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AGRICULTURAL EFFICIENCY OF SMALLHOLDER FARMERS IN EASTERN CAPE PROVINCE OF SOUTH AFRICA

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Abstract

Millions of people in rural South Africa depend on smallholder subsistence agriculture as their major source of livelihood. However, the sector is underdeveloped, stagnant and bound to decline, slowing down development and hindering poverty alleviation. Therefore, there is a need to understand the determinants of production efficiency for increased food security and poverty reduction. This paper examined the allocative and technical efficiencies and determinants of technical efficiency of smallholder farmers at Qamata and Tyefu irrigation scheme. The paper employed the Cobb-Douglas production function and stochastic frontier analysis to estimate both allocative and technical efficiencies of smallholders. The findings of this study indicated that farmers were allocatively inefficient, underutilizing seeds, pesticides and herbicides and incurred higher costs in fertilizer use. Smallholder farmers were, however, technically efficient at approximately 98.8% and determinants of this efficiency included household size, farming experience, use of agro-chemicals, off-farm income, and gross margins earned from maize, and household commercialization level. Proposed key policy options that must be considered to address the inefficiencies include improved quality of extension services, provision of trainings in farm business management skills, and policies that promote investment incentives for agro-input/output small-scale industries.

Keywords: Efficiency; Technical Efficiency; Stochastic Frontier Analysis; Smallholder Farmers

INTRODUCTION

In Sub-Saharan Africa (SSA), agriculture is mostly practiced by rural smallholder subsistence farmers and the sector supports over 2.6 billion people in these countries. Smallholder farmers have a potential role of supplying an extra 70% of food needed to feed the growing populations globally (National Centre of Competence in Research (NCCR), 2012; and Bruinsma, 2010). According to Food, Agriculture and Natural Resources Policy Analysis Network (FANRPAN) (2012), a total of 4.75 million South Africans are employed in agricultural sector of which 4 million people are engaged in subsistence small-scale production and the sector has a potential of employing about 33% of commercial smallholder farmers. In 2006, the sector was reported to employ over 1.32 million farm workers, which is about 10.6% of the country's labour force (Liebenberg and Pardey, 2010). According to FANRPAN (2012), in by 2012, the agriculture sector's employment share had fallen slightly to was estimated to employ about 7% of South African labour work force. The contribution of small-scale farming to millions of rural South African population proves its significance in the rural economic growth and development.

Small scale farmers have no definite definition (WIEGO, 2012). According to Ethical Trading Initiative (2005), and Obi (2012) small scale farmers can be defined as farmers who produce relatively small volumes of produce on relatively small plots (less than 5ha); they are generally more resource poor and usually considered to be part of the informal economy (Spio, 1997; Sishuta, 2005; Obi, 2011). Lack of access to land, lack of access to inputs/implements, lack of access to financial capital, limited access to extension services and input/output market, low adoption of appropriate modern technologies, uncertainties in climate change and farm risks are among factors reported to impede increased smallholder agricultural productivity (Kisaka-Lwayo and Obi, 2012; and NCCR, 2012).

Ethical Trading Initiatives (2005) and Obi (2011) definition of smallholders adequately describes the state of rural farmers in former homeland states of Transkei and Ciskei located in the Eastern Cape Province of South Africa. There have been several attempts by the government to improve the agricultural productivity on small farms , since apartheid andin the post-apartheid period through establishment of small-scale irrigation schemes, agricultural market liberalization policies, provision of credit facilities and enacting a number of land reform policies. In addition to establishment of irrigation schemes, South African government provided farm inputs and implements through programs like siyazondla (Xhosa word meaning "we are feeding ourselves"), Siyakhula (Xhosa word meaning "we are growing") and Massive Food Production Programmes (MFPP) (Muchara, 2011).

Furthermore, the government has established credit and microfinance institutions such as Micro Agricultural Financial Institutional Scheme of South Africa (MAFISA). The government created links between banks and farmers for improved access to input credit. Some smallholders have benefited from land reforms through three main components including restitution, tenure reform and land redistribution (Obi, 2006). The land reforms were enacted to address the resource distribution inequalities which emanated from the skewed racial land distribution during the apartheid regimes that deliberately apportioned black farmers small plots (<5ha) and some were left landless (Seneque, 1982; Obi, 2006; and Aliber and Hart, 2009).

Despite all the support rendered by the government to smallholder farmers, the transition from subsistence to smallholder commercial farming is slow leading to increased food insecurity and wide spread poverty among rural communities (Ramaila et al., 2011). Moreover, some literature has indicated a declining trend in agricultural productivity among smallholders (Aliber and Hart, 2009). More efforts and commitments are being made by the current government to encourage more innovations geared towards increased smallholder productivity (Zuma, 2011). According to Eicher and Staatz (1985), innovation and adoption of new technology like irrigation farming is represent one sure way to lift people quickly out of poverty and restore livelihoods to acceptable levels and several authors have confirmed its the efficacy of these approaches (Steduto et al, 2007). However, literature indicates sub-optimal use of small-scale irrigation schemes in South Africa due to farmers' lack of skills to utilize the available technologies (Muchara, 2011). Empirical studies indicate that farmers in developing countries are unsuccessful in taking full advantage of the potential of technology like irrigation schemes and other support for increased productivity. Therefore, this research evaluated the current status of smallholders' production efficiency and the relationship between smallholder farmers' /Farm characteristic with production efficiency.

One of most widely used methods to assess the performance of farmers is through estimating their production efficiency. Padilla-Fernandez and Nuthall (2001) cited Farrell (1957) defining efficiency as the ability to produce a maximum level of output at the lowest cost. Efficiency can be divided into two concepts, the technical and allocative efficiency. Technical efficiency is the ability of the farm to produce a maximum level of output given a similar level of production inputs. Allocative efficiency literally can be defined as generating of output with the least cost of production to obtain maximum profits. For the farmer to achieve economic efficiency, they have to combine resources in the least combination to generate maximum output as well as ensuring least cost to obtain maximum revenue (Chukwuji, et al., 2006). In cases where farmers' efficiencies differ among the communities or groups, improved technological diffusion and agronomic practices is essential and where all the population is found to be technically efficient, more innovation and adoption of new technologies can be encouraged.

METHODOLOGY

Analytical Methods

A Cobb-Douglas production function was employed to estimate both allocative and technical efficiency. A log-linear Cobb-Douglas production function was ran run separately for smallholder farmers participating on the irrigation scheme and homestead food gardeners to generate elasticities used in the estimation of allocative efficiency. The same log-linear Cobb-Douglas production function was employed by the Stochastic Frontier Analysis (SFA) to generate technical efficiencies of smallholder maize farmers. This study assumes that maize production is dependent on the physical production relationships between output and inputs. Thus, a relationship between the amount of maize output and land size, amount of fertilizer, pesticide, herbicides, capital and number of times a farmer irrigates per hectare per season. The physical relationship can be derived from the Cobb–Douglas production function and it is given by:

$Y=AX_1^{\alpha_1} X_2^{\alpha_2} \ldots\ldots X_n^{\alpha_n} \gamma \ldots\ldots$ (1)

Y = Amount of maize produced per farm

X1= Land allocated to maize production

X2= Amount of fertilizers used

X3= Amount of seed planted

X4= Amount of pesticides

X5= Amount of herbicides

X6 = Number of irrigations/ha/season

A = Constant and α = Random error term

From (1) the linear production function can be re-written as:

$\ln(Y_i)=\beta_0+\Sigma_i\beta_i \ln X_{ij} +\varepsilon_i$ ……………(2)

Where ln is natural logarithm, Yi is output of the ith farmer, β0 is a Constant, βi is a Coefficient, Xij is the j input used by farmer i, εi = error term.

Estimating Allocative Efficiency

Following Chukwuji et al. (2006), allocative efficiency analysis is done by estimating a Cobb-Douglas function using Ordinary Least Squares (OLS) regression model. It is followed by computing the value of marginal product (VMPi) for each factor of production, which then is compared with the marginal input cost (MICi). Results from equation (2) yield the coefficient Beta (βi), estimate for elasticity.

$\partial \ln Y/\partial \ln X= [(1/Y*\partial Y)/(1/X*\partial X)]= [X/Y*\partial Y/\partial X]= \beta_i$ .... (3)

Using the coefficient estimates from (2), MPi the marginal product of the ith factor X is calculated as

$MP_i = \partial Y / \partial X_i = \beta_i \; Y/X_i$ ………………… (4)

But $AP = Y/X_i$

Where Y is the geometrical mean of maize output (mean of natural logarithm); Xi is the geometrical mean of input i; β is the OLS estimated coefficient of input Xi. The value of marginal product of input i (VMPi) can be obtained by multiplying marginal physical product (MPi) by the price of output (Py). Thus,

$VMP_i = MP_i * P_y$ ……………………....(5)

Allocative Efficiency (A.E) = VMP_i/P_i ... (6)

But, Pi = Marginal cost of the ith input

Following, the steps described above, this study determined allocative efficiency by comparing the value of marginal product of input (VMPi) with the marginal factor cost (Pxi). Since farmers are price takers in the input market, the marginal cost of input approximates the price of the factor i, Pxi (Grazhdaninova and Lerman, 2004). Hence, if VMPi > Pxi, then the input is underused and farm profit can be raised by increasing the use of this input. Conversely, if VMPi < Pxi, the input is overused and to raise farm profits its use should be reduced. The point of allocative efficiency (maximum profit) is reached when VMPi = Pxi (Chavas et al., 2005).

Estimating Technical Efficiency

The stochastic frontier analysis was employed to estimate the technical efficiency of smallholder farmers' maize production. Results were used to establish efficiency resource use by farmers as a platform to suggest the best policies to capitalize on a more efficient, profitable and sustainable farming business on smallholder irrigation schemes in the Eastern Cape Province. Following Battese (1992) and Rahman (2003), technical efficiency of maize production is estimated using a stochastic frontier specified in equation (2). Since equation (2) is used to estimate the stochastic frontier, then, εi = a "composed" error term. The "composed" error term (εi) is the essential component that distinguishes the stochastic frontier model from other models (Sharma and Leung, 2000; Bravo-Ureta and Pinheiro 1997; Rahman, 2003; Chavas et al., 2005). The Composite error term (εi) can be rewritten as:

$\varepsilon_i = v_i - u_i$ ………………………….(7)

But i = 1,...n, n=158

When εi is substituted by vi – ui, then equation (2) is rewritten as:

$\ln(Y_i) = \beta_0 + \Sigma_i \beta_i \ln X_{ij} + v_i - u_i$ ……(8)

Where the efficient component vi is a two–sided ($-\infty<v<\infty$) normally distributed random error ($v \sim N[0, \sigma v2]$) that captures the stochastic effects outside the farmer's control (like weather, natural disasters, and luck), measurement errors, and other statistical noise and the efficiency component ui is a one–sided ($u>0$) and measures the shortfall in output Y from its maximum value given by the stochastic frontier f (Xi; βi) + v. We assume u has half or an exponential distribution [$U \approx N(0,\sigma u2)$]. The two components v and u are also assumed independent of each other. The parameters are estimated by the maximum likelihood method following Bravo-Ureta and Pinheiro (1997) and Bi (2004). If the efficient component ui takes on a half-normal distribution then equation (8) above can be rewritten as:

$\ln(Yi)=\beta0+\Sigma\ i\ \beta i\ \ln Xij\ +vi$……………..……(9)

Following Jondrow et al. (1982), in addition to the half-normal distribution, the assumption of conditional distributional error term coupled with the assumed independence of efficient components vi and ui should be satisfied when using a stochastic frontier. If all assumptions are satisfied, then the conditional mean of ui given εi is defined as:

$E(u_i | \varepsilon_i)=\delta_* [(f^{(*)} ((\varepsilon_i \lambda)/\delta))/(1-F^{(*)} [(\varepsilon_i \lambda)/\delta])-(\varepsilon_i \lambda)/\delta]$… (10)

Where $\sigma^* 2=\sigma u2\sigma v2/\sigma2$, f^* = the standard normal density function, F^* = the distribution function, and $f^* = F^* = \lambda\varepsilon/\sigma$

Technical efficiency of a single farm is specifically defined as:

$TEi = \exp(-\hat{u}i/\Sigma i\beta i) = \exp(-E(ui | \varepsilon i)/\Sigma i\beta i)$..(11)

The estimates for v and u are derived by replacing ε, σ*, and λ in equations (2) and (10). Then the stochastic frontier is estimated by subtracting vi from both sides of equation (8).

$\ln(Y^*i) = \beta0+\Sigma i\beta i\ \ln Xij - ui=\ln(Yi) - vi$.(12)

Thus, $\ln(Y^*i) = \beta0+\Sigma i\beta i\ \ln Xij + vi - ui = \ln(Yi)$

Where ln(Yi*) is the observed output of the farm i which regulates the statistical noise contained in vi, and Yi is the corresponding frontier output. Explicitly, for an individual firm, technical efficiency is defined in terms of the ratio of the observed output to the corresponding frontier output and it can be expressed as:

$TE= Y_i/(Y_i^{*})$ ……………..………….. (13)

Technical efficiency levels are predicted from the stochastic frontier analysis estimation. Following Battese (1992), Rahman (2003), and Ojo (2003), this study specified the stochastic frontier analysis using the flexible log linear Cobb- Douglas production function as stated in equation (1) above.

Estimation of Factors Affecting Technical Efficiency

Following Bravo-Ureta and Rieger (1990), Bravo-Ureta, and Pinheiro (1997) the second step to estimate inefficiencies was adapted to establish the relationship between technical efficiency and the farm/farmer characteristics. To estimate this relationship, a linear OLS regression is performed and Durbin-Watson statistic is estimated to determine the extent of autocorrelation (Obi and Chisango, 2011). The linear model is estimated as shown below for each farmer.

$T.E = \beta 0 + \beta Xi + e$……………………….. (14)

Where TE = level of technical efficiency; $\beta 0$ and β = coefficient parameters to be measured; e = error term; and X is a vector of explanatory variables that include farm/farmer characteristics like X1 = Household size, X2 = Age, X3 = Education level (years), X4 = Farming experience, X5 = Amount of land owned, X6 = Training on input use, X7 = Use agro-chemicals, X8 = Use of tractor, X9 = Location of irrigation scheme, X10 = Gross margins, X11 = Commercialization level, X12 = crop incomes, X13 = Off-farm incomes.

Field Methods

The former Transkei and Ciskei states of South Africa located in the Eastern Cape Province are among the beneficiaries of established small-scale irrigation schemes meant to improve food security, employment and alleviate poverty in rural communities. Despite the support rendered people living in these rural communities of former states are languishing in extreme poverty. Therefore, this study selected one small-scale irrigation scheme from each of these states to ascertain the impact of the irrigation schemes on agricultural efficiency and to identify the determinants of farmers' agricultural efficiency. The selected irrigation schemes included Qamata and Tyefu irrigation schemes, the former being located in the Transkei and the latter located in the Ciskei state, respectively. Further, the study selected maize crop to estimate agricultural efficiency of smallholder farmers because it is considered to be the main staple food in Qamata and Tyefu communities and thus, ensuring food security and household income from marketable surplus.

The target group for this study was small-scale farmers who produce maize regardless of whether or not they produce other food crops. With the aid of extension worker's and community development officer's guidance, farmers were randomly selected and interviewed. A total of 102 farmers were interviewed in Qamata and 56 farmers at Tyefu irrigation scheme, respectively. This resulted in an overall sample size of 158 farmers. To generate more authenticable results, both, measurements and observation methods, and participatory approaches were employed. The data for the study were essentially from primary sources with the use of well-structured questionnaire. The majority of the interviews occurred in the communal meeting places. The only exception was in the case of Tyefu smallholder irrigators who were interviewed at their irrigation food plots. The questionnaires were pre-tested on a sample of farmers in the study area. The questionnaires comprised farmer characteristics, agronomic practices and crop production.

EMPIRICAL RESULTS

Table 1 indicates that most farm households were headed by male, the proportions significantly higher among the homestead food gardeners at a 5% level. Male's dominance among both smallholder irrigators and homestead food gardeners (59% and 78% respectively) in the study area may be attributed to loss of jobs through retrenchment policies and retirement. Further, over 90% farm plots on irrigation schemes and dry land were allocated to men due to the bias of the African cultural rules and norms which deny women's legal rights to own such a crucial agricultural resource (Kodua-Agyekum, 2009).

Table 1: Demographic Characteristics of Smallholder farmers the Study Area

Characteristics	**Description**	**Smallholder Irrigator (n =108) (%)**	**Homestead Food Gardener (n = 50) (%)**	**Overall Sample (n=158) (%)**	**Chi-Square Test**
Non-continuous Variables					
Sex of household head	Male	59.0	78.0	69.0	5.290**
	Female	41.0	22.0	31.0	
Level of Formal Education	Non	35	20	28	5.647
	Primary	36	48	42	
	Secondary	26	32	29	
	Tertiary	3	0	1	
Major Occupation	Farmer	94	90	92	3.742
	Self-employed	4	6	5	
	Civil servant	2	4	3	
Continuous Variables					
		Mean-value	**Mean-value**	**Average Mean value**	**T-Test**
Household size		4.537 (2.698)	4.400 (1.990)	4.469 (2.344)	0.358
Age of farmer (Years)		60.232 (12.289)	61.900 (13.117)	61.066 (12.703)	-0.777
Years spent in School		4.944 (4.574)	5.900 (4.142)	5.422 (4.358)	-1.303
Faming Experience (years)		10.833 (11.821)	15.200 (12.036)	13.017 (11.928)	2.147**

** denoted as significance at a 5% level.

According to the results presented in Table 1, there are relatively more women participating in irrigation farming (41%) than in homestead food gardening (22%). The increased number of women participating in irrigation farming may be due to affirmative action programmes and policies in recent years which promote women's access and control over or inherit farm plots. Although there is an increase in women's ownership of plots, that may not be the case for women participating in homestead food gardening where the traditional norms are still prevalent (Kodua-Agyekum, 2009).

Results further suggests that the largest proportion of farmers had some education, mostly up to 5 years of primary school education (42%) although a handful did not have any education at all (28%) and very few had post-secondary education (1%). Education level seems to be higher among the homestead food gardeners (about 6 years spent in school) and lower among the smallholder irrigators (about 5 years of schooling). This implies that most household heads depend on the local language to access farm information especially through their fellow farmers. The household size averaged approximately 5 persons for both smallholder irrigators and homestead food gardeners. The mean household size of the smallholder irrigators is about 5 persons and that of homestead food gardeners is about 4 persons. Results indicate that there are no statistical significant difference in the education level and household size between the smallholder irrigators and homestead food gardeners. Household size in most rural villages of Sub-Saharan Africa is known to be a source of farm and off-farm labour (Kibirige, 2008).

Both smallholder irrigators and homestead food gardeners considered farming as their major occupation (92%), an indication of the endemic unemployment situation among the Qamata and Tyefu population. The average age of the household head among smallholder irrigators and homestead food gardeners is 60.23 and 61.9 years, respectively (Table 1). This indicates that farmers at Qamata and Tyefu irrigation scheme areas may be less productive since their age is far above the youthful productive stage as defined by Ogundele and Okoruwa (2006). Increased number of farmers within this age bracket may be a reflection of more retrenched and retired formal employees who take on farming as their source of livelihood for survival. Most youth migrate to urban areas in search of more paying employment opportunities (Obi and Pote, 2012). Although age and farm experience are considered to be interrelated, age in most cases is associated with decreasing farm output in terms of energy for farm labour (Bagamba, 2007). The average farming experience of smallholder farmers and homestead food gardeners is approximately 10.83 and 13.02 respectively. Thus, this indicates that homestead food gardeners had a significantly higher farming experience than smallholder irrigators at a 5% level. This is probably because of farmers' abandonment of smallholder irrigation plots during the period when government reduced its support on the irrigation schemes.

Input Use among Smallholder Farmers

An independent sample T-test was carried out to establish the difference in input use between smallholder irrigators and homestead food gardeners. According to the results displayed in Table 2, there is a mean difference between average number of times of irrigation/ha/season of maize production, higher among smallholder irrigators (208.78 times/ha/season) and lower among homestead food gardeners (116.14 times/ha/season) at a 1% significant level. Smallholder irrigators devoted slightly less land (0.67ha) and amount of maize seed planted (24.99Kg/ha) compared to the homestead food gardeners maize land (0.72ha) and amount of maize seed planted (26.20Kg/ha). The amount of fertilizer applied (58.03Kg/ha), pesticide (0.74L/ha) and herbicides (0.64L/ha) per hectare used by smallholder irrigators were slightly more compared to homestead food gardeners who applied fertilizer of 50Kg/ha, 0.73L/ha of pesticide and 0.40L/ha of herbicide, respectively. Thus, control of weed using chemicals and pest control using pesticides are mainly carried out by smallholder irrigators in maize production.

In South Africa, the recommended planting rates for improved maize seed generally range from 20Kg/ha to 25kg/ha (Hassan et al., 2001). Therefore, the findings in this study indicate that both smallholder irrigators and homestead food gardeners planted maize using the recommended seed rate. The recommended fertilizer rates for irrigated maize vary depending on the yield potential, but can be as high as 220 kg N ha-1 for a yield target of 10 t ha-1 in South African (Fanadzo et al., 2009). However, findings in this study indicate that both smallholder irrigators and homestead food gardeners apply far less fertilizer than the recommended rate and these findings are consistent with Fanadzo et al. (2009) study whose results showed that on average, farmers applied only 47.6 kg N ha1 of fertilizers at Zanyokwe irrigation-scheme.

Table 2: T-test for Mean Difference in Input Use among Smallholder Farmers

	Smallholder irrigators (n=108)		**Homestead Food Gardeners (n = 50)**		**Overall Sample (n=158)**		**T-Test**
Farm Inputs	Mean	SD	Mean	SD	Mean	SD	
land under maize production (ha)	0.67	0.97	0.72	1.02	0.70	1.00	-0.306
Maize seed planted per ha (Kg/ha)	24.99	28.87	26.20	23.57	25.60	26.22	-0.280
Fertilizer applied per ha of maize (Kg/ha)	58.03	85.44	50.00	87.09	54.02	86.27	0.545
Pesticide applied per ha of maize (L/ha)	0.74	3.03	0.73	3.18	0.74	3.11	0.010
Herbicide applied per ha of maize (L/ha)	0.64	1.93	0.40	1.70	0.52	1.82	0.800
Number of irrigations/season/ha	208.78	217.33	116.14	132.94	162.46	175.13	3.256***

*** denotes significant at a 1% level;

SD = Standard deviation; ha = hectares, Kg = Kilograms, L = Litres

Profitability and Commercialization level of Maize Enterprises

Results presented in Table 3 reveal that smallholder irrigators generate significantly higher maize yield, more total revenues and higher gross margins from the maize enterprise at a 5%, 10% and 1% levels, respectively as compared to the homestead food gardeners. Further, results indicate that smallholder irrigators produce more marketable surplus of maize with a commercialization index score of 0.45 compared to 0.37 index score of the homestead food gardeners. However, homestead food gardeners spent more money in purchase of inputs and this may have contributed to their low gross margins. The low production costs incurred by smallholder irrigators may be due to their ability to benefit from government input subsidies.

In South Africa, the potential grain yields that can be obtained under irrigation farming range from 7 to 12 tons/ha (Fanadzo et al., 2009). This indicates that maize yields for both smallholder irrigators and homestead food gardeners are far below the expected yields. This suggests that smallholder irrigators are sub-optimally utilizing irrigation schemes. The low yields may be attributed to low fertilizer, pesticides and herbicides applications, among others. Further, the low use of these agro-chemicals may be due to lack of investment capital to purchase these inputs.

Table 3: Profitability of Maize Enterprises among Smallholders

	Description	Smallholder Irrigators (n=108)	Homestead Food Gardeners (n=50)	Overall Sample (n=158)	T -Value
		Mean	Mean	Mean	
Maize yields	Kg/ha	2199.59 (2967.64)	1468.497 (1488.9)	1834.04 (2228.27)	2.061**
Total revenues from Maize	Rand/ha	3469.89 (6560.57)	2141.48 (2900.1)	2805.69 (4730.34)	1.765*
Total Cost for maize production	Rand/ha	1448.68 (2280.22)	1869.30 (2803.02)	1658.99 (2541.62)	-0.995
Gross margins from maize	Rand/ha	2021.209 (6035.331)	254.655 (3012.671)	1137.932 (4524.00)	2.444**
Commercialization Index for Maize	Ratio	0.45 (0.37)	0.37 (0.35)	0.41 (0.36)	1.324

*, and **, represents significance levels at 10%, and 5% level, respectively.

(SD) = standard deviation. , ha = hectares, Commercialization Index ratio = Quantity marketed of a given crop divided by total quantity harvested of the same crop

Estimating the Allocative Efficiency of Smallholder Farmers

This section begins with estimating the input elasticities which are then used to estimate the allocative efficiency. The allocative efficiency was estimated using a log-linearized production function of selected inputs. The estimated allocative efficiency was based on availability of input and output prices which could easily be estimated by farmers. This approach calls for price information and without such information it is impossible to execute a single result.

Input Elasticities

When using a stochastic production frontier approach, elasticities (βi) are important in allocative efficiency estimation. The Cobb-Douglas production function was estimated for both smallholder irrigators and homestead food gardeners. The Cobb-Douglas production function was estimated using log-linear Ordinary Least Squares (OLS) and the coefficients estimated represented individual elasticities. The elasticities associated with land under maize production and number of irrigations/ ha/ season for smallholder and land under maize production and quantity of seed planted for homestead food gardeners were greater than one. For such inputs with elasticity greater than one and positively related to maize output, a unit increase in the respective input would result into a more than a unit increase in maize output. In contrast, a 1% increase in input of less than 1% would result in less than 1% increase in maize output. Estimated elasticities are shown in Table 4 for both smallholder and homestead food gardeners.

Table 4: Input Elasticities for Maize Enterprise

Dependent = maize output	**Smallholder Irrigators**		**Homestead Food Gardeners**	
Variable	**Elasticity (β)**	**p-values**	**Elasticity (β)**	**P-values**
Land	2.377	0.000***	2.192	0.000***
Seed planted	0.152	0.238	1.381	0.000***
Fertilizers	-0.065	0.320	0.100	0.472
Pesticide	0.066	0.622	-0.378	0.508
Herbicides	-0.135	0.529	-0.263	0.458
Number of Irrigations/ha/season	1.129	0.000***	0.599	0.006***
Capital	0.397	0.000***	0.037	0.841

*** denotes significant at a 1% level

Land under maize production, number of irrigations/ha/season and capital has positive and significant relationship with maize output at 1% level respectively among smallholder irrigators. Thus, a unit increase in land under maize, number of irrigation/ha/season and capital, would result in an increase of approximately 2, 1 and 0.4 kilograms of maize output for smallholder irrigators, respectively. Among homestead food gardeners, the amount of land allocated to maize, amount of seed planted and numbers of irrigations/ha/season have a positive and significant impact on maize output at a 1% level, respectively. This indicates that, a unit increase in land under maize production, more use of improved seed and number of irrigations/ha/season result in an increase of about 2, 1 and 0.6 kilograms of maize output, respectively, among homestead food gardeners. Therefore, for increased maize output among smallholder irrigators and homestead food gardeners, there is a need to expand land and increase access to irrigation water, although this may call for additional agricultural support services for sustainability.

Amount of fertilizers applied and herbicides have a negative impact on maize production among smallholder irrigators while pesticides and herbicides have the same impact on maize output among homestead food gardeners. This implies that, a unit increase in the amount of fertilizer applied and herbicides result into a decrease of about 0.1 and 0.2 units of maize output, respectively, among smallholder irrigators, while a unit increase in pesticide and herbicides results into a decrease of approximately 0.4 and 0.3 units of maize output, respectively, among homestead food gardeners. One would have expected application of fertilizers, pesticides and herbicides to have a positive relationship with maize output but this was not the case in this study. Increased use of fertilizers, pesticides and herbicides is expected to increase farm output. The negative relationship is probably because most farmers in this study apply small quantities of these agro-inputs, and thus, overall output decreases with an increase in number of smallholders using relatively small quantity of agro-inputs. Further, this may be due to lack of farmers' knowledge and skills on how to apply these inputs leading to low farm output. The negative relationship between output and agro-inputs like fertilizers, pesticides and herbicides in production processes has also been observed in some other studies in the region and elsewhere, notably Chirwa (2003), for smallholder maize producers in Malawi, and Kelemework (2007) who found out unexpected negative relationship between output and pesticide application for Batu Degaga irrigation scheme in Ethiopia.

Allocative Efficiency Estimation

Allocative efficiency estimation assumes that farmers' main goal is to maximise profits. For profits to be maximized, marginal value product (MVP) of a given crop should be equal to the respective unit factor price. Table 5 presents the allocative efficiency of smallholder irrigators and homestead gardener.

Results indicate that both smallholder irrigators and homestead food gardeners were allocatively inefficient in all the inputs considered in this analysis. The smallholder irrigators' estimated average mean allocative efficiency for maize seed, fertilizer, pesticide and herbicide used is approximately 2.5, 0.7, 14.2, and 7.1, respectively. This indicates that smallholder irrigators are sub-optimally using maize seed, pesticides and herbicide while over spending money on fertilizer purchase. Therefore, for maximization of profits earned from maize enterprise, the smallholder irrigators need to use more of the improved seeds, pesticides and herbicide and reduce fertilizers costs. Both smallholder irrigators and homestead food gardener may be lacking business management skills important in calculating input cost minimization and profit maximization.

The allocative efficiency scores among homestead food gardeners do not differ much from the smallholder irrigators. Results in Table 5 indicate that homestead food gardeners were highly inefficient in allocating pesticides (28.4), herbicides (21.8) and seed (10.0) respectively. All these scores are greater than 1 meaning that MVP > MC and therefore there is more room for increased use of these inputs. Homestead food gardeners' allocative efficiency scores for fertilizer (0.754) was relatively lower than 1 and hence inefficiently allocated. Therefore, there is a need to search for cheaper fertilizers for homestead food gardeners in order to realize maxim profits in the maize enterprise.

Table 5: Estimation of Allocative Efficiency for Maize Enterprise

Smallholder irrigators (n= 108)					
Variable	**Coefficients (β)**	**APP**	**MPP**	**VMP_i (MP*Py) (Rand)**	**Allocative Efficiency (VMP_i / P_i) Scores**
Seed (Kg)	0.152	161.094	24.486	57.935	2.483
Fertilizers (Kg)	0.065	40.825	2.654	6.278	0.653
Pesticide	0.066	1497.857	98.859	233.899	14.193
Herbicide (Litres)	0.135	673.084	90.866	214.990	7.063
Homestead Food Gardeners (n =50)					
Variable	**Coefficients (β)**	**APP**	**MPP**	**VMP_i (MP*Py) (Rand)**	**Allocative Efficiency (VMP_i / P_i) Scores**
Seed (Kg)	1.381	71.667	98.972	234.168	10.037
Fertilizers (Kg)	0.100	30.646	3.065	7.251	0.754
Pesticide	0.378	522.500	197.505	467.297	28.355
Herbicide (Litres)	0.263	1066.667	280.533	663.742	21.806

In general, both smallholder irrigators and homestead food gardeners are using maize seed, pesticide and herbicides sub-optimally since their allocative efficiency scores for these inputs is above score 1 meaning that marginal revenues are greater than marginal cost. Therefore increase in amounts of improved maize seeds, pesticide, and herbicide, and low cost fertilizer used in the maize production for both smallholder irrigators and homestead food gardeners will lead to profit maximization at least cost input combination.

Estimating Technical Efficiency of Maize Production: Stochastic Frontier Approach

The stochastic production function was estimated for the pooled data combining the smallholder irrigators and homestead food gardeners. The estimated parameters and the related statistical test results obtained from the analysis are presented in Table 6. The estimated Wald chi-square (625.78) is significantly different from zero at 1 percent. This indicates a good fit of the model and takes into account of the composite random errors. Amount of land under maize production, quantity of maize seed planted, number of irrigations/ha/ season and capital invested positively and significantly influence the amount of maize produced at a 1% level, respectively. Amount of fertilizer, pesticides and herbicides negatively influence the level of maize output though not significantly. The negative impact of such inputs may be attributed to very low applications as presented in Table 2. This estimated stochastic frontier was used to establish the technical efficiency of smallholder farmers at Qamata and Tyefu irrigation schemes, respectively, as presented in Table 7.

Table 6: Estimates of the Stochastic Frontier for Maize Enterprise

Independent Variables	**Maize Output (Y) = Dependent Variable**			
(in natural logarithm)	**Coefficient**	**S.E**	**Z Value**	**P-value**
Land under maize farming (ha)	2.211	0.178	12.39	0.000***
Seed planted (Kg/ha)	0.468	0.124	3.76	0.000***
Fertilizer applied (Kg/ha)	-0.024	0.061	-0.40	0.691
Pesticide used	-0.066	0.144	-0.45	0.650
Herbicide applied (L/ha)	-0.131	0.188	-0.70	0.486
Number of irrigations/ha/season	0.974	0.111	8.76	0.000***
Capital (Rand)	0.271	0.090	3.01	0.003***
Constant	0.706	0.648	1.09	0.276
sigma_v	1.050	0.060		
sigma_u	0.015	0.750		
Sigma2	1.103	0.126		
lambda	0.015	0.757		
Log likelihood = -228.961 Prob > chi2 = 0.000 Wald chi2(6) = 625.78 Number of Observations (n =158)				

*** = significant at 1% and 5%,

ha = hectares, Kg = Kilograms; L = litres; S.E = Standard Error

The overall technical efficiency of smallholder irrigators and homestead food gardeners was estimated and a T-test was carried out to compare the performance of the two groups. Both the smallholder irrigators and homestead food gardeners were technically efficient at about 98.80%. Although the results presented in Table 7 indicate a slight difference between technical efficiency scores of smallholder irrigators and homestead food gardeners, the overall model indicates a significant difference at 1% level where smallholder irrigators were technically more efficient than homestead food gardeners.

Table 7: The T-Test of Technical Efficiency for Smallholder Irrigators and Homestead Food Gardeners

Type of farmer	Sample Size	Mean Efficiency	Standard Error	Standard Deviation
Smallholder irrigators (y)	108	0.988017	0.000001	0.000076
Homestead food gardeners(x)	50	0.987964	0.000010	0.000071
Combined	158	0.9880012	0.000006	0.000078
Mean difference		0.0000536	0.000013	

Satterthwaite's degrees of freedom = 153, t = 4.1224

Ho: mean(y) - mean(x) ≠ 0

Ho: diff = 0

Ha: diff < 0 Ha: diff! = 0 Ha: diff > 0

Pr(T < t) = 1.0000 Pr(T > t) = 0.0001 Pr(T > t) = 0.0000

Determinants of Technical Efficiency in Maize Production

Using an OLS linear regression model of technical efficiency scores against explanatory variables for smallholder maize producers, a relationship between the two was established. The explanatory variables were specified as those related to socioeconomic factors of the smallholder farmers at Qamata and Tyefu irrigation schemes. According to Table 8, the Durbin-Watson statistic for the overall regression model was approximately 2.2, signifying the absence of autocorrelation problems. The F-value indicates that the explanatory variables combined, significantly influence changes in the technical efficiency at a 1% level. Household size, farming experience, use of agro-chemicals, gross margins earned from maize sales and off-farm incomes have a positive and significant impact on the farmers technical efficiency in maize production at 10%, 10%, 5%, 1%, 1% and 5% levels, respectively. Thus, an increase in household size as source of farm labour, farming experience to reduce risks of crop failure, use of agro-chemicals to control weed and pests, gross margins, commercialization level and off-farm incomes to purchase inputs all result in increased technical efficiency of smallholder maize farmers in the study area.

Both the amount of land owned and training on the use of inputs have a negative and significant influence on technical efficiency of maize production at a 10% level, respectively.

This indicates that farmers with small plots are more likely to be more efficient than their counterparts with relatively larger plots. This may be attributed to low incomes of smallholder farmers that are insufficient to purchase inputs necessary for relatively larger plots, so they decide to concentrate on small plots for output maximisation within the available resources and technologies. One would expect that increase in farmers' access to input use training would increase their efficiency in maize production, but rather results in the model indicate that increase in farmers' access to input use training leads to a decrease in the technical efficiency. The negative relationship between training on input use and technical efficiency may be as a result of poor quality extension services rendered to farmers due to technically unqualified extension staff or farmers do not put to practice what is being taught by extension officers (Awoniyi et al., 2007; and Kodua-Agyekum, 2009)

Table 8: Determinants of Technical Efficiency among Smallholder Maize Production

	Dependent Variable = T.E scores in maize production			
Explanatory Variables	**Coefficients**	**Std. Error**	**T-Value**	**P-Value**
Household size	0.000	0.000	1.688	0.094*
Age	-0.000	0.000	-0.520	0.604
Education level (years)	-0.000	0.000	-0.802	0.424
Farming experience	0.000	0.000	1.648	0.102*
Amount of land owned	-0.000	0.000	-1.906	0.059*
Training on input use	-0.000	0.000	-1.927	0.056*
Use agro-chemic	0.000	0.000	2.012	0.046**
Use tractor	-0.000	0.000	-1.481	0.141
Gross margins (maize)	0.000	0.000	3.093	0.002***
Commercialization level	0.000	0.000	3.413	0.001***
farm incomes	0.000	0.000	1.096	0.275
Off-farm income	0.000	0.000	2.456	0.015**
location of irrigation scheme	0.000	0.000	0.863	0.390
(Constant)	0.988	0.000	15487.295	0.000***

Adjusted R^2 = 0.240
F-Value = 4.653***
Durbin-Watson statistics = 2.222
Number of Observations (n = 158)

***, ** and * denotes significant at 1%, 5% level respectively;

Std. Error = Standard Error.

CONCLUSIONS

Smallholder farmers at Qamata and Tyefu irrigation schemes were men with an average age of 61 years, and mean household size of 4 persons with the household head having at least obtained some primary school education. This is an indication that future performance of the industry is doomed to collapse due to low participation of youths as the old generation fades away. This may worsen the situation of increased food insecurity, unemployment and increased poverty levels in the face of increasing population and limited fixed land and water resources. Smallholders plant the recommended amount of maize seed with far less fertilizer, pesticide and herbicide compared to the recommended amounts. The less low levels of use of use of fertilizers, pesticide and herbicides may be one of the reasons for the low yields (overall 1.83 tons/ha) harvested compared to the estimated potential maize yield at a given irrigation scheme in South Africa which ranges of between 7 and 12tons/ha under irrigated conditions. Smallholder irrigators earn more incomes from maize enterprise compared to homestead food gardeners. The findings further indicate that most maize produced is consumed at home (59%) and only 41% of maize is sold to meet the household cash needs. Therefore, this confirms signifies the role of maize production as a crucial food security strategy in the project area for a sustainable food security and the general livelihood of smallholder farmers at Qamata and Tyefu irrigation schemes. Expansion of land under maize production, increased amount of improved seed and increased number of irrigations/ha/season are likely to result into increased amount of maize output.

Both smallholder irrigators and homestead food gardeners are allocatively inefficient users of maize seed, fertilizers, pesticide and herbicides. Both categories of farmers underutilize maize seed, pesticides and herbicides and over spent money on fertilizers since the marginal revenues earned from fertilizer use is lesser are lower than marginal costs (equivalent to their prices). Therefore for maximization of profits, both farmers need to search for cheaper fertilizer prices as well as increasing the use of improved maize seed, pesticide and herbicides. Results of the study indicate that smallholder irrigators are more technically efficient compared to homestead food gardeners in maize production. Factors that are positively associated with technical efficiency in maize production included household size, farming experience, off-farm income, use of agro- chemical, gross margins and commercialisation level. The amount of land owned and access to input use training had a negative impact on technical efficiency.

RECOMMENDATIONS

For sustainable rural food security and general livelihood, the government and development partners need to develop agricultural programmes that encourage creation of more associations or youth clubs engaged in farming. These programmes should incorporate agribusiness trainings, provision of financial assistance to avail start-up capital and enhance the youth economic empowerment.

Maize being the main staple food in Qamata and Tyefu communities, efficient food production and food security can be enhanced through policies that improve access to more resources like land, revitalisation of irrigation schemes and financial related programme for maize production. Research and development is also essential in developing improved breeds that are resistant to diseases and tolerant to adverse climate change.

There is need to catalyse processes of land reform policies, and revitalization and expansion of the irrigation schemes for increased smallholder productivity. This is due to results which indicated a positive and significant relationship between maize production, and land and irrigation water availability. However, improved access to land and water alone may not automatically result into increased marketable output but rather farmers need to be supported financially, provide trainings, and improve infrastructure and creation of market linkages.

Allocative efficiency results indicated that farmers need to search for cheaper fertilizers and increase the use of improved seeds, pesticides and herbicides in order to maximize profits. Use of agro-chemicals was also found to be positively related to technical efficiency. Therefore, use of agro-chemical and improved seeds should be increased through provision of input subsidies for maximization of maize output. In addition, improved allocative efficiency requires provision of more farmer trainings in the efficient use of inputs and improved skills in farm business management.

The forward and backward linkages in the smallholder agricultural sector should be strengthened through establishment of small scale agro-industries. Value addition is thought to improve farm gross margins and trigger increased household commercialisation levels.

Further, the government should set policies that promote investment incentives. Increased investment in agro-industries is thought to improve rural livelihood diversification in terms of increased employment and off-farm incomes. These incomes can be invested in farming through purchase of inputs and implements for improved technical efficiency and increased productivity.

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