Journal of Agricultural, Food Science & Biotechnology

JAFSB, 4(1), 67-79, 2026
https://doi.org/10.58985/jafsb.2026.v04i01.93
ISSN (Print): 2959-3417

Research Article

Comparative and competitive advantage of cooperative cassava farmers under the Anambra state VCDP: Evidence from a policy analysis matrix

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Article Information
Received: *10 February 2026*
Revised: *17 March 2026*
Accepted: *17 March 2026*
Published: *14 April 2026*

Academic Editor
Prof. Dr. Gian Carlo Tenore

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Keywords
Comparative advantage, market share, off-takers arrangement, Anambra State, Nigeria.

Abstract

Previous studies available in the Value Chain Development Programme (VCDP) paid limited attention to the policy distortions and incentive structures that shape production efficiency and competitiveness. While the competitive dimension has often been discussed qualitatively, this study applies the Policy Analysis Matrix (PAM) to examine the policy environment influencing cassava production among farmers participating in the Anambra State VCDP). Data were obtained through random sampling of 380 cassava farmers, of which 350 responses were considered usable after data cleaning. The Policy Analysis Matrix and Heckman double-hurdle model were employed for the analysis. The PAM estimated key indicators, including the Domestic Resource Cost (DRC), Private Cost Ratio (PCR), Effective Protection Coefficient (EPC), Nominal Protection Coefficients (NPC), and profitability measures. The Heckman model examined the factors influencing farmers' participation in off-taker market arrangements and the determinants of competitiveness. The results revealed strong evidence of both comparative and competitive advantages among program beneficiaries. The DRC (0.057) and PCR (0.018) indicate that cassava production is socially efficient and privately competitive. The NPC on output (1.101) and input (0.500) suggests that farmers benefit from favourable output prices and subsidised inputs. Similarly, the EPC (1.125) and profitability coefficient above unity confirmed that policy support enhances value addition and private profitability. The Heckman results showed that socioeconomic variables significantly influenced participation in off-taker market arrangements. The study concludes that the VCDP has strengthened farmers' efficiency, in market participation. Sustained and well-targeted policy support combined with productivity and market improvements is therefore recommended to maintain these gains in the Anambra State.

1. Introduction

Nigeria is widely recognized as one of the world's largest producers of cassava, producing tens of millions of tons annually. However, average yields remain low relative to their global potential due to structural inefficiencies in production and value chains [1-3]. Elaboratively, Esiobu et al. [4] reported that, as of December 2024, global cassava output stood at 303.57 million metric tonnes (MMT), with Africa contributing 57% (173 MMT) of the total production. Nigeria alone contributed 20% (60.0 MMT) of the global output, representing about 35% of Africa's production. Corroboratively, Omoluabi and Ibitoye [5] employed the autoregressive distributed lag (ARDL) technique to project Nigeria's cassava output at 68.09 million tonnes, positioning the country as the world's largest producer of cassava and a major contributor to the global food economy. Although Esiobu et al. [4] noted that Nigeria requires about 88.3 MMT to achieve self-sufficiency, and a 32% gap still exists, indicating a shortfall in social production efficiency that farmers can exploit to maximize private profit.

Prior to formal intervention under the Value Chain Development Programme (VCDP), average national yields hovered around 10 tons per hectare, reflecting a chronic productivity constraint among smallholder farmers. The VCDP, supported by a loan from the International Fund for Agricultural Development (IFAD) to the Federal Government of Nigeria, was designed to tackle these structural weaknesses by integrating producers into consolidated value chains with improved access to inputs, extension services, and market linkages [6-8].

The Value Chain Development Programme became loan effective from 2014 and operational effective from 2015 in six states which include Anambra, Benue, Ebonyi, Ogun, Niger, and Taraba States. The VCDP was conceived to enhance the productivity, competitiveness, and market access for rice and cassava smallholder farmers. It combines input and equipment subsidies or support with extension advisory services, enterprise development, and structured off-taker arrangements to reduce market inefficiencies and strengthen farmer organizations [6-8]. Studies from Nigeria indicate that such interventions can positively influence both output and economic outcomes among participants; for example, the VCDP has been shown to contribute to agricultural enterprise growth in Anambra State through improved operations, even though the effects of marketing support remain statistically muted [8-9].

The concept of comparative and competitive advantage within agricultural value chains is rooted in economic theory but is applied pragmatically in development programmes. Comparative advantage refers to the ability of farmers or countries to produce a good at a lower opportunity cost than others, while competitive advantage emphasized market positioning and the ability to gain and sustain market share relative to competitors [10]. In the context of smallholder cassava farmers in the VCDP, comparative advantage may be understood in terms of subsidized access to inputs and equipment, improved technical knowledge, and assured market mechanisms that reduce transaction costs and exposure to market volatility. Competitive advantage emerged when farmers were able to access structured markets through formalized Memoranda of Understanding (MoU) with processors and buyers, to ensure that commodities are sold at farm-gate prices and to reduce the need for costly logistics [11].

Several studies have explored the impact of the Value Chain Development Programme (VCDP) in Nigeria [8, 11-14], primarily focusing on comparing the profits of beneficiaries and non-beneficiaries of the programme. Comparative analyses conducted in states like Benue and Kogi have shown that VCDP participation is often linked to higher net returns for participants. However, these studies have not thoroughly examined the policy mechanisms underlying these outcomes [11]. Notably, none of the studies employed the Policy Analysis Matrix (PAM) to assess the net policy transfer of the program intervention. This research, therefore, represents the first to adopt the PAM framework, as proposed by Monke and Pearson [15] and used to analyze the comparative and competitive advantages of cassava production in Anambra State [10, 16-18].

Several empirical studies have addressed the comparative and competitive advantages of different staple crops, with a focussing on global evidence. However, the impact of the Value Chain Development Programme (VCDP) intervention on beneficiaries has not been analyzed using the policy analysis matrix (PAM) proposed by Monke and Pearson [15]. While empirical evidence on the comparative advantage of cassava production using formal efficiency and policy distortion frameworks is limited in Nigeria. Important work in related contexts has provided valuable insights. Junnia et al. [16] examined the comparative and competitive advantages of cassava farming in

https://doi.org/10.58985/jafsb.2026.v04i01.93

Simalungun Regency, North Sumatera Province. This study utilized the Matrix Policy Analysis Method (PAM) to assess both the comparative and competitive advantages of cassava farming. The study found that cassava farming demonstrated significant economic benefits, as indicated by a Domestic Resource Cost (DRC) ratio of 0.259 and a Protection Coefficient Ratio (PCR) of 0.66. These ratios are below the threshold of 1, which is a key indicator that cassava farming has both comparative and competitive advantages. The DRC value of 0.259 suggests that cassava is produced efficiently using domestic resources, with lower costs compared to the social opportunity cost. The PCR value of 0.66 further underscores the competitive advantage, showing that cassava farming can be more profitable than relying on imports. The study relied mainly on production efficiency and did not consider how organized agricultural interventions or institutional arrangements influence competitiveness. This limitation highlights the need to examine cassava production within structured development program like VCDP.

Zukifli et al. [17] analyzed the impact of input and output subsidies on the competitiveness of paddy rice farming in Gorontalo Province, Indonesia, focusing on both comparative and competitive advantages using the PAM tool. The study assessed key competitiveness parameters: The Domestic Resource Cost Ratio (DRCR) and Private Cost Ratio (PCR) for comparative and competitive advantages, respectively. Additionally, the study measured protection coefficients, such as the Nominal Protection Coefficient for Output (NPCO), Nominal Protection Coefficient for Input (NPCI), and Effective Protection Coefficient (EPC). The Producer Subsidy Equivalent (PSE) and Consumer Subsidy Equivalent (CSE) were also used to analyze the relative incentives for producers and consumers. The results showed that government subsidies significantly impacted paddy rice production in Gorontalo. The NPCO was 1.35, indicating substantial government protection for rice output, and the NPCI was 0.42, indicating subsidies for tradable inputs. The EPC value of 1.51 confirms the effectiveness of government protection. However, the PCR (1.14) and DRCR (1.52) values, both above 1, indicate that paddy rice farming in the region does not possess a comparative advantage in the global context. The study applied a similar analytical framework to investigate how the policy incentives rolled out in the VCDP influenced the comparative and competitive advantages of cassava farmers in the state.

In another study, Putri et al. [18] studied Indonesia's natural rubber industry, focusing on factors influencing export prices and the competitiveness of rubber exports. Using time-series data from 1995 to 2017, they found that international rubber prices, exchange rates, and domestic consumption significantly impact export prices. Competitiveness was assessed using the Revealed Comparative Advantage (RCA) and Trade Specialization Index (TSI). The RCA value of 1.01 indicates a comparative advantage, while the TSI value of 0.98 suggests that the industry is competitive but may face challenges in further strengthening its market position. These trade-based indicators are useful for analyzing export competitiveness, but they do not capture farm-level production efficiency or the effects of domestic agricultural policies. However, this study employed the PAM model, which allowed for a more comprehensive analysis of both private profitability and social efficiency at the farm level.

In Benue State, Nigeria, Onyemma et al. [19] explored the determinants of adopting improved cassava technologies. They found that awareness and adoption levels of improved varieties significantly influenced farmers' productivity outcomes. This indirectly relates to comparative advantage, as the adoption of improved technologies tends to lower production costs and enhance returns, ultimately contributing to more efficient resource use. Although this study did not explicitly use the PAM framework, it highlighted the importance of innovations, access to inputs, education, and extension services as drivers of comparative cost efficiency.

The study of Bosompem et al. [20] on smallholder farmers' participation in cassava value addition practices in Ghana, used a survey method and found that farm size plays a crucial role in shaping farmers' ability to adopt improved farming practices. Larger farms allow farmers to utilize modern technologies, resulting in improved productivity and, subsequently, a competitive market advantage. Adah et al. [20]

https://doi.org/10.58985/jafsb.2026.v04i01.93

analysed the adoption of improved production technologies among cassava contract and non-contract farmers in Kogi State, Nigeria, used ordered logit model to operationalize the study. They found that participation in contract farming, household size, education, and awareness of contract farming significantly influenced the likelihood of adopting improved cassava production technologies in their study area. However, they did not explicitly examine the comparative and competitive advantages of cassava production within a policy distortion framework.

The input and equipment support provided to farmers in the VCDP presents a valuable opportunity to assess the effectiveness of the policy in terms of both private and social revenues, as well as other PAM indicators such as the Domestic Resource Cost (DRC), Nominal Protection Coefficient for Output (NPCO), Nominal Protection Coefficient for Input (NPCI), and Effective Protection Coefficient (EPC). This approach clearly reveals any divergences in policy transfer, offering insights that enable fund donors to better understand the impact of their investments on the smallholder farmers participating in the program. This study distinguishes itself from previous research [16-18] by being the first to apply a double hurdle regression analysis to investigate the actual determinants of competitive advantage.

The initial step of this analysis involved understanding the extent of farmers' participation in market linkages, which allowed for a detailed examination of competitive market shares as an outcome variable. On this background this study specifically set out to: (1) Assess the comparative advantage of cassava farmers in Anambra State by evaluating their domestic revenue cost, nominal protection coefficient on input and output, effective protection coefficient and profitability coefficient relative to other regions in Nigeria, (2) analyze the competitive advantages of cassava farmers in Anambra State VCDP in terms of market share and (3) determinants of the competitive advantages of cassava farmers with respect to market access, technology adoption, and organizational structures within the Value Chain were ascertained.

2. Materials and methods

2.1. Study area

The study was conducted in eight Local Government Areas (LGAs) of Anambra State, Nigeria, where the Additional Financing phase of the VCDP was implemented. These include Anambra East, Anambra West, Ayamelum, Awka North, Ogbaru, Ihiala, Orumba North, and Orumba South [22]. The VCDP selected these 8 LGAs out of the 21 LGAs in the State based on their comparative advantages in rice and cassava production and processing, which are the mandated crops of the Programme [23]. Anambra State is located in southeastern Nigeria. It covers a land area of approximately 4,800–4,900 km² and lies between latitudes 5°40′ to 6°47′ N and longitudes 6°36′E to 7°21′E ° (NPC, n.d). The State benefits from major water bodies, such as the Niger and Anambra (Omambala) Rivers and a tropical wet–dry climate that supports year-round farming [24-25].

All cassava farmers participating in the Anambra State Value Chain Development Programme comprised the population of the study. The sample frame for the study was the 5872 cassava farmers reported by the Programme Monitoring and Evaluation Officer (PMEO) in 2025. A multi-stage sampling technique was adopted to select the study representatives. Due to the finite nature of the sample frame, the Taro Yamane (1987) sample size determination technique was adopted to arrive at a sample size of 381.

$$n = \frac{N}{1 + N(e)^2}$$

$$n = \frac{5872}{1 + 7872(0.05)^2} \cong 374$$

Where, n = sample size, N = population of cassava farmers, and e = error margin.

At stage one: 4 local government areas (LGAs: Ogbaru, Ihiala. Anambra and Orumba North) were purposively selected from the 8 implementation LGAs; being the most dominant cassava producing LGAs in the program. In stage two, 3 communities were randomly selected from each LGA to make the total number of communities 12. Later on, 4 cassava clusters/villages were randomly selected from each community to make a total of 48 clusters for the study. Lastly, 8 cassava farmers were randomly sampled

https://doi.org/10.58985/jafsb.2026.v04i01.93

Table 1. 3 by 4 policy analysis matrix (PAM).

PAM	Revenue	Tradable input cost	Domestic factor	Profit
Private Price	A	B	C	D
Social Price	E	F	G	H
Divergence	I (A-E)	J (B-F)	K (C-G)	L (D-H)

from 46 (forty-six) clusters and 3 from each of the remaining 2 clusters to bring the sample size to three hundred and seventy-four (374) farmers. Finally, after data treatment (sorting and filtering), only 350 (93.6%) were found to be valid for further analysis.

2.2. Data collection

A structured questionnaire was used for data collection. Primary and secondary data were used for the analyses. Six (6) trained enumerators were recruited to assist with data collection. They administered the structured questionnaire using mobile devices equipped with Kobo Collect for 2 months (from May 6 to July 11, 2025). The digital format ensured real-time data entry, reduced errors and improved efficiency [26]. The enumerators conducted the survey in the participants' preferred language to ensure clarity and full participation.

2.3. Data analysis

This study used a combination of analytical techniques including simple descriptive statistics (minimum, maximum, mean, and standard deviation), policy analysis matrix (PAM), and Heckman double hurdles regression analysis. Objectives I and II were achieved using PAM indicators, and objective III was achieved using double hurdle regression analysis. All analyses were performed using Excel and the most recent version of R software (updated January 2026).

2.4. Model specification

A). Table 1 shows the 3 by 4 policy analysis matrix (PAM) variables developed by Monke and Pearson [15]. The comparative and competitive indicators were operationalized from the matrix:

The policy indicators calculated from the PAM Table include:

a. Domestic Resource Cost: $DRC = \frac{G}{(E-F)}$

Where DRC < 1: Comparative advantage exists, DRC > 1: no comparative advantage.

b. Nominal Protection Coefficient on output:

$$NPCO = \frac{A}{E}$$

Where NPCO > 1: farmers receive price support/output is protected, NPCO < 1: output is taxed or discouraged.

c. Nominal Protection Coefficient on input: $NPCI = \frac{B}{F}$

Where NPCI < 1: Inputs are subsidized, NPCI > 1: inputs are taxed.

d. Effective Protection Coefficient: $EPC = \frac{(A-B)}{(E-F)}$

Where EPC > 1: Value added is protected, EPC < 1: value added is discouraged.

e. Profitability Coefficient: $PC = \frac{D}{H}$

Where PC > 1: overall policy effect on profitable.

f. Private Cost Ratio: $PCR = \frac{(B-C)}{(A-C)}$

Where: PCR < 1: Competitive advantage exists, PCR > 1: competitive advantage does not exist.

B). The Heckman double hurdle regression model used to achieve the objective was defined as:

1) Selection equation (participation, Probit), taking off-taker access as the selection indicator.

$$M^*_i = \alpha_0 + \alpha_1 X_{1i} + \alpha_2 X_{2i} + \alpha_3 X_{3i} + \cdots \alpha_5 X_{5i} + \mu_i$$

$$M_i = \begin{cases} 1 \ if \ M^*_i > 0 \\ 0 \ if \ M^*_i \le 0 \end{cases}$$

Where $M_i = 1$ means farmers *i* have active access to off-taker arrangement, and 0 otherwise, X_1 = sex (dummy: 1 = male, 0 = female), X_2 = age (year), X_3 = farm size (hectare), X_4 = farming experience (years), X_5 = level of education (years spent in school), and $\mu_i \sim N(0,1)$.

2) Outcome equation (competitive advantage, observed only if M_i =1)

$$PCR_i = \beta_0 + \beta X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \cdots \beta_{11} X_{11i} + \delta M_i + \varepsilon_i$$

Where PCR_i denotes the private cost ratio for *ith* farmer, X_6 = *PR* (private revenue in Naira [₦]), X_7 = *TPC* (total private cost in Naira), X_8 = *SR* (social revenue in Naira), X_9 = *TSC* (total social cost in Naira), X_{10} = *DRC* (domestic resource cost), X_{11} = *PC*

https://doi.org/10.58985/jafsb.2026.v04i01.93

Table 2. Variable description.

Variables	Min	Max	Mean	Std. dev.
Off-taker working	0	1	0.64	0.48
Age	18	64	41.2	13.42
Gender	0	1	0.49	0.5
Farm Size	0.34	5	**2.48**	1.57
Experience	1	20	9.86	5.92
Education	0	21	10.28	6.27
Annual Yield (Tonnes per Ha)	5	35	19.23	10.11
Price per Kg (₦)	40	200	105.71	54.11
Annual Revenue (₦)	150000	30000000	5027910	5775501.29
Organic Fertilizers Cost (₦)	2039.52	9995.31	6055.05	2292.51
Inorganic Fertilizers Cost (₦)	5048.27	19975.21	12346.2	4350.58
Chemicals Cost (₦)	3018.78	14945.25	9011.59	3406.76
Stem Bundles Cost (₦)	5002.02	19967.31	12443.54	4368.24
Land Preparation Cost (₦)	10000.47	49792.77	30381.89	11788.82
Land Rent Cost (₦)	5049.8	29972.32	17445.28	7057.65
Labor Cost (₦)	10019.6	39986.73	24715.28	8725.44
Capital Investment (₦)	20002.46	99406.54	58937.57	23020.85
Transport/ton (₦)	5000	14900	9965.43	3011.45

Source: Field Survey, 2025.

(profitability coefficient), ϵ_i is the error term assumed to be uncorrelated with x_i, M_i, and δ captures the effect of selection bias.

2.5. Brief description of Table 2

Table 2 summarized the key variables used in the Policy Analysis Matrix, taken from field data that were carefully sorted and screened before the analysis. The data were presented to clearly reveal the spread of central tendency and measure of dispersion, or to judge how diverse the sampled farmers were. This descriptive step was important because it provided a clear statistical picture of the production and marketing environment for VCDP farmers, in which the PAM results were later interpreted. The table equally showed a heterogeneous group of cassava farmers in terms of resources, costs, and returns. This variation is useful for PAM analysis because it allows the estimation of comparative and competitive advantages under realistic, diverse farm conditions rather than a narrow or uniform sample.

The off-taker variable is binary, and the mean of 0.64 indicates that about 64% of the sampled farmers had a working relationship with an off-taker. The average farmer was about 41 years old, with a fairly wide age range from 18 to 64 years, suggesting participation by both younger and older producers. Gender was almost evenly distributed, with a mean close to 0.5, indicating a near balance between male and female farmers. Farm size averaged 2.48 hectares, although holdings varied from very small plots to as much as 5 hectares, pointing to a mix of small and medium-scale operations. Farmers had roughly 10 years of experience, and about 10 years of schooling, which implied moderate human capital for adopting improved practices. On the production side, the mean yield stood at 19.23 tonnes per hectare, but the large standard deviation showed substantial variability in performance. This average yield outperformed the 20,600 kg produced on 1.8 ha reported by Esiobu et al. (2026), which corresponds to a yield of 11.4 t/h. This result indicates differences in both social efficiency and private profit, likely attributable to the effects of the VCDP intervention. Output prices also varied widely, reflecting the market fluctuations. Revenue and cost variables, including fertilizers, chemicals, labour, land, and capital, showed broad ranges, which is typical in farm level data, where input use intensity and scale differ across households. Transport costs per tonne also varied, indicating differences in distance to markets and logistics conditions.

https://doi.org/10.58985/jafsb.2026.v04i01.93

Table 3. Assessment of the comparative advantage of the farmers (n = 350).

Indicators	Score	Decision	Remarks
Domestic Resource Cost	0.057	DRC < 1: Comparative advantage exists	Yes
Nominal Protection Coefficient on output	1.101	NPCO > 1: farmers receive price support	Yes
Nominal Protection Coefficient on input	0.500	NPCI < 1: Inputs are subsidized	Yes
Profitability Coefficient	1.151	PC > 1: Overall policy effect is profitable	Yes

Source: Field Survey, 2025.

3. Results and discussion

3.1. Comparative advantage of cassava farmers

Table 3 presents the Policy Analysis Matrix indicators used to investigate whether cassava farmers in the Anambra State VCDP were efficient from both private and social perspectives. Taken together, the Domestic Resource Cost, nominal protection coefficients, and profitability coefficient *provide a structured way to understand how farmers perform under current policy support and market* realities. These indicators moved the discussion beyond simple profit comparison, allowing for a deeper look at real economic efficiency, which is consistent with the purpose of PAM in agricultural policy studies [10,15].

The Domestic Resource Cost (DRC) of 0.057 was far below unity and points to a very strong comparative advantage among the cassava farmers. In practical terms, the value of domestic resources used in cassava production was much lower than the value added at the social prices. This means that cassava production in the Anambra State VCDP uses local resources efficiently and generates value for the wider economy. Similar low DRC values have been interpreted as evidence of a strong comparative advantage in cassava systems in Indonesia and other developing economies [10,16]. At the same time, some studies on staple crop systems have reported DRC values closer to or above one, suggesting a weaker comparative advantage where production conditions or policy support are less favourable [17]. In that sense, the results from Anambra signalled a particularly favourable production environment for cassava under the VCDP programme.

The Nominal Protection Coefficient on output (NPCO) of 1.101 revealed that farmers receive output prices slightly above social prices. This suggests mild protection or favourable marketing conditions that allow producers to capture better prices. This could be attributed to the off-taker market arrangements that save farmers the logistics cost of conveying their produce to unstructured or open markets for stronger competition. Earlier studies by Okonkwo et al. [8]., and Odekina et al. [11] on value chain interventions in Nigeria also showed that organized market linkages and off-taker arrangements can stabilize prices and improve farmer earnings. The PAM study by Zulkifli et al. [17]. on rice paddy recorded much higher NPCO values (1.35), reflecting stronger price distortion. The level observed in this study (NPCO = 1.101) appeared moderate and suggested support without any excessive distortion.

The Nominal Protection Coefficient on an input of 0.500 clearly reflected subsidized input costs. Farmers effectively paid about half of the social cost of tradable inputs, lowering production costs and strengthening private returns. This result is in line with the documented subsidy (50%) and machinery (30%) support under the VCDP. This study corroborated the assertion by Zulkifli et al. [17] and Adah et al. [21]. who noted that input subsidies in smallholder agriculture often reduce input costs, improve short-term profitability and encourage technology use. Although, Saptana et al. [10]. cautioned that heavy subsidies can become fiscally difficult to sustain over time or may distort input markets if not well targeted, the subsidy appeared to play a supportive role in improving competitiveness among VCDP farmers.

The Profitability Coefficient of 1.151 indicates that private profits exceeded social profits under the present policy setting. Farmers were therefore gaining from the policy environment, and the incentives created by the program—encouraged continuous cassava cultivation. Similar patterns, where policy support raised private profitability above social profitability, have been observed in other PAM-based studies of staple crops [10, 16]. Simultaneously, the

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Table 4. Competitive advantages of cassava farmers in Anambra State VCDP (n = 350).

PAM	Revenue	Tradable input cost	Domestic factor	Profit
Private Price	5,027,910.00	87,593.10	174,187.55	4,766,129.35
Social Price	4,565,933.60	175,186.20	248,839.36	4,141,908.04
Divergence	461,976.40	-87,593.10	-74,651.81	624,221.31
	Indicators	Score		Decision
	Effective Protection	1.125		added is protected
	Coefficient	0.018		PCR < 1: Competitive
Competitive advantage	Private Cost Ratio		EPC > 1: Value	advantage exists

Source: Field Survey, 2025.

gap between private and social profitability reminds policymakers that part of the farmers' gains is linked to policy support rather than pure market competitiveness. This reinforces the importance of designing support measures that build long-term efficiency, not just short-term profit.

However, these results revealed that cassava production among VCDP beneficiaries was not only privately profitable but also socially efficient. The study suggested that VCDP activities add value to the economy and support food security and agro-industrial development. Subsidy and support mechanisms have played a meaningful role in lowering production costs and stabilizing farmer incomes *[10]*. In summary the findings present a positive case for the careful expansion and scale-up of the program to sustain agricultural development in Anambra State.

3.2. Competitive advantages of cassava farmers in anambra state VCDP

Table 4 presents a clearer picture of the competitive position of VCDP cassava farmers by comparing outcomes at private prices, to showcase actual market realities based on the program's off-takers arrangement, and social prices, which approximate undistorted economic values. This comparison was recognized by Monke and Pearson [15] and Saptana et al. [10] in PAM studies as a practical way to separate true economic efficiency from policy-driven gains. At private prices, farmers realized higher revenue (₦5,027,910.00) and profit (₦4,766,129.35) compared to social prices. Private revenue stood above social revenue, and private profit also exceeded social profit to highlight a net policy transfer value of ₦624,221.31. This finding implies that the present policy and market environment permits farmers to earn more than they would under purely efficiency-based prices. Junnia et al. [16]. and Saptana et al. [10] uncovered similar patterns for cassava and other staple crop systems, where private outcomes outperformed social ones, under supportive policy regimes. This finding does not align with Zulkifli et al. [17], who observed a case in rice production where policy distortions did not translate into strong competitiveness. They opined that support alone does not always guarantee superior performance. In the Anambra State VCDP, evidence from the study revealed that farmers not only covered their costs but also generated meaningful margins that supported farm sustainability and improved household welfare.

The divergence values further elucidated this pattern. The positive revenue divergence (₦461,976.40) suggests that farmers received output price support above the social reference levels. This positive effect was linked to favourable local demand, program supported by market access or off-taker market arrangements, and price incentives. However, Okonkwo et al. [8]. and Odekina et al. [11] studied the value chain interventions in Nigeria noted that organized marketing and off-taker arrangements can improve farm gate prices and income stability of smallholder farmers. The negative divergences for tradable input costs (-87,593.10) and domestic factor costs (-74,651.81) revealed that farmers paid less than the social value of these resources. These results justified the 50% input support and 30% equipment support farmers received in the program. The results are in agreement with Zulkifli et al. [17] and Adah et al. [21], who reported that input support lowers private production costs and strengthens farm-level

https://doi.org/10.58985/jafsb.2026.v04i01.93

competitiveness. Though, Saptana et al. [10] suggest caution, noting that long-term dependence on subsidies can reduce pressure for efficiency if not paired with productivity growth.

The Effective Protection Coefficient (EPC) of 1.125 confirmed that value added is protected. Farmers' value-added at private prices was 12.5% higher than it would be under social prices. This is aligned with previous findings from other PAM-based studies, where EPC values above unity reflect positive protection for producers [10, 16]. In another study, Zulkifli et al. [17] observed situations where protection did not necessarily coincide with comparative advantage, as we had in this study. This should remind us that protection and efficiency are not identical to each other. Also, the Private Cost Ratio (PCR) of 0.018 was very low and well below unity, which implied a strong competitive advantage. This shows that the cost of domestic resources used in production was extremely small relative to the value added at private prices. The PCR values in this study were much lower than the 0.66 reported by Junnia et al. [16], which they interpreted as evidence of strong competitiveness in smallholder systems that benefited from technology and institutional support.

Evidently, farmers clearly responded to support and operated competitively. Expanding and extending the program beyond 2026 could help consolidate these gains, especially where the emphasis shifts towards productivity growth, value addition, and stronger market integration rather than relying on permanent subsidies alone. Furthermore, the results revealed that VCDP cassava farmers in Anambra State were competitive, profitable, and operated in a protected yet productive environment. This finding is consistent with the reported data [8, 10, 15] where noted that well- designed value chain interventions can raise smallholder competitiveness. The authors also recommend that policymakers should balance support with long-term efficiency goals.

3.3. Determinants of competitive advantages of cassava farmers

Table 5 shows the Heckman double hurdle regression analysis used to investigate the determinants of competitive advantage in the Anambra State VCDP. The model distinguishes between two related decisions. The first hurdle explained the likelihood of farmers participating in the program's off-takers arrangement, where producers are linked to processors to off take their produce at the prevailing farm gate price, often guided by a Memorandum of Understanding (MoU). The second hurdle explained the level of competitive advantage among those who actively participated in off-taker arrangements. This approach recognized that the decision to participate and the level of competitiveness are influenced by different factors, a logic consistent with the original justification for double hurdle and sample selection models in agricultural household studies [27-28].

The participation or selection equation revealed that the coefficient on sex ($\beta = 0.354$, $t = 1.86^*$) was positive and significant at the 10% level of probability. This implies that male cassava farmers participate more actively in the program's selling policy of off-taker arrangements than their female counterparts. This pattern is often reported in smallholder commercialization studies, where men tend to have stronger control over land, marketing decisions, and contracts [12]. Although women now have equal access to resources and organized groups, market participation gaps have narrowed, suggesting that this change may reflect structural constraints rather than ability [29]. Age also showed a positive and marginally significant effect ($\beta = 0.013$, $t = 1.94^{**}$), suggesting that older farmers are slightly more inclined to participate in marketing arrangements. This may be linked to stronger networks, accumulated trust, and stable farming conditions. This finding is in agreement with the reported data [11, 23, 30], where positive effects of age on market participation, as documented in contract farming and value chain studies in Nigeria. Farm size was positive and significant ($\beta = 0.144$, $t = 2.29^{**}$) at the 5% level, implying that farmers with larger farm holdings were more likely to engage in VCDP off-taker contracts, because they can meet volume requirements and supply consistency. This finding is consistent with observations made by Tale et al. [12] and Bosompem et al. [20] that farm size improves participation in structural market and value addition schemes.

The outcome equation explains the determinants of competitive advantage among participating farmers.

https://doi.org/10.58985/jafsb.2026.v04i01.93

Table 5. Determinants of competitive advantage of cassava farmers in VCDP.

Selection equation	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	0.301	0.377	0.80	0.425
Sex	0.354	0.191	1.86*	0.064
Age	0.013	0.007	1.94**	0.053
Farm size	0.144	0.063	2.29**	0.022
Farming experience	-0.014	0.016	-0.89	0.373
Level of education	0.008	0.015	0.51	0.611
Outcome equation	**Estimate**	**Std. Error**	**t value**	**Pr(>|t|)**
Intercept	0.908	0.210	4.33	0.000
Sex	-0.009	0.010	-0.96	0.338
Age	-0.001	0.000	-1.48	0.139
Farm size	-0.006	0.004	-1.53	0.126
Farming experience	0.000	0.001	0.39	0.693
Level of education	0.000	0.000	-0.52	0.602
Access to GAP	-0.005	0.003	-1.75*	0.082
Total private cost	0.551	0.059	9.37***	0.000
Total social cost	-0.549	0.061	-9.06***	0.000
private revenue	0.667	0.253	2.64**	0.009
Social revenue	-0.668	0.252	-2.65**	0.008
Domestic Resource Cost	0.285	0.009	31.97***	0.000
Profitability coefficient	-0.599	0.202	-2.97***	0.003
Error terms:	**Estimate**	**Std. Error**	**t value**	**Pr(>|t|)**
Inverse of Mills Ratio	-0.092	0.075	-1.23	0.221
Sigma	0.054			
Rho	-1.708			

Source: Field Survey, 2025. Sign. at 10% (*), 5% (**), and 1% (***) level of probability.

The intercept was positive and highly significant, confirming the existence of competition among the sampled farmers. The absence of significant socioeconomic variables (sex, farm size, age, education and farming experience) at this stage, suggests that once farmers are integrated into structured markets, individual characteristics become less important. These findings are consistent with Abdulai and Huffman [28], which market institutions and price incentive levels differ among farmers. However, access to GAP had a negative coefficient (β = -0.005, t = -1.75*) and weak significance. This suggests short-term adjustment costs as farmers adopt improved practices, since they initially face higher labour or input demands before yields respond. This is consistent with the previous reports [21, 31] which similar transitional effects occurred during the technology adoption.

Total private cost showed a strong positive and highly significant effect (β = 0.551, t = 9.37***), while total social cost showed a strong negative and highly significant effect (β = -0.549, t = -9.06***), both at the 1% level of probability. These results confirm the PAM findings, where private profitability exceeded social profitability. This suggests that program support and market prices enhance measured competitiveness, while social prices reveal the underlying opportunity costs. This is comparable to the report of Monke and Pearson [15] and Saptana et al. [10] in their PAM-based competitive advantage interpretation. Private revenue had a positive and significant influence (β = 0.667, t = 2.64**), whereas social revenue had a negative and significant effect (β = -0.668, t = -2.65**) at the 5% level of probability. This again echoed the idea that favourable market conditions and program support shape farmers' private performance. Moreover, the DRC was positive and highly significant (β = 0.285, t = 31.97***), implying that resource use efficiency is key to competitiveness. This finding is consistent with the work of Monke and Pearson [15] and Junnia et al. [16] who treated the DRC as a core indicator of real economic strength. The

https://doi.org/10.58985/jafsb.2026.v04i01.93

profitability coefficient was negative and significant (β = -0.599, t = -2.97***) at the 1% level of probability. This negative observation could have resulted from the way competitiveness is specified in the model and the divergence between private and social profit. This finding is in line with Saptana et al. [10], who observed mixed signs in policy distortion analyses, where support alters the private social profit relationship. Finally, the inverse Mills ratio was not statistically significant, suggesting a minimal selection bias or not being a serious concern. This supports the reliability of the estimates, which is an important diagnostic result in Heckman models [27]. Thus, the findings echo a consistent message that competitive advantage among cassava farmers is shaped more by cost structures, revenues, and policy support than by personal characteristics.

4. Conclusions

This study set out to assess the comparative advantage of cassava farmers in Anambra State using the Policy Analysis Matrix indicators. The findings revealed a strong comparative advantage, as evidenced by a Domestic Resource Cost far below unity, favourable nominal protection coefficients, and a profitability coefficient above one. These indicators confirm that cassava production under the VCDP is both socially efficient and privately profitable. The results demonstrate that the VCDP in Anambra State created a supportive policy environment that enhanced resource use efficiency and value addition, implying that cassava production in the state contributed positively to the wider economy.

Equally, the study analyzed the competitive advantage of cassava farmers within the VCDP operations. The results showed that farmers operate competitively under prevailing market conditions, with private revenues and profits exceeding their social counterparts. The positive divergence values, effective protection coefficient above unity, and very low private cost ratio revealed that farmers benefited from favourable output prices, subsidized inputs, and structured market arrangements such as off-taker linkages, implying that VCDP has strengthened farmers' market position and improved their ability to compete within both local and organized markets.

Furthermore, the Heckman double hurdle model revealed that participation in off-taker arrangement was influenced by factors such as sex, age, and farm size. The level of competitiveness was mainly driven by cost structures, revenue factors, and policy incentives rather than individual characteristics. The insignificance of the inverse Mills ratio further confirms the robustness of the model. Finally, this study uncovered the role of institutional support, market access, and policy-driven incentives in shaping competitiveness, rather than mere socioeconomic attributes.

Therefore, this study recommends deepening the off-taker model and extending it to more farmers and locations in the state. Again, the VCDP should promote inclusive participation, especially for female farmers, as participation was higher among male farmers. There should be more support for women through credit access, training, and group marketing.

Disclaimer (artificial intelligence)

The author(s) have declared no competing interest. The study is not sponsored by and funding agency or institution. However, the findings from the study have not been subjected to third party view or dotted.

Authors' contributions

Conceptualization, O.J.N., O.A.C.; data curation, O.A.C., A.E.C.; formal analysis, O.A.C., U.V.U.; investigation, A.F.C., N.E.C., A.E.C.; methodology, N.C.C., O.A.C.; project administration, O.J.N., O.A.C.; resources, O.A.C.; software, O.A.C., A.F.C.; supervision, N.E.C.; validation, N.C.C., A.F.C., U.V.U.; visualization, O.A.C.; drafted the manuscript, O.A.C.

Acknowledgements

The author(s) wish to appreciate all the VCDP cassava farmers who made themselves available for the study. We appreciate the research assistants who helped with data collection.

Funding

This research received no external funding.

Availability of data and materials

All data will be made available on request according to the journal policy.

Conflicts of interest

The author(s) have declared no competing interest. The study is not sponsored by and funding agency or institution. However, the findings from the study have not been subjected to third party view or dotted.

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