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Determinants of Economic Farm-Size–Efficiency Relationship in Smallholder Maize Farms in the Eastern Cape Province of South Africa

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Abstract: The economic farm-size–efficiency relationship for maize remains unclear. A question that has yet to be answered conclusively is whether farm size affects productivity. The debate on land-appropriation-without-compensation ultimately revolves around the optimal land size and conditions under which farmers can benefit from a more rational utilization of available land. As important as the farm-size–efficiency debate is, it has not received much attention since the launch of the land reform programme. Again, the farm sizes examined in the previous studies reflected large-scale commercial agriculture and were mainly in relation to wheat production rather than the dietary staple of maize. This paper applied parametric efficiency measures under alternative distributional assumptions to data generated from 267 maize-farming households, to understand the economic farm-size–efficiency relationships and their determinants. It emerged that, while farm size is a key determinant of economic efficiency in maize production, its effect on technical efficiency is still contested. Findings suggest that farmer support should be prioritized, and the government's efforts to make farmers more productive should emphasize gender equity and optimal use of land.

Keywords: economic farm size; trans-log stochastic frontier; land reform; cost and economic efficiency

1. Introduction

Maize dominates the South African food system, being both a dietary staple [1] and crucial commodity in food security and reduction of malnutrition [2]. However, producing more of this crop by expanding the area cultivated among black farmers has come up against severe challenges [3,4], including the on-going land reform programme which is failing to effectively redistribute the land held by white commercial farmers. At the same time, traditional tenure practices continue to concentrate land in the hands of local chieftains and their cronies [5]. Thus, the unequal distribution of agricultural land that was institutionalized by apartheid rule to the disadvantage of the black population has remained unchanged, as farm sizes remain small within black areas [6]. According to Moyo [7], much of the deteriorating welfare conditions in SA derive from the slow pace of land reform and restricted access to farming inputs. In addition, Moyo [8], Cotula et al. [9], as well as Jayne et al. [10], reported that inequitable land distribution is a legacy of apartheid, which prevented SA black farmers from competing in the agricultural market [11].

The African National Congress (ANC) government is now considering changes in the relevant provisions in the legislation to allow for land expropriation without compensation to hopefully accelerate the pace of the land reform process [12]. Redistributing resources is important because land ownership distribution was the driving force behind the struggle of the black population [13].

The sense of urgency to achieve redress is also manifested in the plethora of government programmes accompanying the land reform programme [14].

At the very highest levels, the government's commitment to creating jobs and reducing inequality and poverty in the nation has been regularly stressed [15]. To achieve these goals, it is often stated that the government is committed to revitalizing the irrigation schemes in the poor areas of the country. During his presidency (2009–2017), President Jacob Zuma promised that infrastructures would be rehabilitated as a means to rebuild and uplift communities around the irrigation schemes and stimulate profitable agribusiness through a comprehensive programme that would train and build farmers' capacity to manage their businesses profitably and sustainably [15].

In spite of this, there has been huge disgruntlement and disappointment about the implementation of land reforms. The earlier expectation was that by 2014, the black farmers' ownership of the country's agricultural land would have increased by as much as 30% [6]. Despite the actions taken by the government to redress the legacy of apartheid, evidence [6,7,13,14] shows that the land transfer process under the land reform programme has been far from efficient, with the slow pace resulting in that deadline being missed. Expectedly, the substantial investment for restructuring the agricultural sector has failed to yield the anticipated redistribution of land and improvements in rural welfare, especially for the black population. At present, particularly in the former homeland of SA, farmlands have become smaller and crops are cultivated mostly on food plots and homestead gardens where farmers live [16]. At the same time, practices remain traditional and basic, inevitably resulting in the persistent low productivity of smallholder agriculture [17].

2. Literature Review

Seeking answers to the question as to the role of farm size in farm productivity, several studies have focused on the relationship between farm size and performance of farms. In relation to that, studies have evaluated the socioeconomic and political precursors of concerns over land availability, distribution, and implications for levels of farm investment. In addition, the literature has examined government farmer support arrangements such as public subsidies and their effects on cultivated area and productivity achieved in terms of diverse efficiency measures.

The South African land question is still hotly debated on both academic and policy platforms. A situation where the minority white population owned the bulk of the agricultural land remains puzzling, and largely explains the discontentment among the black population [6]. Inequality in the distribution of landownership [16] is seen to account for worsening poverty and delay in the emergence of a modern growth economy [18]. It is contended that unequal distribution of landownership does this through stalling the development of institutions that create or promote human–capital institutions such as government-owned schools [18]. Without a doubt, the effect will differ from country to country and may be pervasive in some, as noted by an Advisory Panel set up to guide the government on the expropriation proposal [19]. For instance, the Panel deplores the continuing deprivations faced by the black population on account of the enduring legacy of land dispossession through forced removals and various coercive and repressive actions by the erstwhile Apartheid regime in South Africa [19,20]. It would seem that, regardless of the form that land dispossession takes, be it the communist collectivization process implemented in Slovenia [21], or the forced removals in South Africa, it almost always results in the arrested development of one group or the other as a consequence of the inequalities it engenders.

According to Bojnec and Ferto [22], farm size is often employed to explain differences in farm performance. The question is: does farm size affect agricultural productivity? Theoretically, farm size influences a range of farm resource allocation decisions, including labour use patterns [22]. The reasons adduced for such influence include " ... production and pecuniary economies of size, management ability to cope with risk management strategies, and the likelihood of off-farm employment" [23], as cited by [22]. The contention surrounding more land may arise from the common-sense notion that "more is better than less" and that agricultural development should be accompanied by more resources, including land, per production unit, which invariably translates to increasing farm size. According to Gollin [24], the narrative that expansion of farm size is consistent with "agricultural development and economic growth" is a commonly held one. The fact that developed countries generally have larger average farm sizes than poorer, less developed countries [24] could be a natural driver of the desire for more land in poorer countries. However, in the face of growing land shortage under the pressure of expanding populations, which in turn leads to the need for a larger output from farms, there is both academic and policy interest to assess the role of farm size in agricultural productivity.

Sen [25], Berry and Cline [26], Cornia [27], Bhatt and Bhat [28], Ladvenicova and Miklovicova [29], and Akudugu have reported a negative relationship between farm size and productivity [30] across the world. Studies carried out in transitional economies such as Slovenia have yielded diverse and sometimes contradictory results [21,22] The assumed relationship which informed the whole question of redistributing land seems to lack credibility within the SA context, where it is difficult to relate output to land holding. In their seminal work, Sen [30] and Shultz [31], drew the same conclusion. This negative relationship presented smallholder farmers as efficient and productive farming units. However, interventions to improve the livelihooods of small farmers have not borne out these theoretical or empirical findings (Berry and Cline [26]; Deolalikar [32]; Cornia [27]; Binswanger et al. [33]; Vollrath [34]; Hazell [35]) in different contexts that contend that farm size and the performance of farms are inversely related. The same relationship was observed in data obtained from households in Kenya, Malawi, Tanzania and Uganda [36]. Given these conflicting claims, it is difficult to be definitive about the farm-size–efficiency nexus in the case of South Africa. Several notable commentators, including Van Zyl et al. [37], have expressed misgivings about studies that attempt to measure economies of scale in South African commercial agriculture in the pre-reform era, describing them as "not reliable". More significant is that the studies in which Van Zyl et al. [37] and Ngwenyi et al. [38] disputed quite animatedly in the early- to mid-1990s referred exclusively to commercial agriculture, where land holdings ranged between 32 and 4700 ha (Van Zyl [39]), which do not apply to small farms in the former homeland areas [16] in the current era of agricultural restructuring and intensified efforts to integrate black farmers into the nation's agricultural economy. Concern over the pace of the land reform programme is definitely not helped by advice that are not based on "sound analysis", as Van Zyl et al. [36] enjoined. The fact that those earlier studies focused on wheat production is also significant; maize is not only the dietary staple, but is also the most popular crop in the smallholder farming system. According to Thapa and Gaiha [40], the farm-size–efficiency relationship varies with the food commodity group analyzed.

Information clarifying the farm-size–efficiency relationship and its determinants are important policy indicators for policy makers to chart the interventions capable of increasing the food production capacity of farmers. Therefore, an informed decision is relevant to gaining a better understanding of the economic farm-size–efficiency relationship and to provide better guidelines on how to pursue the land reform programme.

The present study revisits the foregoing questions with respect to smallholder maize production for the first time in the country. In line with this, the study estimates the output elasticity with respect to each of the inputs used. Similarly, it estimates the total cost elasticity with respect to each input's average cost and identified causal factors. In a situation where about 25 years of agrarian reforms have produced little or no change in small farmer circumstances, interrogating these fundamental questions is urgent. The remaining sections of this paper present and discuss the results regarding the aforementioned objectives and conclude with appropriate recommendations.

3. Materials and Methods

3.1. Study Area

The research was conducted in the Eastern Cape Province, South Africa [16]. The area presents agrarian scenery (cultivated food crop fields and livestock herds) interspersed with a small number of agro-industrial and eco-tourism infrastructures. An estimated 6,562,053 people reside in this area, of which the majority (60%) reside in rural areas, where the poverty rate is high. About 2.5 million residents are unemployed, compelling a large proportion of the population to rely on diverse government grants [41].

3.2. Sampling Method and Data Collection

On account of its historical significance from the perspective of the struggle for land, the study area was purposely selected. Two district municipalities, namely the Amathole and Chris Hani District municipalities, were selected purposely out of the six in the province. Within each district, one local municipality was selected so as to enumerate the functional irrigation schemes selected from eight revitalized schemes because they were the only ones in which significant farming activities were taking place.

Within the 12 villages selected from the two local municipalities, a total of 300 households were registered and participating on the irrigation schemes. Given the high heterogeneity of the households, it was difficult to determine a sampling procedure to yield a representative sample. It was therefore decided to enumerate all the 300 households. In the end, only 267 questionnaires, representing 89% of the total enumerated sample, were considered sufficiently valid to be included in the final analysis, the rest being either improperly completed or returned uncompleted.

3.3. The Data

The questionnaires administered during structured single-visit interviews on respondents were the primary data collection instruments. Respondents were household heads or persons in a position to make decisions on resource allocation for their households. Table 1 also presents a description of the data, their measurement types and their hypothesized relationship with the dependent variables. Data collection began in October 2017 and was completed in June 2018. The field data were subsequently cleaned and coded in a spreadsheet to facilitate data entry into Stata 14 and SPSS 25 for the analyses. Some transformations were also performed to generate the interaction terms. Costs and time constraints made it necessary to limit the study to the Eastern Cape Province. A more national study is required to better understand the land dynamics in South Africa.

Table 1. Data collected/transformed for the study.

Variable	Description	Measurement Type	A Priori Expectation (+/−)
Age	Age of farmer in years	Continuous	
Gender	The sex of the farmer (male/female)	Dummy	+/−
Education	Number of years spent in school by farner	Continuous	+
Experience	Years in farming	Continuous	−
Area Cultivated	Land area in hectares	Continuous	−
Land Inequality	Land inequality index based on Gini Coefficient	Continuous	+
Irrigated Land Inequality	Ratio of Irrigated Land to Total Cultivated Area	Continuous	+
Total Labour Intensity	Number of persons employed per unit land cultivated	Continuous	+
Family Labour Intensity	Family Members Working Working on Farm per unit land cultivated	Continuous	+
Fertilizer	Quantity of fertilizers used on maize and cabbage (Kg)	Continuous	+
Cost of Land	Amount paid (rent) for the land under cultivation (Rand)	Continuous	+
Cost of Labour	Amount paid for use of labour (Rand)	Continuous	+
Cost of Seed	Total expenditure on seeds (Rand)	Continuous	+
Total Production	Quantity of output produced (Kg)	Continuous	
Value of Output	Market value of physical output	Continuous	
Total Revenue	Total amount realized from sales of output	Continuous	+
Marital Status	Whether or not farmer is married	Dummy	+
Association	Whether or not farmer belongs to association	Dummy	+
Access to credit	Availability of accessible credit (yes/no)	Dummy	+
Access to Extension	Frequency of Extension Visits	Continuous	+
Main Occupation	What the farmer considers as "Main"	Dummy	+/−
Irrigation	Whether or not farmer applied irrigation	Dummy	+
Mode of acquisition of land	The mode of acquisition	Dummy	+/−
Location of Project	Which of the two administrative areas respondent is located	Dummy	+/−

Source: Field Survey, 2017–2018.

3.4. Model

The literature has revealed the popularity of Least Square techniques for estimating the farm-size–yield-per-acre relationship (Mburu et al. [42]; Ladvenicová and Miklovičová [29]; Msangi [43]). This model suggests an inverse relationship when total output (Q) and β are less than 1, and also when total output (Q) per acre and β are negative [44]. However, a major gap in many of these studies, according to Bardhan [45] is that they assume homogeneity in farm output, whereas the total value of output is crop-specific. Put differently, these studies are usually spurious because the value of crops is different across crop types or the same for crops across regions. However, Nkonde [46] and Abdi [47] have maintained that OLS remains important in assessing the farm-size–yield-per-acre nexus, and studies of Mburu et al. [42]; Nkonde [46]; Msangi [43] have accordingly adopted OLS.

Alternatively, a range of deterministic and stochastic models, including the stochastic frontier analysis, the Data Envelopment Analysis (DEA) model and several productivity indices based on growth accounting and index principles [48] have been applied. These approaches have typically assessed inverse relationships. The deterministic frontier techniques account for deviation from the frontier arising from inefficiencies. It follows that the deterministic approach relaxes the attention paid to property of error in measurement and other noise [49].

According to Aiger et al. [50,51], the stochastic frontier approach provides an edge over the former as it accounts for random effects such as hazards and measurement error. While it has an outstanding strength in estimating single output, its application on multiple outputs requires data disaggregation and price data which are mostly difficult to access in transition economies. In addition, Lansik [51] reported that varying production technology renders SFA unsuitable, citing production function as an approach that is firm-specific.

Extensive use of non-parametric approaches has been widely reported. With the Data Envelopment Analysis (DEA) approach, the assumption imposed by functional forms and error term distribution is eliminated by linear programming which uses a system of equations to disclose the best frontier practices [51]. DEA facilitates the simultaneous estimation of multiple input–output scenarios [52]. Any deviation from the frontier reflects inefficiency [53,54]. However, Gorton and Davidona [55] contend that data with statistical noise are usually spurious because DEA overestimates the frontier relative to the parametric approach, since frontier is firm-specific, as indicated earlier.

In addition to the foregoing approaches, researchers have also advocated for Malmquist or Tornquist–Theil productivity indices [56]. Although their statistical consistency cannot be guaranteed, they permit adequate consideration of inputs and outputs. They are easy to compute and they can analyse small samples, an attribute that makes them very popular for studying dynamic economies.

According to Amaechi et al. [57] and Alufohai et al. [58], the translog model affords the opportunity to assess if the deviation from the expected production output arises from stochastic error and/or inefficiency terms. It shows the inefficiency of farmers and factors that are beyond the control of farmers [59]. The Cobb–Douglas Production Function is a convenient model but a number of researchers have drawn attention to certain restrictions that need to be imposed for it to run efficiently, including theoretical consistency and concavity [60–62]. With these principles in mind, the model was employed to assess the relationship between economic farm size and efficiency in respect to maize and specified as

$$\begin{aligned} n(PROT_i) = \beta_{07} \quad & +\beta_{17} ln(FMSZ_{1i}) + \beta_{27} ln(FET_{2i}) + \beta_{37} ln(SED_{3i}) + \beta_{47} ln(LAR_{4i}) \\ & +\tfrac{1}{2}\beta_{57}[ln(FMSZ_{1i})]^2 + \tfrac{1}{2}\beta_{67}[ln(FET_{2i})]^2 + \tfrac{1}{2}\beta_{77}[ln(SED_{3i})]^2 \\ & +\tfrac{1}{2}\beta_{87}[ln(LAR_{4i})]^2 + \beta_{97} ln(FMSZ_{1i}) * ln(FET_{2i}) + \beta_{107} ln(FMSZ_{1i}) \\ & * ln(SED_{3i}) + \beta_{117} ln(FMSZ_{2i}) * ln(LAR_{4i}) + \beta_{127} ln(FET_{2i}) \\ & * ln(SED_{3i}) + \beta_{137} ln(FET_{2i}) * ln(LAR_{4i}) + \beta_{147} ln(SED_{3i}) \\ & * ln(LAR_{4i}) + V_i - U_i \end{aligned} \tag{1}$$

where:

PROT = Production Output valued in Rand, FMSZ = Farm Size measured in hectare, FET = Fertilizer, total quantity applied in Kilogram, SED = Seed, total value in Rand and quantity measured in Kilogram, LAR = Labour workday (amount of labour used), ln = Natural logarithm, β_{07} = Intercept term, β_{17} through β_{47} = First derivatives, β_{57} through β_{87} = Own second derivatives, β_{97} through β_{147} = Cross second derivatives, $[ln(FMSZ_{1i})]^2$ = the log of Farm size Squared, applied to other inputs (fertilizer, seed and labour), $ln(FMSZ_{1i}) * ln(FET_{2i})$ = the interaction between farm size and fertilizer, and interactions between other inputs following the same pattern, and, lastly, the composite error term, $(V_i - U_i)$, which allows the model to accommodate both uncontrollable (represented by V_i) and controllable (represented by U_i) disturbances in the production process [63]. The distribution of the controllable disturbance component, U_i, depends on the estimation approach; for the one-step approach, the half-normal distribution with truncation on the left at zero is assumed as [63]:
$U_i \sim N(0,\sigma(z,\delta)^2)^+$,
which depicts its zero mean and truncated variance. It is assumed that a vector z of exogenous variables determines the size/level of the error term [64]. In the 2-step estimation approach, the controllable disturbance term U_i is assumed not to depend on the vector of expogenous variables z_i, being normally and independently distributed as [63,64]:
$U_i \sim N(0,\exp(2z_i'\delta)\sigma_u^2)^+$

According to Schmidt [65], it is this assumption that creates the problem of omitted variables bias in the estimates and results in the size of the error being either over- or under-stated.

The output elasticity with respect to each input is stated as

$$\frac{\partial \mathrm{lnPROT_i}}{\partial \mathrm{lnFMSZ_{1i}}} = \beta_{17} + \beta_{57}\ln(\mathrm{FMSZ_{1i}}) + \beta_{97}\ln(\mathrm{FET_{2i}}) + \beta_{107}\ln(\mathrm{SED_{3i}}) + \beta_{117}\ln(\mathrm{LAR_{4i}}) \tag{2}$$

$$\frac{\partial \mathrm{lnPROT_i}}{\partial \mathrm{lnFET_{2i}}} = \beta_{27} + \beta_{67}\ln(\mathrm{FET_{2i}}) + \beta_{97}\ln(\mathrm{FMSZ_{1i}}) + \beta_{127}\ln(\mathrm{SED_{3i}}) + \beta_{137}\ln(\mathrm{LAR_{4i}}) \tag{3}$$

$$\frac{\partial \mathrm{lnPROT_i}}{\partial \mathrm{lnSED_{3i}}} = \beta_{37} + \beta_{77}\ln(\mathrm{SED_{3i}}) + \beta_{107}\ln(\mathrm{FMSZ_{1i}}) + \beta_{127}\ln(\mathrm{FET_{2i}}) + \beta_{147}\ln(\mathrm{LAR_{4i}}) \tag{4}$$

$$\frac{\partial \mathrm{lnPROT_i}}{\partial \mathrm{lnLAR_{4i}}} = \beta_{47} + \beta_{87}\ln(\mathrm{LAR_{4i}}) + \beta_{117}\ln(\mathrm{FMSZ_{1i}}) + \beta_{127}\ln(\mathrm{FET_{2i}}) + \beta_{147}\ln(\mathrm{SED_{3i}}) \tag{5}$$

Furthermore, the Cobb–Douglas Stochastic Frontier cost function stated below was employed to assess the cost structure of maize production. Its choice is premised on the low variation in the data which did not allow the fitting of the trans-log function.

$$\begin{aligned}\ln(\mathrm{TOCP_i}) = \beta_{01} \quad & +\beta_{11}\ln(\mathrm{COFS_{1i}}) + \beta_{21}\ln(\mathrm{COSF_{2i}}) + \beta_{31}\ln(\mathrm{COSD_{3i}}) + \beta_{41}\ln(\mathrm{COLR_{4i}}) \\ & +\beta_{51}\ln(\mathrm{VAPT_i}) + \mathrm{V_i} - \mathrm{U_i}\end{aligned} \tag{6}$$

where:

TOCP = Total cost of production (Total cost in Rand), COFS = Cost of farm size (Total cost in Rand), COSF = Cost of fertilizer (Total cost in Rand), COSD = Cost of seed (Total cost in Rand), COLR=Cost of labour (Total cost in Rand), VAPT = Value of Agricultural Product, ln = Natural logarithm, U_i = Non-negative cost inefficiency error term is assumed to be normally distributed, β_{1i} = Cost output elasticities with respect to input. All costs of inputs are average values.

The total cost elasticity in respect to each input's average cost was estimated using the following equations

$$\frac{\partial \mathrm{lnTOCP_i}}{\partial \mathrm{lnCOFS_{1i}}} = \beta_{12} + \beta_{52}\ln(\mathrm{COFS_{1i}}) + \beta_{92}\ln(\mathrm{COSF_{2i}}) + \beta_{132}\ln(\mathrm{COSD_{3i}}) + \beta_{142}\ln(\mathrm{COLR_{4i}}) \tag{7}$$

$$\frac{\partial \ln \mathrm{TOCP_i}}{\partial \ln \mathrm{COSD_{3i}}} = \beta_{32} + \beta_{72}\ln(\mathrm{COSD_{3i}}) + \beta_{112}\ln(\mathrm{COSF_{2i}}) + \beta_{122}\ln(\mathrm{COFS_{1i}}) + \beta_{132}\ln(\mathrm{COLR_{4i}}) \quad (8)$$

$$\frac{\partial \ln \mathrm{TOCP_i}}{\partial \ln \mathrm{COSD_{3i}}} = \beta_{32} + \beta_{72}\ln(\mathrm{COSD_{3i}}) + \beta_{112}\ln(\mathrm{COSF_{2i}}) + \beta_{122}\ln(\mathrm{COFS_{1i}}) + \beta_{132}\ln(\mathrm{COLR_{4i}}) \quad (9)$$

$$\frac{\partial \ln \mathrm{TOCP_i}}{\partial \ln \mathrm{COLR_{4i}}} = \beta_{42} + \beta_{82}\ln(\mathrm{COLR_{4i}}) + \beta_{122}\ln(\mathrm{COSF_{2i}}) + \beta_{132}\ln(\mathrm{COSD_{3i}}) + \beta_{142}\ln(\mathrm{COFS_{1i}}) \quad (10)$$

These elasticities represent the percentage change in the total cost of maize production in respect to the cost of each of the inputs. The elasticity represents the effect of additional unit of input used which results in constant (Ep = 1), increasing (Ep > 1), or decreasing (Ep < 1) productivity. The addition of all the elasticities yields the rate of return to production. This depicts the stage of production (that is, whether it is stage 1, 2 or 3 of the production function) at which farmers operate, as noted in a study of cassava production in Nigeria [65].

3.4.1. Determinants of Technical Efficiency

This study employed the two-step estimation approach as default in which the effect of farm size on the technical efficiency level of the farmers was assessed by means of the Ordinary Least Square (OLS) regression technique. Subsequently, the one-step approach was run to test the reliability of the initial estimates. The one-step estimate followed the procedure described by Kumbhakar and Wang [59], and Belotti, Daidone, Ilardi and Atella [60] and employed the Battese and Coelli model and truncated distribution. To obtain the estimates of the technical inefficiency by means of the one-step approach, the emean command was used. Both estimates are presented in this paper and show that the concern about persistent bias associated with the two-step approach was not obvious in this case.

Heterogeneity was controlled by including respondent's socioeconomic attributes. The study on cassava production in Nigeria [65] denoted technical efficiency as the ratio of the observed output to the maximum feasible output which mathematically appears as

$$TE_i = \frac{Y_i}{\hat{Y}_i} \quad (11)$$

where:

TE_i = Technical efficiency, Y_i is Output in Rand, $\hat{Y}_i$ = Expected output in Rand based on the chosen production frontier; $0 \leq TE_i \leq 1$.

The empirical model was estimated as

$$\begin{aligned} \mathrm{U_i} = \delta_{01} + \delta_{11}\mathrm{SEX_{1i}} + \delta_{21}\mathrm{MAR_{2i}} + \delta_{31}\mathrm{EDU_{3i}} + \delta_{41}\mathrm{HHSZ_{4i}} + \delta_{51}\mathrm{ASON_{5i}} + \delta_{61}\mathrm{EXT_{6i}} \\ + \delta_{71}\mathrm{CRED_{7i}} + \delta_{81}\mathrm{MAON_{8i}} + \delta_{91}\mathrm{EXP_{9i}} + \delta_{101}\mathrm{FRZE_{10i}} + \theta \end{aligned} \quad (12)$$

where:

SEX = Sex, MAR = Married, EDU = Education, HHSZ= Household size, ASON = Association, EXT = Extension, CRED = Credit, MAON = Main Occupation, EXP = Experience, FRZE = Farm SIze, δ_{01} = Intercept term and $U_i = 1 - TE_i$ Technical inefficiency.

3.4.2. Determinants of Cost Efficiency Model

The relationship between the socioeconomic characteristics of the respondents and the efficiency with respect to cost is estimated by means of the following model

$$\begin{aligned} \mathrm{U_i} = \delta_{02} + \delta_{12}\mathrm{SEX_{1i}} + \delta_{22}\mathrm{MAR_{2i}} + \delta_{32}\mathrm{EDU_{3i}} + \delta_{42}\mathrm{HHSZ_{4i}} + \delta_{52}\mathrm{ASON_{5i}} + \delta_{62}\mathrm{EXT_{6i}} \\ + \delta_{72}\mathrm{CRED_{7i}} + \delta_{82}\mathrm{MAON_{8i}} + \delta_{92}\mathrm{EXP_{9i}} + \theta \end{aligned} \quad (13)$$

where:

$U_i = CE_i = \frac{C}{\hat{C}_i}$, C_i is realized cost of production, $\hat{C}_i$ = is the expected cost of production based on the cost frontier, Z_{ji} = Socio-economic characteristics, δ_{j2} = Partial regression coefficients, δ_{01} = Intercept term.

The allocative efficiency of the ith farmer can then be deduced as

$$AE_i = \frac{1}{CE_i} \tag{14}$$

where:

$$0 \leq AE_i \leq 1 \text{andwhere} CE_i \geq 1$$

The economic efficiency level of the respondents was estimated using the following ratio

$$EE_i = TE_i * AE_i \tag{15}$$

where:

$$0 \leq EE_i \leq 1 \tag{16}$$

4. Results and Discussion

4.1. Descriptive statistics of Farmer and Farm Characteristics

The mean values of the variables modelled for each of the study sites as well as the combined dataset are presented in Table 2 along with their statistical significance for the sampled farmers.

Table 2. Summary statistics of modelled variables.

Variables	Combined (267)	Qamata (182)	Tyhefu (86)	Diff. Test
Age [a]	61 (12.60)	62 (12.56)	58 (12.26)	−2.65 ***
Education [a]	5 (4.48)	6 (4.67)	5 (3.98)	−1.94 *
Household size [a]	5 (2.43)	4 (2.13)	5 (2.94)	2.15 **
Experience [a]	13 (12.38)	17 (12.91)	6 (6.69)	−7.37 ***
Farm cultivated [a]	1.07 (0.97)	1 (1.11)	1 (0.52)	−1.95 *
Land inequality [a]	0.30 (0.13)	0.34 (0.13)	0.21 (0.07)	−8.97 ***
Ir. land intensity [a]	0.95 (1.09)	0.83 (1.22)	0.36 (0.28)	−6.56 ***
F. lab to total lab [a]	0.15 (0.08)	0.15 (0.08)	0.19 (0.04)	1.85 *
Total lab intensity [a]	53.17 (43.52)	52.77 (43.4)	59.08 (46.88)	0.48
Quantity of fert [a]	56.08 (94.04)	77.83 (104.2)	10.56 (39.90)	−5.78 ***
Cost of fertilizer [a]	871.39 (1645.2)	1207.39 (1873.6)	168.15 (553.8)	−5.04 ***
Cost of land [a]	450.94 (409.8)	484.36 (470.4)	380.22 (221.4)	−1.95 *
Cost of labour [a]	778.60 (687.1)	1038.59 (657.9)	228.37 (332.1)	−10.78***
Cost of seed [a]	602.76 (1252.7)	835.17 (1451.3)	116.05 (319.7)	−4.51 ***
Cost of production [a]	2695.05 (3253.1)	3566.2 (3585.4)	870.75 (971.5)	−7.09 ***
Output Value [a]	9486.74 (24631.7)	10633.56 (26210.2)	2057.39 (5271.8)	−1.56
Total income [a]	7794.94 (4733.0)	8487.66 (4362.1)	6328.94 (5162.2)	−3.56 ***
Per capita income [a]	2300.36 (2085.6)	2613.13 (2260.4)	1638.47 (1459.4)	−3.65 ***
Gender [b]	176 (66)	134 (76)	42 (24)	−4 ***
Married [b]	195 (73)	132 (68)	63 (32)	0.13
Association [b]	163 (61)	147 (90)	16 (10)	−9.73 ***
Access to credit [b]	12 (4)	4 (33)	8 (67)	2.62 ***
Extension [b]	164 (61)	128 (78)	36 (22)	−4.46 ***
Main occupation [b]	245 (91)	160 (65)	85 (35)	2.98 ***
Irrigators [b]	181 (68)	126 (70)	55 (30)	−0.86
Restitution [b]	9 (3)	9 (100)	0 (0)	−2.09 **
Redistribution [b]	75 (28)	4 (5)	71 (95)	13.68 ***
Ngqushwa [b]	75 (28)	0 (0)	75 (100)	14.82 ***
Amalahila [b]	24 (9)	24 (100)	0 (0)	−3.54 ***

Source: Authors' computations *** $p < 0.01$, ** $p < 0.05$ and * $p < 0.1$. Note: Values in parenthesis are standard deviation for continuous variables, and percentage for discrete/dummy variables. Difference tests were applied: T-test for continuous variables, and Z-test for discrete/dummy variables. Continuous and discrete/dummy variables are identified by notations *a* and *b*, respectively.

4.2. Farm size and Production Efficiency Assessment of Maize

The interaction between size of farmland and how efficient farmers organize farm inputs have important policy implications on the aggregate crop output. To understand this relationship, the maximum likelihood estimate of the stochastic trans-log production frontier was applied to the data. According to Table 3, the value of sigma squared is 20.01 and is highly statistically significant ($p < 0.00$).

Table 3. Estimates of stochastic frontier trans-log production function for maize.

Variable	Parameters	Maize
Constant	β_{07}	−8.45 (1.46) ***
Farm size	β_{17}	−1.43 (1.08)
Fertilizer	β_{27}	−3.76 (0.98) ***
Seed	β_{37}	2.88 (0.77) ***
Labour	β_{47}	10.95 (1.13) ***
Squared terms		
Farm size squared	β_{57}	0.21 (0.19)
Fertilizer squared	β_{67}	0.15 (0.03) ***
Seed squared	β_{77}	0.32 (0.08) ***
Labour squared	β_{87}	−2.14 (0.25) ***
Interaction terms		
Farm size* Fertilizer	β_{97}	1.01 (0.25) ***
Farm size*Seed	β_{107}	−0.76 (0.18) ***
Farm size*Labour	β_{117}	0.15 (0.24)
Fertilizer * Seed	β_{127}	−0.55 (0.11) ***
Fertilizer * Labour	β_{137}	1.52 (0.26) ***
Seed * Labour	β_{147}	−0.80 (0.19) ***
Sigma squared	σ^2	20.01 (1.61) ***
Gamma	γ	0.99 (0.001) ***
Likelihood function		−455.13
LR test		148.5 ***
Number of observations		267

*** $p < 0.01$, ** $p < 0.05$ and * $p < 0.1$; R-squared = 0.7323, Adj R-squared = 0.6996.

This result indicates that the model was significant with good fit. Further, the half-normal distributional assumption was adequate. The results on Table 4 lean in same direction.

The variance ratio parameter (γ) in Table 3 revealed a value greater than zero and large (0.99). This estimate implies that farm performance is influenced strongly by farmers' agronomic practices rather than random variability. The technical efficiencies generated post-estimates indicate that mean technical efficiency averaged at 70%, and ranged from 22% to 99.8%. From the results, maize farmers could optimize maize production by paying more attention to the different agronomic practices adopted and input organization in cultivating the crop. This estimate further confirms the suitability of the stochastic frontier model for this study, since it accounted for the inefficiency effect going by the statistical value of the likelihood ratio (148.5) test.

Seed and labour used in maize production exhibited positive and significant positive effects (Table 3). This suggests that an increase in this input in the right proportion will increase maize production, *ceteris paribus*. However, fertilizer was significant but had a negative sign along with farm size. This suggests that fertilizer was under/over-utilized in cultivating maize. The linear term of farm size appeared to be neutral in predicting changes in the production of maize. The implication is that if other important factors are carefully combined, a farmer will make more profit using the present farm size. In Table 4, only labour and fertilizer exhibited statistical significance in the frontier model estimates in the top panel.

Table 4. One-step technical efficiency and inefficiency estimates for maize in Eastern Cape Province.

Variables/Parameters	**Coef.**	**z**	***p* > z**
Frontier			
Fertilizer	−0.0003618	−1.83	0.067 *
Seed	−0.0000357	−0.61	0.541
Labour	0.0011724	12.66	0.000 ***
Maize Output	0.0001104	4.45	0.000 ***
constant	0.0645407	0.59	0.557
Inefficiency Estimates			
Gender	−0.2542272	−1.25	0.211
Marital Status	−0.0432067	−0.57	0.571
Education	−0.3561013	−5.15	0.000 ***
Household Size	−0.0529091	−1.74	0.083 *
Association	0.5140144	2.53	0.011 **
Extension Contact	0.5740945	3.12	0.002 ***
Credit Access	−0.8850235	−0.31	0.758
Main Occupation	1.698518	0.70	0.482
Experience	−0.019814	−2.52	0.012 **
Constant	−0.2726573	−0.11	0.911
Usigma			
_cons	−5.288991	−3.43	0.001 ***
Vsigma			
_cons	−0.6542061	−6.07	0.000 ***
sigma_u	0.0710412	1.30	0.194
sigma_v	0.7210094	18.57	0.000 ***
lambda	0.0985302	1.49	0.137
Stoc. frontier	normal/tnormal model	Number of obs =	174
	Wald chi2(4) =	201.34	
	Prob > chi2 =	0.0000	
Log likelihood	= −190.7995		

*** $p < 0.01$, ** $p < 0.05$ and * $p < 0.1$; R-squared = 0.7323, Adj R-squared = 0.6996.

Table 3 shows that the squared term of farm size was unimportant in predicting maize production. The squared terms of fertilizer, seed and labour were significant, but the squared term of labour has a negative sign, which suggests that as labour increases, maize production decreases. This result could mean that using more labour on a fixed size of land might lead to labour redundancy and a labour surplus whose withdrawal would leave output virtually unchanged.

For the interaction terms, the estimates indicate positive and significant effects for farm size and fertilizer as well as for fertilizer and labour, whereas negative but significant effects were indicated for fertilizer and seed and for seed and labour. These interactions provide insights into the importance of appropriate resource combination to optimize maize output.

4.3. Estimating the Cost Function

The revenue accruable to a farmer is a function of farmers' capability to effectively allocate financial resources to production inputs. In assessing the cost implication of maize produced in the study area, the maximum likelihood estimate of the Cobb-Douglas cost function was adopted (Table 5).

The statistically significant Sigma value ($p = 0.03$) (Table 5) suggests a good fit. Further, the gamma value of 0.96 ($p = 0.02$), suggests that 96 percent of deviations from the maximum feasible level was due to cost inefficiency.

The result in Table 5 shows that most of the cost expended on inputs had a direct bearing on the aggregate cost of producing maize by the enumerated farmers. However, this was not the case with respect to farm size probably because of market imperfections in the absence of a functional rural land market. This suggests that, being a fixed input resource in farming, farmers would acquire land regardless of the cost implication. It could be inferred that farmers hold farmland more as a way of life than an economic resource, cultivating it for the pride of owning a farm rather than optimizing land use.

Table 5. Estimates of the Cobb–Douglas cost function for maize farms.

Variable	Parameters	Maize
Constant	β_{01}	3.53 (0.35) ***
Farm size	β_{11}	−0.02(0.06)
Fertilizer	β_{21}	0.33 (0.02) ***
Seed	β_{31}	0.13 (0.01) ***
Labour	β_{41}	0.19 (0.01) ***
Output	β_{51}	0.02 (0.01)
Sigma squared	σ^2	0.09 (0.03) ***
Gamma	γ	0.96 (0.02) ***
Likelihood function		159.11
LR test		44.57 ***
Number of observations		267

*** $p < 0.01$, ** $p < 0.05$ and * $p < 0.1$.

The quantity of maize produced and the cost of maize production are also seemingly linked. Specifically, the cost of maize production will increase by less than the proportion by which the quantity of maize increases. The coefficients in the model represent the elasticity of the cost of production with respect to the various costs of inputs.

The estimated elasticity of production and cost in maize production are presented in Table 6, which suggests an increasing return to scale of maize production in the study area, meaning that both maize area and output will increase by the same proportions.

Table 6. Estimates of production and cost elasticities and return to scale of maize.

	Elasticity	
Variables	**Production**	**Cost**
Farm size	0.25 (0.13) *	−0.02 (0.06)
Fertilizer	0.38 (0.19) *	0.33 (0.02) ***
Seed	0.31 (0.01) ***	0.13 (0.01) ***
Labour	0.17 (0.08) **	0.19 (0.01) ***
TRS	1.11	

*** $p < 0.01$, *** $p < 0.05$ and * $p < 0.1$.

In the maize farms, it was observed that the production of maize was inelastic and associated with farm size, fertilizer, seed and labour, meaning that these variables were efficiently utilized. Put differently, their use was in the second stage of the production function, which is regarded as the economically efficient stage of production, although the highest profit point within that region still needs to be located. The cost of maize production, on the other hand, revealed an inelastic relation with the cost of fertilizer, cost of seed and cost of labour.

4.4. Determinants of Production Efficiency in Maize Farming

The overall output in a given production system depends on a combination of factors. Based on the 2-step approach, the determinants of efficiency in maize production are as shown in Table 7. The results show that the coefficients of the technical, cost and economic efficiency differ substantially.

Table 7. Determinants of production efficiency in maize farms.

		Production efficiency		
Variables	**Parameters**	**Tech. Ineff**	**Cost. Eff.**	**Eco. Eff.**
Constant	δ_0	0.54 (0.15) ***	−0.91 (0.63)	−0.04 (0.04)
Gender	δ_1	−3.25 (0.80) ***	0.04 (0.07)	−0.06 (0.04)
Married	δ_2	−3.65 (0.97) ***	0.09 (0.07)	−0.05 (0.02) **
Education	δ_3	−1.42 (0.24) ***	−0.01 (0.04)	0.01 (0.01) *
Household size	δ_4	0.33 (0.16) **	−0.003 (0.01)	0.026 (0.05)
Association	δ_5	1.35 (0.96)	0.23 (0.11) **	−0.05 (0.04)
Extension	δ_6	1.90 (0.89) **	−0.08 (0.06)	0.09 (0.09)
Credit	δ_7	−27.73 (2.10) ***	−1.85 (0.99) *	0.07 (0.06)
Main occupation	δ_8	7.35 (1.46) ***	0.28 (0.14) **	0.001 (0.002)
Experience	δ_9	−0.11 (0.04) ***	−0.002 (0.002)	0.064 (0.037) *
Farm size	δ_{10}	−4.27 (1.22)	0.08 (0.09)	0.47 (0.16) ***

*** $p < 0.01$, ** $p < 0.05$ and ** $p < 0.05$. Values in brackets are standard errors.

Table 7 shows that only association membership and farm size are insignificant and not related to technical inefficiency out of the ten variables fitted in the model. Of the variables that significantly influenced technical efficiency, it was shown that gender, marital status, education, credit, experience and farm size were directly related to technical inefficiency. An increase in these variables will therefore result in an increase in technical efficiency. On the other hand, association, extension and main occupation were directly related to technical inefficiency, which means that an increase in these variables will result in a decrease in the level of technical inefficiency.

A gender effect on technical efficiency was assessed and the results suggest a strong significant and positive effect. This result could suggest that male farmers were more technically efficient in the production of maize. This result concurs with Kibara's [66] finding that male farmers are more efficient. But the result contradicts the findings of Onyenweaku and Effiong [67]. Married respondents, as a variable, had an indirect relationship with technical inefficiency. This suggests that married farmers were more technically efficient.

Education was negatively related to technical inefficiency of the enumerated farmers, suggesting that education improves technical efficiency. Owen et al. [68] and Addai and Owusu [69] report similar results.

Household size had a positive coefficient in the inefficiency estimate, which means that larger household sizes may not improve technical efficiency. While this negated the popular notion that households with many members often use family labour on their farms, the findings presented by Essilfie [70] suggest that families with a large household size have more obligations, which diverts resources away from farming operations to household maintenance needs.

Access to credit clearly improves technical efficiency, a finding supported by Addai and Owusu [69] who observed that farmers with access to credit generally performed better.

Main occupation had a negative relationship with technical inefficiency. This implication is that farmers whose main occupation is farming could be technically less efficient farmers than farmers reporting farming as main occupation. This result is in accord with Abdulai and Huffman [71]. It could be as a result of the greater access to additional finance enjoyed by persons employed off-farm, which enables them to access better technology. They are also likely to be more knowledgeable about applying improved technology to their farming.

The relationship between experience and technical efficiency was indirect. This outcome presents farmers with more experience as more technically efficient than those with less experience. This outcome agrees with the findings of Addai and Owusu [69] where they reported that experienced farmers were likely to be more technically efficient.

Being a member of an association, access to credit and the main occupation are important determinants of cost efficiency. Being a member of an association and main occupation were directly related to cost efficiency while credit had an indirect bearing on cost efficiency. Specifically, the positive relationship between being a member of an association and cost efficiency implies that farmers who are members of farmer associations were more cost efficient than their counterparts. The negative relationship between credit and cost efficiency implies that farmers with access to credit were less cost-efficient than their counterparts.

The positive relationship between main occupation and cost efficiency implies that respondents whose primary occupation is farming are more cost-efficient than their counterparts.

Married farmers, educational status, experience and farm size were found to be the important determinants of economic efficiency. Married farmers had an indirect relationship with economic efficiency. This implies that economic efficiency declines with marriage. On the other hand, education, experience and farm size were directly related to economic efficiency in maize farming, meaning that when these variables increase, economic efficiency could also increase.

Specifically, the negative coefficient on married farmers' variable implies that married farmers were less economically efficient than their counterparts. The positive relationship between education and economic efficiency implies that educated farmers were more economically efficient in maize farming than less educated farmers.

The positive sign on farm size variable implies that farmers with larger farm sizes were more economically efficient than those with smaller farm sizes. This result is supported by the results of Magreta et al. [72], to the effect the larger the farm sizes, the more economically efficient the farmers.

Researchers, including Wadud [73] and Ogundari and Ojo [74], have regularly pondered the question of the relative strengths of the techniques employed to measure efficiency, more specifically making the distinction between parametric and non-parametric approaches. However, investigating which of the measures is a better predictor of firm health has not been done in the literature. However, such an insight would be helpful. For instance, when confronted with the urgent need to make a decision, a policymaker would benefit from knowledge as to which measure conveys a better picture of the firm's capacity to deliver on performance. From Table 7, technical efficiency seemed more sensitive to changes in input and output levels than either allocative or economic efficiency. Of the 10 explanatory variables examined, two appeared to have a neutral impact on technical efficiency, while seven were neutral for allocative efficiency, and six were neutral for economic efficiency. It would seem that TE more precisely reflects the conditions in and around the farm, and can therefore be a more reliable basis for decision.

5. Practical Implications and Conclusions

This paper has provided estimates of efficiency in relation to economic farm size and the determinants of production efficiency in maize farming in South Africa's Eastern Cape Province. It was revealed that deviations from the optimal output arose from the inefficient practices of smallholder maize farmers in the area. The observation that the linear and squared terms in the model were not crucial in predicting maize production could suggest that the efficient use of available land, rather than the expansion of cultivated areas, can, on its own, lead to an increase in maize production. In light of the slow pace of the land reform, this is probably the most reasonable option open to smallholders and policy makers.

An increasing return to the scale of production was observed for maize, an indication that maize farming could make the farmers earn more. However, it was also observed that appropriate resource input combination and utilization could make farmers more efficient. The study has shown that a number of factors determine the technical, cost and economic efficiency of maize production and that the effects of these factors are not uniform across the spectrum of the technical, cost and economic efficiencies of farmers producing maize. It is clear from the results that farmer's experience, education, extension contact, membership of farmers' association and access to credit are important determinants of farm performance, albeit to different degrees.

These findings point to the importance of farmer support for improving production efficiency. The proper identification and prioritization of key factors is a crucial need. A clear policy is needed to ensure that the necessary coordination of the key factors and processes is provided as part of the package of agrarian restructuring and land reform. Land alone cannot make farmers successful entrepreneurs, as has been revealed by the experience of the last quarter of a century, during which the country has implemented a land reform programme. A whole range of complimentary inputs are needed to make the programme successful. Moreover, extension services would immensely promote farmers' participation in activities that disseminate innovative practices and the adoption of technology that aims to make farmers more efficient.

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