ANALYSIS OF FACTORS INFLUENCING OUTPUT AND COST OF SOYBEAN PRODUCTION: A COMPARISON BETWEEN CONTRACT AND NON-CONTRACT FARMERS IN THE NORTHERN REGION OF GHANA

ABSTRACT

Contract farming has emerged as a crucial remedy for bolstering the prospects of small-scale soybean farmers in Ghana. Both governmental bodies and non-governmental organizations, including the Savanna Farmers Marketing Company (SFMC), the Northern Development Authority (NDA), and the Adventist Development and Relief Agency (ADRA), are actively engaging farmers in contracts to grow soybeans. This initiative is especially prominent in the Northern Region of Ghana**.** This study investigates the factors influencing the output and cost of soybean production, drawing a comparison between contract and non-contract farmers. The research employs stochastic frontier analysis (SFA) and translog functional forms to analyze data collected from 374 soybean growers. The findings reveal that farm size, labour, and agrochemical usage significantly impact soybean output for both contract and non-contract farmers. However, contract farmers exhibit increasing returns to scale, while non-contract farmers experience decreasing returns. Regarding production costs, the study identifies farm size, seed cost, agrochemical cost, and output as significant determinants for the pooled sample. Contract farmers' production costs are primarily influenced by farm size, seed cost, and agrochemicals, whereas non-contract farmers' costs are driven by farm size, seed cost, agrochemicals, and output. The analysis highlights the complementary and substitute relationships among input variables, providing valuable insights for policymakers and stakeholders in the soybean industry. The findings underscore the need for targeted interventions to enhance productivity and cost efficiency for both contract and non-contract soybean farmers.

Key words: Stochastic Frontier Analysis, Contract Farming, efficiency, Output.

1. INTRODUCTION

Soybean is a crop of paramount significance for Ghana's economy, its income potential is substantial, and its nutritional value is undeniable. Recognizing this, key stakeholders like the Council for Scientific and Industrial Research (CSIR) and the Ministry of Food and Agriculture have joined forces to champion soybean cultivation [1]. The production of soybean in Ghana has proven to be both economically viable and nutritionally advantageous. Furthermore, soybean offers therapeutic benefits, making it an excellent choice for preventing and treating cardiovascular diseases [2]. The crop plays a vital role in addressing food security and income generation for smallholder farmers, especially in developing countries.

According to the Statistics, Research and Information Directorate (SRID) of the Ministry of Food and Agriculture, in 2022, more than 77% of Ghana's soybean production originated from the Northern Region. As a result, a majority of soybean interventions, such as the Agricultural Value Chain Mentorship Project (AVCMP) funded by the Danish International Development Agency (DANIDA) through the Alliance for a Green Revolution in Africa (AGRA), Contract Farming (CF) have been concentrated in the region.

In recent years, CF has emerged as a potential strategy to enhance the productivity and profitability of soybean cultivation [3,4]. CF involves formal agreements between farmers and agribusinesses, providing farmers with access to inputs, credit, and assured markets for their produce [5]. However, the impact of CF on output and production costs remains an area of investigation, particularly in comparison with non-contract farming systems.

Previous studies including; [6,7,3,8,9] have highlighted the influence of various farm, household, and socioeconomic factors on farm-level efficiency and productivity. These factors include age, gender, education level, household size, credit access, cooperative participation, farming training, and crop varieties. Understanding the dynamics of these variables is crucial for designing effective interventions to improve soybean production.

Several literatures have extensively focused on farm-level efficiency, employing stochastic frontier analysis (SFA) and translog functional forms to assess the determinants of output and cost [10,11,12,13]. However, there is a need for comprehensive investigations comparing the performance of contract and non-contract soybean farmers, particularly in the context of developing countries such as Ghana.

This study aimed to bridge this gap by analyzing the factors influencing soybean output and production costs, drawing a comparison between contract and non-contract farmers. The research utilizes SFA and translog functional forms to examine data collected from 374 soybean farmers in Ghana's Northern region. By identifying the key drivers of output and cost for both farming systems, the findings can inform policymakers and stakeholders in designing targeted interventions to enhance productivity, cost efficiency, and the overall sustainability of the soybean industry.

2. LITERATURE REVIEW

Soybean cultivation holds particular importance in the Northern Region, being a vital leguminous crop cultivated predominantly across Ghana's five northern regions [14]. The region leads nationwide soybean production, benefitting from its climate and ample agricultural land. The production of the crop in Ghana was approximately 225,345MT in 2022 [15]. The Northern Region accounted for 131,151MT of this total. A total of 58.2% of the country's soybeans come from this region. Initiatives such as Contract Farming (CF) facilitated by organizations like ADRA, SFMC, SADA, and Masara N'Arziki in collaboration with smallholder farmers, have the potential to enhance soybean productivity and farmer incomes.

Despite some development partners' and non-governmental organizations' efforts to make soybean production a priority, there is still a market gap due to insufficient soybean output and/or storage [7], which may worsen if efforts are not made to make the soybean sector's growth more sustainable. For instance, the actual output of the crop was 1.65 metric tons per hectare (on farm) while the potential output is 3 metric tons per hectare in 2016 [16].

Contract Farming is defined as a system in which a central processing or exporting unit purchases the harvest of an individual farmer, with the terms of the purchase established in advance via contract [17]. Farmers benefit from CF agreements because they have access to a variety of services that they would not have had otherwise. Thus, CF is an agricultural and horticultural production and supply system based on pre-contractual agreements between producers/suppliers and customers [18].

CF has emerged as a vital institutional arrangement aimed at addressing production and marketing constraints faced by smallholder farmers in developing countries [19]. Several studies have examined the impacts of contract farming on farmer's output, costs, incomes and technical efficiency across various crops and regions.

In Ghana, [4] found that contract farming improved technical efficiency among rice farmers in the Northern Region. [7] also reported higher technical efficiency levels for soybean contract farmers compared to non-contract counterparts in the same region. However, [6] revealed mixed results, with soybean contract farming increasing farmer incomes but not productivity.

Focusing on costs, [20] observed lower production costs among Vietnamese tea contract farmers due to access to credit and inputs on credit. Conversely, [21] noted higher costs for Indian poultry contract growers attributed to stipulated input purchase requirements.

Regarding output, [22] documented significant output gains from contract farming across various crops in India. Similarly, [23] found contracted vegetable farmers in Nepal had 37% higher yields versus non-contracted peers. Contrarily, [24] reported minimal output difference between sorghum contract and non-contract farmers in Kenya.

Factors influencing farmer performance under contracts include farmer education [25], farm size [23], input access [26], and output market access [27]. Agribusiness contracting models and contractual provisions also shape farmer incentives and outcomes [28,29].

While contract farming shows promise for raising productivity and incomes for smallholders, the evidence is mixed across different farmer groups, crops and institutional arrangements. More localized empirical analysis is needed, particularly for soybean production systems in Northern Ghana.

3. DATA AND METHODS

3.1The Study Area, Sampling Technique and Data

The study was carried out in three Districts; Yendi, Cheriponi and Saboba Districts of Ghana's Northern Region. The region has a population of 2,310,943 according to the 2021 census, ranking it as the sixth most populous region in Ghana [30]. Tamale serves as the regional capital. The region comprises fourteen administrative and political districts and shares borders with the North East Region to the north, the Oti Region to the south, the Savanna Region to the west, and the Republic of Togo to the east. The prominent lakes in the region are formed by the merging of the White and Black Volta rivers. Its terrain is predominantly flat and low-lying [14], conducive to agricultural activities, with approximately 68.5% of the workforce engaged in farming. Given the region's prominence in soybean production and contract farming initiatives, it was purposefully selected for the study.

A multi-stage sampling approach was employed to select soybean farmers for the study. First, the Northern Region of Ghana was purposively chosen as it leads national soybean production [31]. The three districts with the highest soybean output in this region were then purposively selected based on their prominence in soybean cultivation and existing contract farming arrangements.

In the second stage, Probability Proportional to Size (PPS) sampling was used. Ten communities were randomly selected from each district, proportional to the number of soybean farmers and presence of contract farmers, resulting in a total of 30 communities across the 3 districts.

The soybean farmers were stratified into two groups: contract farmers (participants) and non-contract farmers (non-participants). Prior to the survey, the Soybean Farmers Marketing Company (SFMC) and Northern Development Authority (NDA), two firms engaged in soybean contract farming, provided a list of 655 contract farmers across the 3 districts.

To determine the sample size, Slovin's formula, used by [32] and [33], was adopted:

$$n = \frac{N}{1 + Ne^2} \tag{1}$$

Where n is the sample size, e is the margin of error (0.06 for a 94% confidence level), and N is the population of 655 contract farmers. Applying Slovin's formula yielded a sample size (n) of 195, which was increased to 210 to account for potential design effects. Thus, 210 contract farmers were randomly selected, representing 32% of all soybean contract farmers in the region. To facilitate comparison, an equal number (210) of non-contract soybean farmers with similar characteristics were also randomly chosen across the communities. In total, 420 respondents were interviewed, although after data cleaning, this was reduced to 374 (200 contract farmers and 174 non-contract farmers).

3.2 The stochastic Frontier Analysis (SFA)

This study employs Stochastic Frontier Analysis (SFA) and translog functional forms to investigate the factors influencing soybean output and production costs, drawing a comparison between contract and non-contract farmers.

3.2.1 Stochastic Production Frontier Model

The stochastic production frontier model is specified as:

$$Y_i = f(X_i\ ; \beta) + v_i - u_i \qquad (2)$$

Where:

Y_i= output of the ith farm

X_i = vector of input quantities

β = vector of parameters to be estimated

v_i= random error term

u_i = non-negative random variable associated with technical inefficiency

The translog functional form is used to estimate the production frontier:

$$ln\, Y = ln\, \beta_0 + \Sigma_{i=1}^{n} \beta_i\, ln\, X_i + {}^1/_2\, \Sigma_{i=1}^{n} \Sigma_{j=1}^{n} \beta_{ij}\ ln\, X_i\, ln\, X_j + v_i\ - u_i \qquad (3)$$

Where the βs are parameters to be estimated.

3.2.2 Sample Selection in a Stochastic Frontier Model

Stochastic Production Frontier (SPF) models have been used widely in many areas, including agriculture, to model input–output relationships and to measure the EE of farmers [34]. Additionally, comparable methodologies have been used to evaluate farmer performance in response to a range of technological interventions. For instance, the approach was employed to investigate the effect of technology adoption on rice farm output and TE [10].

Most studies that used stochastic production frontiers (SPFs) to compare the EE of participants versus non-participants versus non-adopters failed to account for selectivity bias caused by both observable and unobservable variables in a manner consistent with the nonlinear nature of the SFM.

For example, various attempts have been made to account for selection bias using [35] methods in a stochastic frontier framework. Sipilainen and Oude (2005) examined sample selection bias in a comparison of organic and conventional farms by inserting an inverse Mill's ratio (IMR) into the deterministic section of the frontier function. [34] used a similar approach in examining Central American farmers who adopted varying degrees of soil conservation. This method, however, has been shown to be ineffective for nonlinear models such as the SPF [36].

Recent years have seen the development of alternative strategies for addressing this issue, including one by [37], who developed a model in which the selection mechanism is assumed to operate via one-sided error in the frontier and then used their model to compare the performance of organic and conventional dairy farming in Finland. [36] extended Heckman's technique to include sample selection within a stochastic frontier framework by assuming that the selection equation's unobserved attributes are related to the stochastic frontier's noise. The following blocks of equations summarize [36] model, which was used in this study.

$d_i^* = 1[\alpha' z_i + w_i](d_i^* > 0), w_i \square N(0,1)$ (Selection equation) (4)

$$y_i = \beta' x_i + \varepsilon_i \qquad (5)$$

(y_i, x_i) were observed only when $d_i = 1$.

The error structure was specified as:

$$\boldsymbol{\varepsilon_i = v_i - u_i} \qquad (6)$$

Where $U_i = |\sigma_u U_i| = \sigma_u |U_i|\, where U_i \sim (0,1)$ (7)

$v_i = \sigma_v V_i\, where V_i \sim (0,1)$ (8)

$(w_i v_i) \sim N_2[(0,0),(1,\ \rho\sigma_v, \sigma_v^2)]$

Bivariate standard normal $\left[(0,\quad 0),(1,\quad \rho,\quad 1)\right],\ (y_i, x_i)$ only observed when $d_i = 1$.

- *d* is a binary variable, specified as 1 for contract farmers, and 0 for non-contract counterparts
- The (binary) sample selection model includes a vector of explanatory factors called *z.*
- *wi*is the unobservable error term;
- y is the output for soybean farmers;
- x is an input vector on the production frontier; and
- ε is the composite error term.

The coefficients α and β were estimated, whereas the factors in the error structure correspond to those often included in stochastic frontier formulations. Sample selection occurred in this case because the noise in the stochastic frontier v_i-u_i was related to unobserved attributes in the sample selection equation. If the selectivity variable ρ is statistically significant, then sample selection bias exists. Is this study, the ρ was significant for the stochastic production function after the analysis was done as seen in Table 3 in the discussion, justifying the use of this approach.

3.2.3 Stochastic Cost Frontier Model

The stochastic cost frontier model is specified as:

$$lnC_i = f(P_i;\ Y_i; a\ ) + v_i + u_i \qquad (9)$$

Where:

C_i= total cost of production of the ith farm

P_i = vector of input prices

Y_i= output quantity

a = vector of parameters to be estimated

v_i= random error term

u_i= non-negative random variable associated with cost inefficiency

The translog functional form for the cost frontier is:

$$ln\,C_i = \beta_o + \sum_{n=1}^{N}\beta_n\, ln\,P_{ni} + \frac{1}{2}\sum_{n=1}^{N}\sum_{n=1}^{N}\beta_{ij}\, ln\,P_{ni}\, ln\,P_{nj} + \beta_y\, ln\,Y_i + \frac{1}{2}\beta_{yy}\,(ln\,Y_i)^2 + \sum_{n=1}^{N}\beta_{iy}\, ln\,Y_i\, ln\,P_i + v_i + u_i \qquad (10)$$

Where ln$C_i$is the natural logarithm of the total cost of producing soybeans for an ith farmer in (GH¢). According to the Bank of Ghana (2024), the average exchange rate in dollars ($) is $1 to GH¢12.80. P_{1i}, P_{2i}..........P_{4i} symbolize the standard input prices in GH¢. (indicates cost of labour, seed, herbicide, and farm size) is the quantity of soybeans produced in kilograms. Furthermore, there is a random variable associated with production disruptions, as well as farm-specific and socioeconomic characteristics linked to production efficiency.

The generalized likelihood ratio test was used to test hypotheses and select the appropriate functional form (see Table 2). Maximum likelihood estimation was performed to obtain the parameters of the stochastic frontier models.

4. RESULTS AND DISCUSSION

4.1 Variables used in the Analysis

A variety of farm, household and socioeconomic factors influence output and cost of soybean production. This study looked at age, gender, education level, household size, credit access, cooperative participation, soybean farming training, and cropped varieties. The study looked at the data of 374 soybean growers in the area.

Table 1 shows summary statistics for the important variables in the model. These variables are listed to indicate the distribution of contract and non-contract soybean farmers. Contract and non-contract farmers differ significantly in terms of average total cost of production, farm size, cost, quantity, and quality of seeds used, cost of herbicides, cost of labor, sex, crop diversification, respondents' education, distance from farm to nearest market, and FBO membership. At the 1% level, there is a significant mean difference in total cost of production between contract and non-contract soybean farmers. Contract farmers, as expected, spend more
on soybean cultivation than their non-contract counterparts. Contract farmers' land is on average 2.2 ha, while non-contract farmers' land is on average 1.8 ha. In comparison to their non-contract counterparts, contract farmers spend more on seed purchases for sowing.

At the 5% level, the difference in output between contract and non-contract farmers is significant, as expected. The high investment made by contract farmers can be attributed to this. Contract farmers have greater labour and herbicide costs than non-contract farmers.

The sex of the respondents is significant and positive, implying that many male farmers participate in CF. There is a significant difference in educational achievement between contract and non-contract farmers. According to the findings, 69% of contract soybean farmers have at least a primary education, compared to only 55% of non-contract farmers. On the average, contract farmers travel 12 kilometers to the market, while non-contract farmers travel 10 kilometers. Almost all contract soybean producers (89%) are members of an FBO whilst less than 1% of non-contract farmers belong to any FBO. As indicated, one of the criteria for participating in any contract obligation is to belong to a farmers' group or organization.

Table 1: Summary of the SFA variables:

Variable	Non-contract farmers		Contract farmers		Pooled		t-test value
	Mean	SD	Mean	SD	Mean	SD	
Total cost (GHC)	220.944	195.214	289.781	301.121	255.728	354.120	3.897***
Output (output/ha)	2949.634	3215.214	3247.791	3142.21	3086.754	3214.045	1.480**
Farm size (ha)	1.855	2.784	2.230	4.251	2.057	5.901	-2.661***
Seed (GHC/ha)	20.559	22.561	27.874	31.245	24.510	30.147	-6.318***
Seed (Kg/ha)	9.945	10.321	14.646	18.124	12.485	20.702	-6.179***
Herbicides (GHc/ha)	17.55	18.1245	24.460	30.021	21.283	25.540	-2.360***
Labour (GHc/ha)	35.884	42.024	43.212	54.124	40.000	51.001	-1.735**
Sex	0.552	0.654	0.649	0.124	0.604	0.802	-1.900**
Crop diversification	2.919	4.215	3.060	6.014	2.995	5.031	-1.277
Education	0.547	0.600	0.688	0.201	0.623	1.045	-2.839***
Farm–market-	10.174	18.651	12.445	15.245	11.401	13.010	-3.343***

distance							
FBO membership	0.029	0.046	0.886	1.285	0.492	0.605	-31.716**

Source: Field data analysis.Note: ***, **, * Significance at 1%, 5%, 10% level.

4.2 Results of Hypothesis Tests

The generalized likelihood ratio test was used to examine the relevance of agricultural input usage, costs and socioeconomic factors in explaining the stochastic production and cost frontiers as well as the technical and cost (in)efficiencies as shown in Table 2. To assess which model was most suited for the investigation, the generalized likelihood ratio (LR) test was also used. The LR Chi^2 was 93.97 (Prob>chi^2 = 0.0000) and statistically significant at 1% level. This suggests that the Translog frontier cost function performed better in the analysis than Cobb-Douglas. As a result, the null hypothesis that Cobb-Douglas model is the most appropriate for the analysis was rejected. Similarly, when testing for cost inefficiency, the model with inefficiency effect recorded a lower AIC value than the deterministic translog model, indicating that cost inefficiencyhad a non-trivial effect on soybean production in the sample. This informed the rejection of the null hypothesis that there was no cost inefficiency.

Table 2: Generalised likelihood-ratio test of hypothesis

Model		**(model)**	**DF**
Cobb-Douglas function		388.322	8
Translog function		341.335	23
LR Chi^2=	93.97*** Prob>chi^2 = 0.0000		
Decision:	Reject Ho: Estimated Cobb-Douglas Frontier not different from translog frontier		
Deterministic Translog function		341.335	23
Translog function with inefficiency variables		329.715	30
	LR Chi^2 = 23.25*** Prob> Chi^2= 0.0015		
Decision:	Reject Ho: there is no inefficiency among soybeans farmers.		

Note: *** represents 1% level of significance.
Source: Field survey.

4.3 Factors Influencing Contract and Non-contract Farmers Soybean Output

The results of maximum likelihood estimations of the stochastic production frontier model with selection are shown in Table 3. A translog functional specification was used to estimate both conventional SPF and sample selection SPF. All variables in the translog models were normalised by their corresponding geometric means so that the first-order coefficients can be interpreted as partial elasticities of output with respect to inputs at geometric mean values [10, 11]

Table 3: Maximum Likelihood Estimates for Parameters of the Stochastic Frontier Model

Model	Conventional SPF			Sample selection SFP		
Column	(1)	(2)	(3)	(4)	(5)	(6)
Variable	Pooled	CF	NCF	Pooled	CF	NCF
	Coef. (Std. Err.)	Coef. (Std. Err.)	Coef. (Std. Err.)	Coef. (Std. Err.)	Coef. (Std. Err.)	Coef. (Std. Err.)
Farm size	(0.767)*** (.087)	0.721*** (0.052)	0.765*** (0.062)	(0.724)*** (0.035)	0.901*** (0.081)	0.817*** (0.124)
Seed	-0.021 (.063)	0.021 (0.032)	0.011 (0.042)	-0.018 (0.038)	0.097 (0.06)	-0.035 (0.126)

Agrochemicals	-0.260)	0.038	0.058	-0.047	0.015	-0.534
	(0.245)	(0.321)	(0.202)	(0.141)	(0.228)	(0.525)
Labour	0.3811***	0.312***	0.214***	0.147***	0.370***	-0.146*
	(0.105)	(0.065)	(0.077)	(0.049)	(0.123)	(0.081)
Farm size squared	-0.439***	-0.343**	-0.240**	-0.176***	-0.302**	-1.123***
	(0.120)	(0.075)	(0.099)	(0.061)	(0.122)	(0.138)
Seed squared	-0.174***	-0.056	-0.041	-0.061*	0.011	-0.281***
	(0.049)	(0.043)	(0.031)	(0.035)	(0.054)	(0.040)
Agrochemicals squared	0.296	0.123	0.162	0.373***	.00049	-0.188
	(0.253)	(0.332)	(0.221)	(0.103)	(0.203)	(.795)
Labour squared	-0.095	-0.234*	-0.128*	-0.197***	-0.086	-0.412***
	(0.081)	(0.073)	(0.066)	(0.030)	(0.132)	(0.054)
Farm size*seed	0.320***	0.054	0.033	0.035	-0.143**	0.327***
	(0.063)	(0.056)	(0.046)	(0.026)	(0.058)	(0.031)
Farm size*agrochemicals	0.131	-0.076	-0.064	-0.283***	0.242	-0.945**
	(0.209)	(0.167)	(0.193)	(0.090)	(0.196)	(0.476)
Farm size*labour	0.374***	0.675***	0.542***	0.467***	0.244	-0.027
	(0.138)	(0.201)	(0.103)	(0.058)	(0.173)	(0.088)
Seed*agrochemicals	-0.213**	-0.023	-0.015	-0.050	-0.082	1.087**
	(0.102)	(0.092)	(0.056)	(0.092)	(0.152)	(0.483)
Seed*labour	0.040	-0.021	-0.036	0.007	-0.047	0.197***
	(0.55)	(0.026)	(0.038)	(0.023)	(0.078)	(0.037)
agrochemicals*labour	-0.195*	-0.145***	-0.327***	-0.368***	-0.149)	-0.939***
	(0.111)	(0.054)	(0.079)	(0.045)	(0.129)	(0.263)
Constant	0.454	0.988***	0.988***	1.021***	0.873***	1.572***
	(23.370)	(0.214)	(0.104)	(0.072)	(0.126)	(0.183)
Lambda	0.25D-04	7.287***	7.287***			
	(39.705)	(1.056)	(1.066)			
Sigma	0.738***	1.191***	(1.191)***			
Sigma (u)				1.339***	1.151***	1.084***
				(0.027)	(0.068)	(0.019)
Sigma (v)				0.156***	0.270***	0.105***
				(0.0155)	(0.029)	(0.017)
Rho(w,v)				-1.000***	-0.999***	-0.990***
				(0.002)	(0.003)	(0.083)
Returns to scale				0.806	1.983	0.102

Note: *, **, * ==> Significance at 1%, 5%, 10% level.**

Source: Field survey.

Examining the productivity differences between contract and non-contract soybean producers is not straightforward because of sample selection problem. Therefore, two sets of hypothesis tests were conducted by using conventional SPF and sample selection SPF. The diagnostics of the model are shown in the Table 3. Both sigma (u) and sigma (v) are highly statistically significant at the 1% level, according to the estimations. Similarly, at the 1% level, the estimated coefficient of the selectivity variable rho (w,v) is highly statistically significant. This corroborates the findings of a selection bias problem, justifying the employment of a selectivity correcting approach. The coefficients and efficiency scores have been found and adjusted using the sample selection approach, thus they are bias-free.

Furthermore, because the rho is significant, there are variations in soybean productivity between contract and non-contract farmers; thus, estimation of separate frontiers for each group is reasonable and legitimate. This finding is consistent with [38,39], who discovered a strong selection bias in Thailand's Jasmine rice and Bangladesh's contemporary rice production systems. Since there is evidence of selectivity bias problem which has been corrected, the results of sample selection SPF are chosen for discussion. All the variables used for the estimation in the first order term exert direct relationship to the output of soybean. When the direct relationship effect of input variables on the output satisfies the a priori expectations, the functional form behaves normally. This demonstrates that the correct amounts of conventional inputs will increase soybean output. Increases in all production inputs will lead to a higher-than-proportional increase in soybean output.

All of the input factors were mean-corrected except for the socioeconomic variables; therefore, the coefficients of the input variables are described as output elasticities. From the Table 3 (column 5), four variable inputs were found to exert significant effects on soybean output by contract farmers. These variables include farm size and labour (two conventional factors), one for the squared terms (farm size) and one for the interaction's terms (farm size and seed). Also, column 6 on Table 3 illustrates the drivers of output of soybean producers who are not participating in CF (non-contract farmers). The first order conventional variables found to significantly affect soybean output of non-contract farmers are farm size and labour.

The farm size for the pooled data according to the findings has a positive coefficient of 0.724 and is statistically significant at the 1% level. This suggests that if the size of the farm is extended by 100%, soybean output will increase by 72.4 percent, provided all other things remain constant. The farm size coefficient had the highest coefficient value, indicating that farm size plays a larger role in increasing productivity. Significant relationship in farm size and maize productivity in southern Malawi, rice productivity in Nigeria's Cross River State, and soybean productivity in Northern Ghana were reported by [40], [41] and [3]. Furthermore, [4] conducted an empirical evaluation of rice farmers' TE in Northern Ghana, concluding that farm size and rice yield are positively related.The study also corroborates with [50], who found a positive relationship between farm size and output in Northern Ghana.This study, however, contradicts [42] findings in Ethiopia, which indicated a negative link between farm size and commercial wheat production.

The coefficient of labour in the pooled results has the second highest coefficient (0.147) and is statistically significant at the 1% level. In other words, increasing the number of man-days on a soybean farm by 100% would result in a 14.7 percent increase in soybean yield in the research area. The greater value of the coefficient of labour emphasizes the importance of labor in the production process. According to [43], labour had a considerable positive impact on increasing pulse productivity in Bangladesh.

The squared terms of the input variables explain the continuous effect on soybeans production. For the squared terms, farm size squared, agrochemical squared, and labour squared were found to have significant effects on soybean output in a long term. The negative coefficient (-0.176) for farm size squared is statistically significant at the 1% level. This means that continuing to farm soybeans on the same amount of land will result in a 17.6 percent reduction in soybean output.

Similarly, the coefficient of -0.197 for labour squared measured in man-days is significant at the 1% level for the pooled data. Also, the coefficient for the same variable (labour squared) for NCF is -0.412. This suggests that if same amount of labour is continuously employed in the production of soybean, with time soybean output will decrease by 19.7% for the pooled and 41% for NCF. These findings confirm that production function is a quadratic function and conform to production theory. These results are in harmony with [5]. Unit cost of agrochemicals, on the other hand, had a positive coefficient (0.374) and was statistically significant at the 1% level. This means that continuous application of the proper amount of pesticide herbicides in the study area enhances soybean output by 37.4 percent.

The significant interactive terms show whether conventional inputs in soybean production are substitutes or complements. The interaction of farm size and agrochemicals had an inverse relationship with soybean output. It was statistically significant at the 1% level and had a negative coefficient (-0.283). This means that having a larger farm and using agrochemicals on a regular basis does not always imply higher outputs. It also implies that farm size and agrochemicals are interchangeable, implying that you can expand your farm without using agrochemicals while still recording some outputs. This is in direct opposition to the study's presumption.

The interaction between farm size and labour had positive coefficient (0.467) and highly significant at 1%. The elasticity from Table 3 implies that as farmers increased their farm size and labour by a unit each, the output will increase by 47%. [44] reached the same conclusion. This finding also corroborates those of [45], and [38]. This finding indicates that farm size and labour are complements in soybean production. Labour in production process plays a critical role. Without labour, every activity in the production process will come to a halt. Labour helps in translating farm inputs to output (i.e. production goal). Hence, it is not surprising to have the interaction of farm size and labour having a positive coefficient. This also conforms to production theory.

The final interaction variable is agrochemicals and labour, which has a negative coefficient (-0.368), which is significant at the 1% level. This explains that the pairs of these input variables are substitutes in soybeans production. From the results, the return to scale value for the pooled is 0.806 showing decreasing returns to scale. It is 1.983 for CF and 0.103 for NCF. This shows increasing and decreasing returns to scale respectively for CF and NCF. The total of all the output elasticities in the first order term is the return to scale value. This means that increasing the usage of traditional variable inputs in the production process, such as farm size, seed, agrochemicals, and labor, will result in a less than proportionate rise in soybean output for the pooled and NCF. However, for CF increasing the usage of traditional variable inputs in the production process will lead to a more than proportionate increase in soybean output. This also means that if all other parameters remain constant, a 100 percent increase in all factors of production will result in an 81 percent increase in soybean yield for both CF and NCF. This result agrees with [46] who reported decreasing returns to scale, but differs from the findings of [12], [47], and [5].

4.4 Drivers of Production Cost of Soybeans

This section is divided into three subsections: determinants of soybean production cost, determinants of soybean production cost for contract farmers, and determinants of soybean production cost for non-contract farmers. Each subcategory is discussed in detail.

Table 4 shows the findings of the translog stochastic cost frontier model for the three categories. Except for labour cost, the analysis included four input and one output factors, all of which had a positive effect on soybean production costs and were statistically significant. All the estimated coefficients for input prices were significant and had both positive and negative signs, indicating that the cost function behaved well.

Decision to participate in CF is a self-choice; hence there could be selectivity bias problem. Therefore, LIMDEP statistical software was used to perform the estimates to check whether there is evidence of selectivity bias in participating in CF in the study area. After the study, the rho value (see Table 4) was not significant, indicating that the data had no evidence of selectivity bias. As a result, the discussions are based on conventional SPF results. The variables' first, second and third orders are discussed in the following order. Because all the input variable prices were mean-corrected, the estimates of the translog cost function show a relative change in soybean production costs resulting from a change in the explanatory variables (i.e., input prices). The discussion of the parameter estimates is based on the cost elasticities with respect to each individual input price evaluated at their mean values [48]. Column 1 (pooled results) represent the determinants of cost of soybean production.

Table 4: Maximum Likelihood Estimates for the Parameters of the Stochastic Cost Frontier Model

Column	(1)	(2)	(3)	(4)	(5)	6)
Model	Conventional SPF			Sample selection SFA		
Variable	Pooled	CF	Non-CF	Pooled	CF	Non-CF
	Coeff. (Std. Err.)	Coeff. (Std.Err.)	Coeff. (Std. Err.)	Coeff. (Std. Err)	Coeff. (Std. Err.)	Coeff. (Std. Err.)
Constant	0.072 (20.364)	0.076 (37.972)	0.077 (0.144)	0.750*** (0.083)	0.873*** (0.138)	0.640 (0.524)
Farm size	0.16166* (0.086)	0.342*** (0.124)	-0.224* (0.135)	0.337*** (0.090)	0.513*** (0.140)	-0.144 (0.290)

Labour	-0.081	-0.103	-0.117	0.025	0.238**	0.086
	(0.076)	(0.1087)	(0.132)	(0.066)	(0.107)	(0.39)
Seed	0.565***	1.531***	1.020***	0.482***	0.096	0.966**
	(0.099)	(0.202)	(0.150)	(0.129)	(0.144)	(0.471)
Herbicides	0.863***	0.845***	2.761***	0.820***	0.681**	2.714
	(0.164)	(0.210)	(0.640)	(0.160)	(0.313)	(2.909)
Output	0.156***	0.012	0.256***	0.055	0.042	0.288
	(0.053)	(0.082)	(0.090)	(0.057)	(0.088)	(0.380)
Farm size sq.	0.192*	0.064	0.265	0.141	-0.034	0.155
	(0.104)	(0.139)	(0.290)	(0.106)	(0.152)	(0.412)
Labour sq.	-0.109**	-0.070	-0.109	-0.028	-0.004	-0.092
	(0.049)	(0.075)	(0.072)	(0.047)	(0.097)	(0.183)
Seed sq.	0.936***	0.337	2.280***	0.744***	0.378	2.074***
	(0.235)	(0.400)	(0.361)	(0.239)	(0.489)	(0.501)
Herbicides sq.	-0.609***	-0.619***	-3.073***	-0.597***	-0.441	-3.009
	(0.132)	(0.154)	(0.654)	(0.178)	(0.373)	(3.307)
Output sq.	-0.102***	-0.055	-0.181***	-0.070**	-0.057	-.158**
	(0.026)	(0.036)	(0.039)	(0.029)	(0.038)	(0.074)
Farm size*labour	-0.035	-0.066	-0.174	-0.185	-0.127	-0.181
	(0.147)	(0.189)	(0.340)	(0.129)	(0.218)	(0.741)
Farm size*Seed	-0.702***	-0.008	-2.020***	-0.714***	0.086	-1.878***
	(0.228)	(0.338)	(0.350)	(0.244)	(0.441)	(0.574)
Farm size*herbicides	0.837***	0.703***	1.678***	0.839***	0.857	(1.628)
	(0.223)	(0.256)	(0.644)	(0.220)	(0.602)	(1.463)
Farm size*Output	-0.084	0.009	-.240***	-0.027	0.096	-0.220
	(0.056)	(0.086)	(0.089)	(0.061)	(0.107)	(0.136)
Labour *Seed	-0.010	-0.175	0.619**	0.058	0.237	0.557*
	(0.164)	(0.264)	(0.256)	(0.154)	(0.320)	(0.301)
Labour*Herbicides	0.186	0.355**	-0.453	0.143	0.112	-0.452
	(0.140)	(0.171)	(0.492)	(0.171)	(0.378)	(2.767)
Labour*Output	0.252***	0.254**	0.240***	0.312***	0.289**	0.261**
	(0.063)	(0.101)	(0.082)	(0.078)	(0.119)	(0.105)
Seed*Herbicides	-0.548***	-0.299	-0.705*	-0.515**	-0.438	-0.668
	(0.185)	(0.257)	(0.398)	(0.219)	(0.407)	(2.952)
Seed*Output	-0.120	-0.213	-0.300	-0.099	-0.032	-0.245
	(0.111)	(0.174)	(0.184)	(0.158)	(0.171)	(0.314)
Herbicide*Output	0.124	0.090	0.073	0.020	-0.026	0.118
	(0.094)	(0.109)	(0.443)	(0.120)	(0.373)	(2.648)
Lambda	0.651	0.346	0.715***			
	(42.345)	(74.441)	(0.189)			
Sigma	0.603***	0.639***	0.534***			
	(0.0014)	(0.003)	(0.003)			
Sigma(u)				0.903***	0.965***	0.388*
				(0.047)	(0.051)	(0.233)
Sigma(v)				0.264***	0.172***	0.416***
				(0.035)	(0.041)	(0.070)
Rho(w,v)				0.305	0.355	-0.044
				(0.635)	(1.657)	(0.828)

Note: ***, ** and * represent 1%, 5% and 10% level of significance, respectively
Source: Field survey, 2019

The coefficient of unit cost of land was 0.162, which is marginally significant at the 10% level. The positive coefficient suggests that, in the research area, as the value of land increases by 100%, cost of soybean production will increase by 16.2 percent for all soybean farmers, holding other factors constant. This conclusion is supported by [49] and [12].

The coefficient of the unit cost of seed was found to have positive coefficient (0.565) associated with cost of soybean production and it is significant at 1% level. As seed cost increases by 100%, cost of soybean production will increase by 56.5% for all soybean farmers, holding other factors constant. Seeds are one of the major farm inputs in production process. This finding is in line with the findings of [12**]** who found that the cost of seeds can lead to an increase in total cost of production in Ghana. [13] in Swaziland came to similar conclusions. Farmers have been encouraged to adopt improved/certified seeds in production to reap benefits such as drought and pest tolerance. However, these seeds are mostly costly compared to the conventional seeds used for production. Adoption of improved seeds results in a higher cost of production.

A positive relationship (0.863) was found between the cost of agrochemicals and the cost of producing soybeans, which is statistically significant at the 1% level. When all other factors remain constant, a 100 percent increase in the cost of agrochemicals will result in an 86.3 percent increase in the cost of soybean production. In Ghana, [12] found something similar.

As expected, the output of soybean in kilogram had positive association with cost of production. The output coefficient is 0.156, and it is statistically significant at 1%. In other words, if soybean output is increased by 100%, the total cost of soybean production will increase by 15.6 percent. This finding corroborates the findings of two Ghanaian studies, [12] and [5].In the production process, if the output (productivity) is higher, it increases cost of production.

Sixty percent (60%) of the squared and interaction terms had statistically significant effects on total production cost, indicating that the translog cost functional form is appropriate. The total cost of production increased or decreased for all second order terms; the coefficients of the squared terms for farm size, labour cost, seed cost, agrochemicals cost, and output. The squared terms explain the long-term effects of input prices on total cost of production. For instance, in future, 100% increase in labour cost and output would increase and decrease total cost of production by 5.9% and 10.8% respectively, *ceteris paribus*.

The interaction terms show whether the variables are complements or substitutes in cost of production. If the two interaction variables have positive coefficient, it means that the variables are complements while negative means the variables are substitutes. Variables that have negative coefficients and statistically significant effects on total cost of production include farm size and seed cost and seed and agrochemicals. On the other hand, the interaction terms for farm size and agrochemicals as well as and labour cost and output cost were found to have positive coefficients.

Columns 2 and 3 of Table 4 present the determinants of costs of production by contract and non-contract soybean farmers. The first order variables used for the analysis all had positive coefficients but only farm size, soybean seed and agrochemical significantly exerted some effects on cost of soybean production.

The study found that farm size allocated for soybean production under CF has a positive coefficient of 0.342, which is highly significant at the 1% level. This means that, if all other factors remain constant, increasing farm size for soybean production by 100% in the case of contract farmers will result in a 34.2 percent increase in total production costs. The positive coefficient of farm size could also mean that contract farmers are more efficient in soybean production. Ideally, farmers who are into CF have access to farm inputs and this makes them to expand their farm sizes to enjoy economies of scale.

On the part of non-contract farmers, farm size was found to have inverse relationship to total cost of production of soybean. It had a -0.224 coefficient and was marginally significant at the 10% level. This means that if farm size is increased by 100%, the total cost of soybean production will be reduced by approximately 22.4 percent. This finding does not meet our *a priori* expectation, it is inconsistent with the findings of [20] who found a direct relationship between farm size and total cost of tea production in Vietnam.

In the study area, the price of soybean seed had a positive and statistically significant effect (coefficient=1.531) on total cost of production for contract farmers. This means that if the unit price of soybean seed for planting increases by 100%, the total cost of soybean production will rise by 153.1

percent, assuming all other variables remain constant. Access to soybean seeds, particularly improved/certified seeds is a key factor to participation in CF and productivity. As farmers have access to certified seeds, productivity is assured to increase thereby improving the welfare of smallholder farmers in the rural areas.

For non-contract farmers, both soybean seeds and agrochemical usage were found to have positive coefficients of 1.020 and 2.761 respectively and both are highly significant at 1% levels. The indication is that increasing the use of seeds and agrochemicals by 100% will result in a 102 percent and 276 percent increase in the total cost of soybean production, respectively. However, at the 1% level, output was found to have a positive coefficient of 0.256 and a statistically significant effect on total cost of production of non-contract farmers. This means that if non-contract farmers increase their output of soybeans by 100%, the total cost of production will increase by almost about 26%. This finding is consistent with the findings of [5].

Only herbicide squared variable was found to have a significant impact on total cost of soybean production in the second order of variables for the pooled, CF and NCF. The herbicide squared has a coefficient of -0.609 for pooled, -0.619 for CF and -3.073 for NCF. The explanation to this effect is that the continuous use of herbicides on the same land will reduce total cost of production of the crop by about 61% for the pooled, 62% for CF and 307% for NCF.

Reducing the use of herbicide lowers the total cost of production. The health of consumers is also not threatened by these inorganic chemicals. Similarly, agrochemical usage and output square terms both have a negative relationship with the total cost of non-CF soybean production in the study area. Also, the output for contract farmers had a coefficient of -0.181, which is significant at the 1% level on the total cost of soybean production for non-contract farmers.

The interaction terms of the variables (third order term) found to have a positive effect on the total cost of production for contract farmers were farm size and agrochemicals; labour and agrochemicals; and labor and soybean output. These interaction term variables are all statistically significant and have positive coefficients, meaning that they are complements in usage to reduce total cost of soybean production.

Similarly, for non-contract farmers the interaction terms of farm size and agrochemicals; labour and seed; and labour and output all have positive coefficients and statistically significant effects on non-contract farmers total cost of soybean production in the area. This means that the variables are complements in soybean production to reduce total cost of production by non-contract farmers. Additionally, farm size and seed; farm size and output; and seed and agrochemicals were found to exert negative coefficients effects on total cost of soybean production. They were all significant.

5. CONCLUSIONS AND RECOMMENDATIONS

The study reveals that farm size, labour, and agrochemical usage are key drivers of soybean output for both contract and non-contract farmers. Contract farmers show higher returns to scale, while non-contract farmers experience decreasing returns. Farm size, seed cost, agrochemical usage, and output also influence production costs.

The results alsoreveal complementary and substitute relationships between input variables like farm size, labour, and agrochemicals, while substitution effects exist between variables like farm size and seed cost. Negative coefficients suggest decreasing marginal returns, emphasizing the need for efficient input management strategies.

The study suggests several recommendations to improve soybean production productivity and cost efficiency. These include targeted interventions for contract and non-contract farmers by stakeholders and policymakers. Further more, government agencies and contracting firms should collaborate effectively to ensure quality inputs are delivered to farmers, strengthen extension services and training, and foster collaborations between agribusinesses, farmers' organizations, and research institutions. These measures aim to improve smallholder farmers' livelihoods, promote food security, and drive industry growth and sustainability.

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