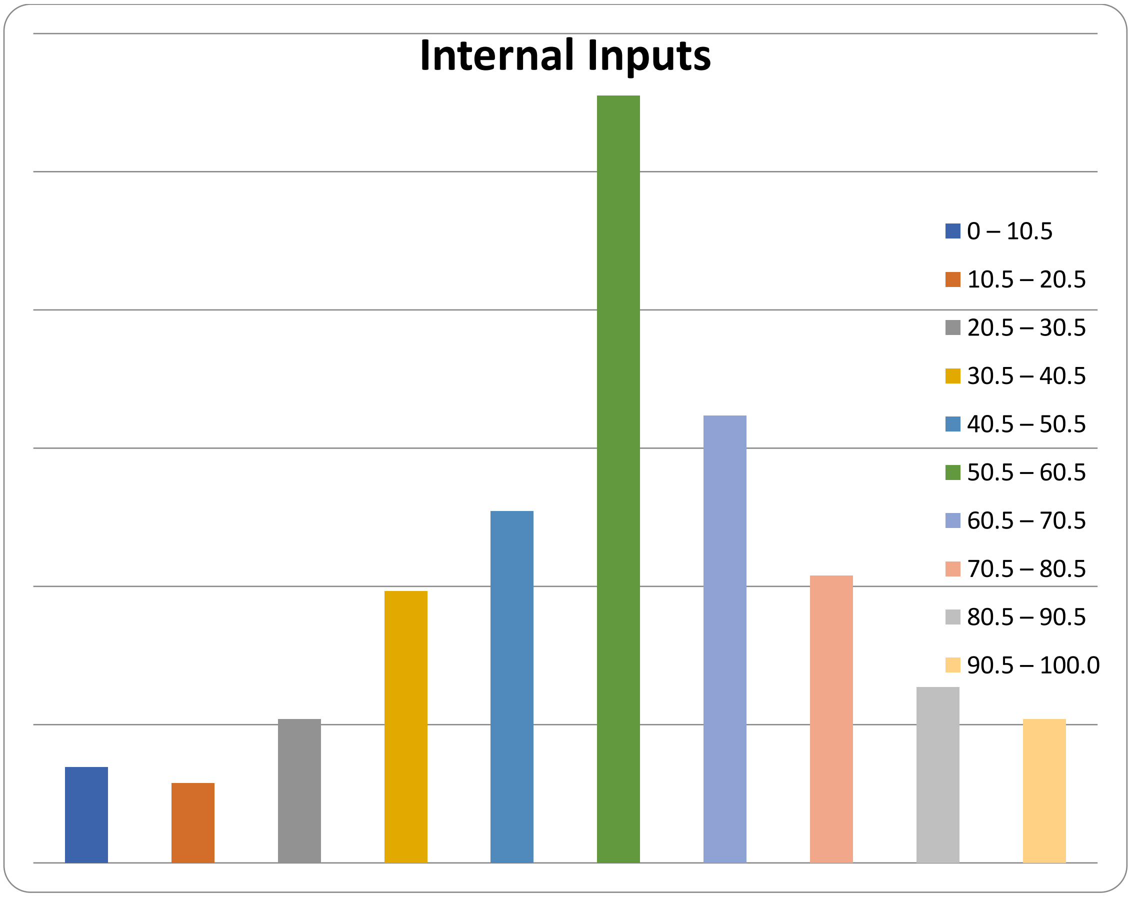

Fig. 1: Levels of technical efficiency in internal input use

Similarly, externally sourced farm inputs used by cassava farmers demonstrated varying technical inefficiency, which ranges from 6.23 to 63.62 per cent, with a mean of 31.27 per cent. It could be seen from the result that majority (22.36 percent) of the farmers have between 20.5 to 30.5 percent technical inefficiency. The low mean technical inefficiency of farmers with externally sourced cassava farm inputs may be due to the scarcity and high-cost implication of these externally sourced farm inputs. However, a few (24.20 percent) of the farmers who sourced their farm inputs for cassava production externally have technical inefficiency of above 50.0 percent. Majority (75.80 percent) of them have their technical inefficiency of less than 50 percent.

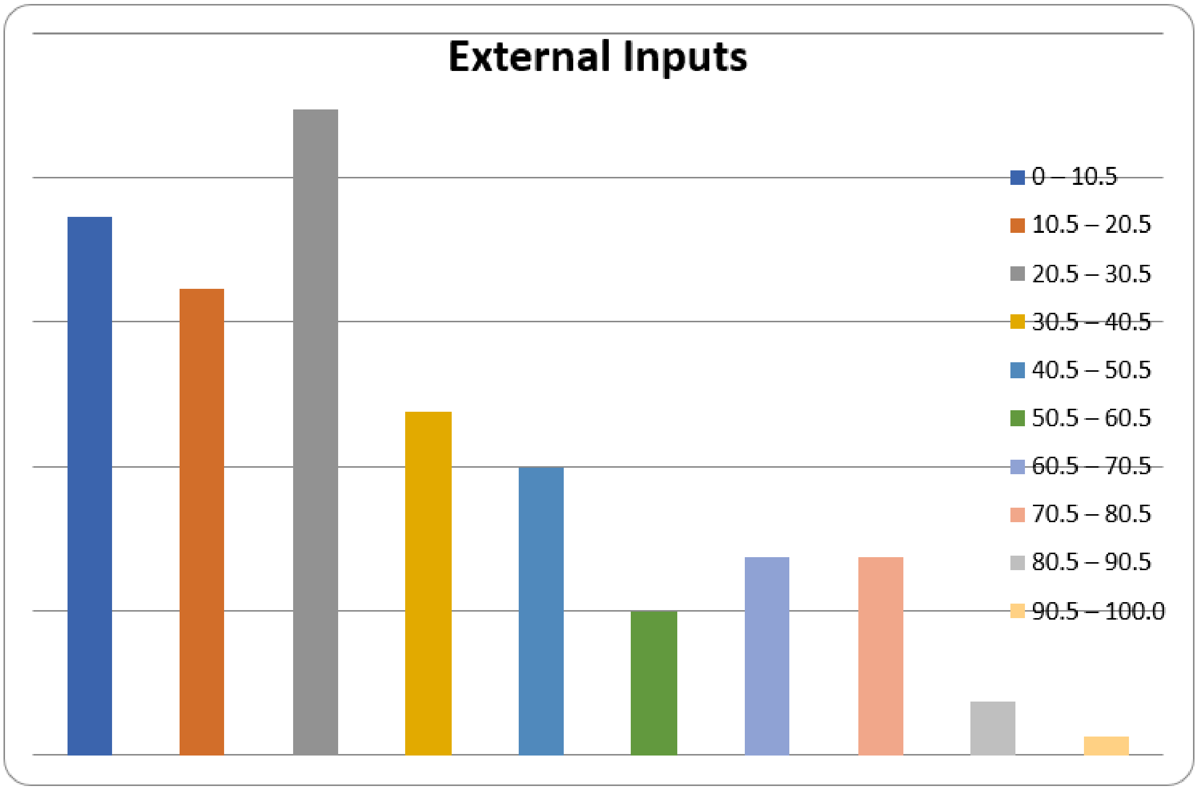

Fig. 2: Levels of technical efficiency in external input use

The technical efficiency of external farm inputs for farmers in cassava production ranges from 0.0623 to 63.23 (6.23 to 63.62 per cent), with 6.23 per cent of the farmers having the least. Such farmers can attain maximum technical efficiency with careful management in saving some external devices in the production. To attain maximum technical efficiency, cost savings of about {1 - (0.0623/0.6362)}, which is 0.9638 (96.38 per cent) of their external inputs, device to become the highest technically efficient farmers. In the same way, those farmers with mean technical inefficiency can attain highest technical efficiency by saving the waste of external farm inputs in cassava production by reducing external inputs device {1 - (0.31275/0.6362)}, which is about 0.5085 (51 percent) cost saving to become the most technically efficient cassava farmers in the use of external inputs.

CONCLUSION

This study has provided valuable insights into the production risk and technical efficiency of cassava farmers in Bayelsa State, Nigeria, focusing on those using internal and external inputs. The socio-economic analysis revealed key differences between the two groups. Internal input users tended to be older and more experienced in farming, while external input users were generally

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more educated and operated on larger farms. Despite these differences, both groups showed similar household sizes and income levels per hectare.

The technical efficiency analysis indicated that both internal and external input users were technically inefficient, but with distinct patterns. Internal input users exhibited decreasing returns to scale, while external input users experienced increasing returns to scale. These findings suggest that while external input use could lead to greater scale advantages, both groups face substantial inefficiencies that need addressing to enhance agricultural productivity.

Generally, the study underscores the importance of both socio-economic factors and input choices in determining cassava farming outcomes. By focusing on improving technical efficiency and addressing the unique risks faced by each group, targeted policies can help boost productivity and resilience among cassava farmers in Bayelsa State.

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