

Research Article

The Impact of Contract Farming on Efficiency Among Soybean Producers in Northern Ghana: Evidence from an Endogenous Treatment Effect Model

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Abstract

This study investigates the association of contract farming (CF) with technical, allocative, and economic efficiencies among soybean farmers in Northern Ghana. The study employed multistage sampling techniques to collect data from 374 soybean farmers (200 contract farmers and 174 non-contract farmers) across three districts in the study area. The endogenous treatment effect regression model was used for the estimation to address potential self-selection bias in contract participation, using the maximum likelihood estimation method. A stochastic frontier analysis was first used to estimate efficiency scores, which were then used as dependent variables in the endogenous treatment effect model. Results demonstrate that contract farming has significant positive effects on all efficiency measures. Specifically, CF soybean farmers technical efficiency increases by 37%, allocative efficiency increases by 35%, and economic efficiency increases by 6%. The estimated correlation between treatment assignment errors and outcome errors are statistically significant, suggesting that farmers with above-average efficiency metrics are more likely to participate in CF arrangements. We conclude that CF is a pathway to enhance soybean productivity and efficiency. These findings provide valuable insights for policymakers and agricultural development practitioners seeking to improve efficiency in soybean production through institutional arrangements like CF, while accounting for the farmers' inner ability and behavioral factors in CF decision-making.

Keywords

Contract Farming, Technical Efficiency, Allocative Efficiency, Economic Efficiency, Endogenous Treatment Effects, Soybean Production

1. Introduction

Soybean (*Glycine max* (L.) Merrill) holds immense importance for agricultural development, food security, and

economic empowerment in the global south and West Africa [1, 2]. This significance stems from its multifaceted benefits

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across various aspects of the agricultural value chain and its potential to address key challenges faced by smallholder farmers. The crop is a critical crop for enhancing soil fertility through its remarkable ability to fix atmospheric nitrogen into the soil via a symbiotic relationship with *Bradyrhizobium* bacteria [3]. This biological nitrogen fixation (BNF) reduces the reliance on expensive inorganic nitrogen fertilizers, making it an economically viable option for resource-poor farmers in northern Ghana where soils are often nutrient-deficient [4]. By improving soil health, soybean cultivation not only benefits its own yield but also enhances the productivity of subsequent cereal crops in rotation, contributing to a more sustainable and resilient farming system.

Furthermore, soybeans are an asset for food and nutritional security. It is a highly nutritious legume, rich in protein, making it an affordable and accessible source of protein for human consumption, particularly for women and children who are often most vulnerable to malnutrition [5-7]. Beyond direct consumption, soybean is a vital component of animal feed, especially for the rapidly growing poultry and aquaculture industries in Ghana, indirectly contributing to the availability of animal protein. Initiatives like the inclusion of soybean in the Ghana School Feeding Program highlight its potential to improve child nutrition and encourage school attendance [6].

Also, the food crop offers significant economic benefits and poverty reduction potential for smallholder farmers in northern Ghana. It serves as a valuable cash crop, providing a reliable source of income due to its increasing demand in both local and industrial markets [8]. The burgeoning demand from the poultry, aquaculture, and agro-processing sectors creates a robust market for soybeans. This allows farmers to earn higher incomes and improve their livelihoods. Projects like the Sustainable Soybean Production in Northern Ghana have demonstrated how investments in improved seeds, mechanization, and value chain development can lead to increased yields and expanded cultivation areas, directly boosting farmers' net annual income [9, 10].

Notwithstanding, the soybean has increasingly been recognized as a climate-smart crop for northern Ghana [11]. Its relative drought tolerance compared to other staple crops makes it a suitable choice for a region experiencing erratic rainfall patterns and increased temperatures due to climate change [3, 12]. Furthermore, by improving soil fertility and reducing the need for synthetic fertilizers (whose production is energy-intensive), soybean cultivation contributes to lower greenhouse gas emissions, aligning with climate change mitigation efforts. Investing in and promoting soybean production. This, therefore, offers a viable pathway to build resilience, ensure food security, and drive economic development in northern Ghana's climate-vulnerable agricultural landscape [13, 14].

Despite soybean significance to sustainable socioeconomic development, the crop productivity remains relatively low, hindered by various challenges faced by smallholder farmers,

including limited access to improved inputs, credit constraints, inefficient resource allocation, and lack of technical knowledge [15-17]. Addressing these challenges is crucial to realize the full potential of soybean production and its contribution to agricultural development and poverty reduction in Ghana. One potential strategy that has emerged is contract farming (CF), an institutional arrangement involving formal agreements between farmers and contracting firms [18, 19]. Under this model, the contracting agent(s) provides farmers with inputs, credit, extension services, and a guaranteed market, while farmers commit to producing a specific commodity under specified conditions [20, 21]. These input services are always promoted as a package by CF agents to promote effective delivery service and enhance farm productivity. Based on this, the CF has been widely adopted in various agricultural systems and has shown potential to improve productivity, efficiency, and farmers' incomes [22, 21]. However, the question which development economists keep on debating is that, do CF effectively promote farm productivity through enhancing farmers technical, economic, and allocative efficiency? This study sought to contribute to CF and agricultural development debate by investigating the effect of CF on soybean productivity outcomes such technical, economic, and allocative efficiency in the northern region of Ghana.

Contract farming is a prevalent institutional arrangement in global agriculture, involves agreements between farmers and buyers for the production and supply of agricultural products under predetermined conditions [18]. While often touted as a mechanism to enhance agricultural development and improve farmer livelihoods, particularly for smallholders in developing countries, literature on its outcomes presents a complex and often mixed picture. For instance, numerous studies highlight the potential benefits of CF for agricultural development. The CF is a vehicle that provides smallholder farmers with assured markets for their produce, reducing market risks and uncertainties often faced in spot markets. This linkage to buyers, especially agribusiness firms, can integrate farmers into higher-value supply chains [20]. Other studies demonstrated that CF enhances farm income and welfare of farmers [23, 24]. In China, a study reported a positive impact of CF on farmers' incomes, often due to higher yields, better prices, and reduced transaction costs [23]. Similarly, [24] has shown increased income for CF participating farmers. A meta-analysis by [25] indicated positive income effects in a significant proportion of cases, although caution is advised regarding potential publication bias. [26] investigated the technical efficiency of soybean farmers in the Northern region of Ghana and found that contract farmers were more technically efficient than non-contract farmers. The authors attributed this difference to the provision of inputs, extension services, and assured markets provided by the contracting firms. Another study by [14] examined the impact of contract farming on the technical efficiency of soybean farmers in the Northern region of Ghana. The study found that contract

farming had a positive impact on technical efficiency, but the impact varied depending on the type of contract and the contracting firm.

Despite the potential advantages, literature also reveals several challenges and mixed or even negative outcomes. that is CF effect on agricultural development can be heterogeneous and insignificant impacts.: While many studies report positive effects, results are often heterogeneous, and in some cases, the impact on farmers' income and welfare has been found to be insignificant or even negative [19, 27]. A study in Vietnam, found an insignificant impact of CF on farm income in the short term [28]. Also, a study by [29] on the economic efficiency of soybean farmers in the Northern region of Ghana revealed mixed results. While contract farmers were more technically efficient, non-contract farmers were more allocatively efficient. The authors argued that the contracting firms' pricing strategies and input provision mechanisms may have contributed to the allocative inefficiency of contract farmers.

Despite these studies, most of the studies concentrated is either estimating CF effect on farm productivity, income, technical efficiency, economic efficiency, or allocative efficiency individually. To an extent, the studies did not account for endogeneity of CF participation and technical efficiencies, particularly among soybean farmers. Therefore, this contributes to existing knowledge by investigating CF relationship with technical efficiency as a package (technical, allocative, and economic efficiencies) in the northern region of Ghana by using Stochastic Frontier Analysis (SFA) and the endogenous treatment effect regression models. Understanding the CF implications for soybean production and other determinants are crucial for designing effective interventions to enhance soybean productivity, reduce production costs, and improve smallholder farmers' livelihoods.

2. Materials and Methods

2.1. Study Setting and Data Source

The study was conducted in the Northern Region of Ghana, which had a population of 2,310,943 as per the 2021 Population and Housing Census [30]. The region is bordered by the Northeast Region to the north, Oti Region to the south, Savanna Region to the west, and the Republic of Togo to the east. The terrain is predominantly flat and low-lying, with major water bodies including the White and Black Volta Rivers, making it suitable for agricultural activities [31].

Agriculture is the dominant economic activity in the region, employing approximately 68.5% of the labour force. The Northern Region falls within the Guinea Savanna agro-ecological zone, characterized by a uni-modal rainfall pattern that spans from March or April to October, peaking in September. Rainfall variability is estimated at 15-20% [32], impacting agricultural productivity. Despite this, the region remains a major producer of cereals, tubers, and legumes, with soybeans being a key crop.

2.2. Sampling Technique and Sample Size

The research employed a multi-stage sampling approach to select soybean farmers. Northern Region of Ghana was deliberately chosen as the study area due to its position as leading soybean producer in the country [33]. The researchers then purposively selected the three highest soybean-producing districts in the region, focusing on areas with established contract farming arrangements.

In the second stage, researchers used Probability Proportional to Size (PPS) sampling to randomly select ten communities from each district based on soybean farmer population and contract farmer presence, resulting in 30 communities across the three districts. Soybean farmers were stratified into two groups: contract soybean producers (participants) and non-contract soybean producers (non-participants).

Before conducting the survey, researchers obtained a list of 655 contract farmers across the three districts from contracting companies. To determine the appropriate sample size, researchers applied Slovin's formula:

$$N = \frac{N}{1 + Ne^2} \quad (1)$$

Where n represents the sample size, e denotes the margin of error (0.06 for 94% confidence level), and N indicates the contract farmer population (655). This calculation yielded a sample size of 195, which researchers increased to 210 to account for potential design effects, representing 32% of all soybean contract farmers.

An equal number (210) of non-contract soybean farmers with comparable characteristics were randomly selected across the communities to create a matched comparison group. In total, 420 respondents were interviewed, though data cleaning reduced the final analytic sample to 374 (200 contract farmers and 174 non-contract farmers).

3. Analytical Framework

The study employed both descriptive and inferential statistical analyses. Descriptive statistics were used to summarize and describe the characteristics of the 374 soybean farmers. The stochastic frontier analysis was used to estimate the production efficiencies, which were then used as the dependent variables in the endogenous treatment effect regression model (ETRM) for the outcome model.

3.1. Measurement of Production Efficiency

Production efficiency measurement evolved significantly with [34] work, which was built upon the contributions of [35] and [36]. Farrell established that economic efficiency (EE) comprises two elements: technical efficiency (TE) and allocative efficiency (AE). Technical efficiency relates to technology usage, referring to either minimizing inputs for a given output (input orientation) or maximizing output at given

input levels and technology (output orientation). Allocative efficiency concerns optimizing input combinations based on their prices. Together, these measures provide a comprehensive assessment of total economic efficiency.

Two primary methodologies exist for estimating relative efficiency indices: Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA) [37]. SFA employs parametric statistical techniques, assuming a functional relationship between outputs and inputs while incorporating an error term with two components: a symmetric component accounting for statistical noise from measurement errors and a non-negative component measuring production inefficiency [38]. This study utilized the SFA approach for estimating production efficiencies.

3.2. Specifications of SFA Model for Production Efficiency Estimation

The stochastic frontier analysis (SFA) model for soyabean production frontier function can be expressed as:

$$Y_i = f(X_i, \beta) e^{v_i - u_i} \quad (2)$$

Where Y_i denotes soybean output in Kg, X_i denotes the factor inputs, the subscript i identifies the soybean farm, β represents the parameters to be estimated and e the term representing both inefficiency u_i and noise factors v_i . following the Cobb-Douglas stochastic frontier, the equation [2] can breakdown as:

$$\ln(Y_i) = X_i\beta + v_i - u_i \quad i = 1, 2, \dots, n \quad (3)$$

Where: $\ln(Y_i)$ is the logarithm of the soybean output of the i_{th} sample farm ($i = 1, 2, \dots, 374$) x_i are the logarithms of the input quantities used by the i_{th} farm; these include farm and farm household characteristics, inputs and input prices β is a column vector of unknown parameters to be estimated for each covariate u_i is the technical inefficiency (TE) of the i_{th} farm, and in this study it is assumed to be an independent and identically distributed (*i.i.d.*) half normal random variable v_i is the random error term, assumed to be (*i.i.d.*) normal random variable with zero mean and constant variance, σv^2 , independent of the u_i . The technical efficiency of the i_{th} soybean farm, in period t , is given by the ratio of observed output to the maximum potential output, as defined by the frontier.

$$TE = \frac{Y_i^*}{Y_i} = \exp(-u_i) \quad (4)$$

Where Y_i = the total production frontier, Y_i^* = the stochastic production frontier.

Following [39], the production cost frontier function can be mathematically expressed as:

$$C_i = f(X_i, P_i, \beta) e^{v_i + u_i} \quad (5)$$

Where C denotes the total production cost observed in Ghana cedi, X_i is the output quantity for household i (soybean produced), P_i is the input price vector used, β is the parameters to be estimated and e_i is the composite term representing both inefficiency, u_i , and noise factors, v_i .

Allocative efficiency is calculated as:

$$AE = \frac{C_i^*}{C_i} = \exp(u_i) \quad (6)$$

where C_i the total production cost frontier, C_i^* = the stochastic cost frontier. This will give us the AE from which EE (economic efficiency) will be estimated as:

$$EE = TE \times AE \quad (7)$$

After using SFA to generate the efficiencies scores for the TE , AE , and EE , then the endogenous treatment effect model was applied to correct the correct both unobserved and observed factors that might affect the efficiencies through CF.

3.3. The Endogenous Treatment Effect Regression Model (ETERM)

The endogenous treatment effects model is a linear model that allows for correlation between unobservable and observed factors affecting household choice decisions (such as CF) and those affecting household efficiency measures (TE , AE , and EE). These efficiency measures are expressed as proportional values, with 0 representing perfect inefficiency and 1 indicating maximum efficiency.

The outcome model is specified as:

$$ES_i = X_i\beta + \delta CF_i + \varepsilon_i \quad (8)$$

The ES denotes the efficiency scores for the study. The influence of CF on TE , AE , and EE is quantified here. The influence of CF on TE , AE , and EE efficiencies are not captured by the δ as participation in the CF program was a personal choice of the participants (case of self-selection). Therefore, failing to account for CF's potential endogeneity will lead to inaccurate treatment model estimates and an overestimation of the impact of contract participation on farmers' TE , AE , and EE efficiencies. Participation or non-participation in farmer contracts is based on household, individual, and farm characteristics G_i , and is modeled as follows:

$$CF_i' = G_i\alpha + \mu_i \quad (9)$$

$$CF_i = \begin{cases} 1 & \text{if } CF_i^* > 0 \\ 0 & \text{Otherwise} \end{cases} \quad (10)$$

Where CF_i^* indicates CF, X_i and G_i are unrelated variables. β and α are parameters to be estimated. The assumption

is that ε_i and μ_i are jointly normally distributed, with a mean vector of 0 and a variance covariance matrix Σ given as:

$$\Sigma = \begin{pmatrix} \sigma_1^2 & \rho\sigma_1 \\ \rho\sigma_1 & 1 \end{pmatrix} \quad (11)$$

To estimate the model, the maximum likelihood or two-step approaches can be employed. Maximum likelihood analysis was used to assess the model. The CF decision model (equation (8)) as well as an outcome model are used to model this (equation (9)). When endogenous involvement is considered, estimates of the impacts of households' decisions to participate in CF on their TE, AE, and EE efficiencies become more consistent. The factors that influence the CF decision and the efficiency are calculated in tandem.

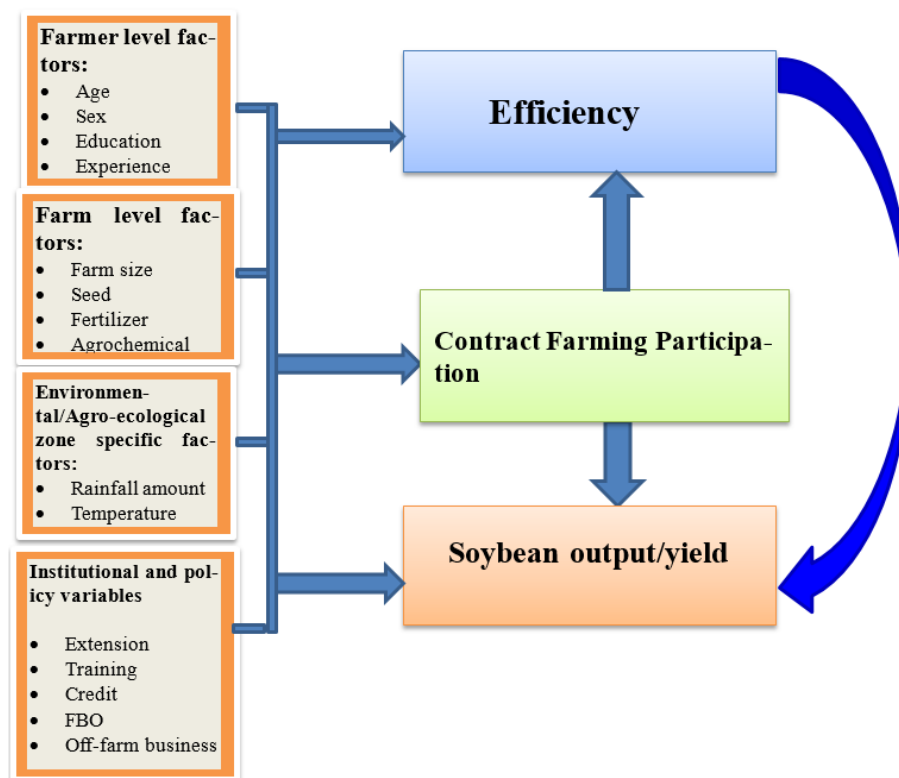
3.4. The Conceptual Framework

The conceptual framework in Figure 1 illustrates how various interrelated factors influence soybean farmers' participation in contract farming (CF) and its subsequent effect on efficiency and output in Northern Ghana. It posits that farmers' decisions to engage in CF depend on both internal

(farmer- and farm-level) and external (institutional, policy, and environmental) factors.

At the farmer level, characteristics such as age, gender, education, experience, and crop diversity shape farmers' capacity and willingness to join CF schemes. The farm-level factors—including farm size, seed quality, fertilizer use, agrochemicals, and labor—determine the production potential and resource utilization. Environmental and agro-ecological conditions like rainfall, temperature, pests, diseases, and road networks also affect productivity and access to markets. Meanwhile, institutional and policy variables such as extension services, training, credit access, and participation in farmer-based organizations (FBOs) play a vital role in enabling or constraining CF participation.

The framework assumes that farmers act rationally to maximize profit or utility. Those engaged in CF are expected to achieve higher technical, allocative, and economic efficiency due to improved access to inputs, information, and markets, compared to non-contract farmers. Ultimately, CF participation enhances farm efficiency and productivity, contributing to improved soybean output and livelihood outcomes.



Source: Modified from [45]

Figure 1. Conceptual Framework of the Study.

3.5. The Theoretical Framework

The study is anchored on three main theoretical foundations:

utility maximization theory, random utility theory, and stochastic frontier theory. These collectively explain farmers'

decision to participate in contract farming (CF) and how such participation affects production efficiency.

First, the theory of producer decision assumes that farmers are rational economic agents who aim to maximize utility or profit when faced with alternative choices—whether to produce soybeans under contract or independently. A farmer will participate in CF if the expected utility (benefit) from contracting exceeds that from non-contracting. This decision-making process is captured through random utility models, which treat farmers' preferences as partly observable (influenced by socioeconomic, farm, and institutional factors) and partly random. To model these choices statistically, probit or logit models are employed depending on the assumed distribution of the error terms.

Since farmers self-select into CF participation, potential bias in comparing contract and non-contract outcomes is corrected using the Heckman selection model [46]. This ensures unbiased estimation of the factors influencing participation and its effects.

Finally, the stochastic frontier theory is used to analyze and compare economic efficiency (EE) among soybean producers under the two systems—contract and non-contract. It decomposes inefficiency into technical, allocative, and economic components, helping to quantify how CF participation

enhances resource use and productivity.

Together, these theories provide the analytical basis for assessing farmers' participation behavior and the efficiency implications of contract farming in soybean production.

4. Results and Discussions

This section presents the results and discussions of the study findings.

4.1. Socio-economic Factors Associated with Participation in Contract Farming

Table 1 presents the statistics for variables used for the study, highlighting the distribution characteristics of contract and non-contract soybean farmers. Significant differences were observed in farm size, education levels, distance from farm to nearest market, Farmer-Based Organization (FBO) membership, and access to extension services. The significant differences of these variables for CF and non-CF imply that soybean farmers participated in CF are systematically different from those who did not participate in CF.

Table 1. Socioeconomic factors associated with participation in contract farming.

Variable	Non-contract farmers		Contract farmers		Pooled		t-test value
	Mean	SD	Mean	SD	Mean	SD	
Farm size (hectares)	1.855	3.620	2.230	1.054	2.057	1.021	-2.661***
Crop diversification	2.919	8.541	3.060	4.257	2.995	1.254	-1.277
Education	3.450	5.142	4.034	5.051	4.103	2.581	-2.839***
Farm– market-distance	10.174	8.164	12.445	8.212	11.401	6.001	-3.343***
FBO membership	0.029	0.547	0.886	0.142	0.492	0.142	-31.716***
Experience	5.953	2.651	5.639	3.895	5.783	2.870	1.147
Extension	0.052	0.501	0.528	0.023	0.147	0.014	-4.912***
Off-farm business	0.081	0.147	0.218	0.042	0.155	0.042	-3.689***
Age	38.762	11.920	40.446	42.124	39.671	35.147	-1.405
Credit	0.308	0.415	0.361	0.654	0.337	0.114	-1.085

Contract farmers operate significantly larger farms, averaging 2.2 hectares compared to 1.8 hectares for non-contract farmers ($p < 0.001$). This difference reflects the enhanced capacity of contract farmers to cultivate larger areas, supported by credit and input provisions from contracting firms. The overall average farm size of 2.0 hectares aligns with typical smallholder farming patterns in the Northern Region. Educa-

tional levels also differ significantly between the groups, with contract farmers averaging 4.0 years of formal education compared to 3.5 years for non-contract farmers ($p < 0.001$). While this difference is statistically significant, both groups demonstrate relatively low educational attainment. This finding is consistent with regional education statistics from GSS [30], which show that only 55.7% of 15-year-olds in the

Northern Region have ever attended school, substantially below the national average of 85.3%. The inclusion of Arabic education in these figures highlights the diverse educational pathways available to farmers in the region.

Interestingly, contract farmers are located at greater distances from markets, averaging 12.4 kilometers compared to 10.2 kilometers for non-contract farmers ($p < 0.001$). This counterintuitive finding suggests that contract farming arrangements may provide alternative market channels that reduce the disadvantage of geographic remoteness, allowing farmers in more distant locations to participate effectively in commercial agriculture. The most striking difference between the groups lies in Farmer Based Organization (FBO) membership, where nearly 89% of contract farmers belong to FBOs compared to less than 3% of non-contract farmers ($p < 0.001$). This disparity reflects the institutional requirement that farmers must be FBO members to participate in contract farming schemes, highlighting the role of collective organization in accessing formal agricultural markets.

Both groups possess similar levels of soybean production experience, averaging approximately 6 years, with no statistically significant difference between them. However, access to agricultural extension services varies dramatically, with 53% of contract farmers receiving extension services compared to only 5% of non-contract farmers ($p < 0.001$). This disparity reflects broader challenges in Ghana's agricultural extension system. According to GSS [30], the country maintains a 1:3000 extension agent to farmer ratio, well below recommended standards. The low coverage results from inadequate government investment in agriculture and systemic issues in deploying extension workers from agricultural training colleges to farming communities. Qualitative findings from focus group discussions reveal that many non-contract farmers avoid contract arrangements believing their experience makes additional training unnecessary, potentially limiting their access to improved technologies and practices.

Contract farmers also demonstrate higher levels of economic diversification, with 22% engaged in off-farm businesses compared to 8% of non-contract farmers ($p < 0.001$). This difference may reflect either the financial stability provided by contract arrangements enabling investment in other enterprises, or the need for additional income sources to complement farming activities. These findings highlight the multifaceted nature of contract farming participation, showing that it is associated with not only larger farm sizes and better market access, but also stronger institutional connections and enhanced access to support services. The results suggest that contract farming may serve as a pathway for agricultural development, particularly for farmers who can meet the institutional requirements for participation.

4.2. Effects of Contract Farming on Production Efficiency

This study examined the determinants of technical effi-

ciency (TE), allocative efficiency (AE), and economic efficiency (EE) in soybean production using a two-stage approach. While traditional models such as ordinary least squares, Tobit, and probit models have been widely applied [40, 41], concerns about their appropriateness have emerged. [42] criticized the Tobit regression approach, arguing that censoring efficiency estimates between zero and one is questionable since efficiency estimates are not generated through a censoring process, potentially leading to inconsistent estimates.

To address these limitations, this study employed fractional response models (FRMs) as proposed by [43]. Unlike OLS and Tobit models, FRMs effectively handle dependent variables defined on the unit interval, regardless of whether boundary values (0, 1) are observed [43]. The application of fractional regression was further validated by [43], who advocated for comprehensive specification testing beyond the logit models used by previous researchers.

Table 2 below presents the maximum likelihood estimates for the fractional regression model parameters. The results reveal several important determinants of efficiency in soybean production:

Education significantly enhanced both TE and AE at the 5% level, though its effect on EE was not significant. This finding aligns with previous research and supports the notion that formal education improves farmers' knowledge, skills, and adoption of new technologies. Educated farmers can access diverse information sources and make better-informed decisions, improving farm management and production efficiency.

Farming experience positively influenced both TE (5% significance) and EE (10% significance). Experienced farmers demonstrated superior efficiency levels, supporting findings by [44] who reported similar results for tomato farmers in Ghana's Upper East region. According to previous research, farming experience facilitates skill acquisition over time, while increased agricultural experience enhances production context awareness.

Diversification negatively affected EE at the 1% significance level, indicating that cultivating multiple crops reduces farmers' economic efficiency. This suggests that resource allocation becomes more challenging and costly when managing diverse crops simultaneously.

Engagement in off-farm activities significantly reduced all three efficiency measures (TE, AE, and EE) at the 1% level. This likely reflects the opportunity cost of time and resources diverted from farming activities to alternative income sources.

Access to extension services positively and significantly influenced TE, AE, and EE. Extension services enhance farmers' knowledge of agronomic practices, including pest control, improved varieties adoption, and resource conservation technologies, enabling better resource utilization and improved efficiency.

Training access positively affected TE and EE at the 5% significance level, though not AE. Training exposure provides

farmers with new technologies, improved practices, and information-sharing opportunities, facilitating better farm management and efficiency improvements.

Soybean contract farming significantly enhanced all efficiency measures (TE, AE, and EE) at the 5% level. This positive effect stems from: (1) regular training provided by contracting firms, (2) access to subsidized inputs including herbicides, machinery services, and credit, and (3) guidance on optimal input allocation to minimize waste and reduce

costs.

The analysis demonstrates that human capital factors (education, experience, training), institutional support (extension services, contract farming), and resource focus (avoiding diversification and off-farm activities) are key determinants of efficiency in soybean production. These findings provide valuable insights for policy interventions aimed at improving agricultural productivity and efficiency.

Table 2. Maximum Likelihood Estimates for Parameters of the Endogenous Treatment Effect Model.

Variable	Panel A						Panel B	
	TE		AE		EE		CF participation	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Gender	-0.032	0.035	-0.021	0.030	0.004	0.008	-0.098	
Age	0.000	0.001	0.000	0.001	0.000	0.000	-0.035	
Household size	-0.001	0.003	0.001	0.003	0.002**	0.001	-0.011	
Farmer experience	0.009	0.006	0.009*	0.005	0.002	0.001	-0.063	
Crop diversification	-0.007	0.017	-0.015	0.014	-0.013***	0.004	0.543**	
FBO membership	-0.306***	0.098	-0.284***	0.079	-0.038**	0.016	0.495***	
Off farm activity	-0.218***	0.040	-0.200***	0.035	-0.027***	0.010	3.540	
Farm size	-0.023**	0.011	-0.024**	0.009	-0.008***	0.003	0.228*	
Land tenure system	-0.108*	0.055	-0.093*	0.048	-0.008	0.014	-0.412	
Distance to market	-0.020	0.031	0.043	0.045	0.021	0.001	0.057***	
Credit	-0.143***	0.035	-0.008	0.026	0.015*	0.008	-0.918***	
Extension	0.042	0.044	-0.134***	0.038	-0.001	0.021	1.208**	
Training	0.125	0.213	0.012	0.312	-0.020	0.023	0.564	
Education	0.042	0.032	0.040	0.028	0.008	0.008	0.810***	
1.CF	0.367***	0.117	0.352***	0.094	0.061***	0.018		
Constant	0.745***	0.087	0.630***	0.076	0.836***	0.022	-0.098	
Rho	-0.628***	0.763	-0.679***	0.797	-0.628***	0.109		
Sigma	0.063	0.096	0.2248	0.105	0.063	0.025		
Wald test $\chi^2(15)$	82.87***		80.36***		46.57***			
LR test $\chi^2(0)$	0.01***		5.10***		7.32***			

Source: Field survey, 2018 Note: ***, **, * => Significance at 1%, 5%, 10% level.

Contract farming has a significant positive effect on technical efficiency, with an estimated average treatment effect (ATE) of 0.367, indicating that CF participation increases technical efficiency by approximately 37%. Similarly, CF shows a strong positive impact on allocative efficiency with an ATE of 0.352, suggesting that contract farmers are about

35% more allocatively efficient than non-contract farmers. The impact on economic efficiency is positive and significant with an ATE of 0.061, indicating that CF participation improves economic efficiency by approximately 6%.

The negative and significant rho values (-0.628 for TE, -0.679 for AE, and -0.628 for EE) confirm the presence of

self-selection bias, indicating that farmers with higher efficiency levels are more likely to participate in contract farming. The highly significant Wald tests and likelihood ratio tests confirm the appropriateness of the endogenous treatment effect model and the presence of endogeneity in the CF participation decision.

4.3. Summary of Treatment Effects

Table 3 summarizes the impact of contract farming on the three efficiency measures, providing a clear overview of the Average Treatment Effects (ATE) identified in this study:

Table 3. Summary of the Impact of CF on Technical, Allocative, and Economic Efficiencies.

Study Unit	Efficiency Type	Impact (ATE)	Significance Level
CF	Technical Efficiency	0.37	1%
CF	Allocative Efficiency	0.35	1%
CF	Economic Efficiency	0.06	1%

Source: Field survey, 2018

These findings are consistent with the broader literature on contract farming impacts. The substantial positive effects of CF on technical, allocative, and economic efficiency can be attributed to several mechanisms: input access and quality, where contract farmers receive guaranteed access to high-quality inputs, including improved seeds, fertilizers, and agrochemicals; technical assistance through provision of extension services and technical training; market assurance through guaranteed market access and predetermined prices; and economies of scale through collective procurement and marketing.

5. Conclusions and Recommendations

This study provides robust empirical evidence that contract farming significantly improves technical, allocative, and economic efficiency among soybean farmers in Northern Ghana. By employing an endogenous treatment effect regression model, the research successfully addresses self-selection bias that could overestimate CF's impact, providing more credible estimates than conventional approaches.

The findings reveal that CF participation increases technical efficiency by 37%, allocative efficiency by 35%, and economic efficiency by 6%. The significant negative correlation

between treatment assignments and outcome errors confirms the presence of self-selection, with more efficient farmers being more likely to participate in CF arrangements.

Based on the findings, it is recommended to promote and expand contract farming arrangements for soybean production, as it has been shown to enhance the technical, allocative, and economic efficiency of farmers. Investing in education and training programs for farmers to improve their knowledge and skills in efficient resource allocation and adoption of best agricultural practices is crucial. Strengthening and improving access to extension services is also recommended, as they play a crucial role in enhancing farmers' efficiency and facilitating CF participation.

The study contributes to the growing literature on CF impacts by providing methodologically rigorous evidence that accounts for endogeneity concerns. For policymakers and development practitioners, the findings support continued investment in CF programs while highlighting the need for complementary interventions to ensure broad-based participation and impact. Future research should explore the long-term sustainability of these efficiency gains and examine how different contract designs and support services can maximize the benefits of CF for smallholder farmers across diverse agricultural contexts.

Abbreviations

AE	Allocative Efficiency
ATE	Average Treatment Effect
BNF	Biological Nitrogen Fixation
CF	Contract Farming
DEA	Data Envelopment Analysis
EE	Economic Efficiency
ETRM	Endogenous Treatment Effect Regression Model
FBO	Farmer-Based Organization
FRM	Fractional Response Model
PPS	Probability Proportional to Size
SFA	Stochastic Frontier Analysis
TE	Technical Efficiency

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Author Contributions

Yahaya Abdulai: Conceptualization, Data curation, For-

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Conflicts of Interest

The authors declare no conflicts of interest.

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