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A COMPARATIVE STOCHASTIC FRONTIER ANALYSIS OF IRRIGATED AND RAIN-FED POTATO FARMS IN EASTERN ETHIOPIA

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Abstract. Irrigation development has been considered as one of the viable strategies for achieving food security. Accordingly, the government of Ethiopia has been increasing water resource development and utilization. However, to what extent the irrigation users are better off than rainfall dependent counterparts on their technical efficiency (TE) and variability in productivity among the farmers is not well known. Therefore, this study compared the technical efficiency of farmers who are producing potato under irrigation and through rainfall in Eastern Ethiopia. Propensity Score Matching was applied to select irrigated farms with comparable attributes to rain-fed farms to see the true efficiency differences between the two groups. Cobb-Douglas production function was fitted using the stochastic production frontier for both irrigated and rain fed farming. The result indicated that irrigated farms have high inefficiencies compared with the rain-fed farms. This indicates the existence of considerable potential for increasing output by improving the efficiency of irrigated farms than rain-fed farms. Among the factors hypothesized to determine the level of TE, landholding, family size and extension contact were found to have a significant effect on irrigated farms whereas, landholding, non/off income, farm income, livestock size and extension contact were the determinants in rain-fed farms. This indicates that factors that affect technical efficiency in irrigated farms are not necessarily the same as rain fed farms. Therefore, it is important to consider both farms groups in evaluating strategies aimed at improving technical efficiency of smallholder farmers.

Key words: irrigation, rain-fed, technical efficiency, stochastic frontier, PSM, potato

INTRODUCTION

Although the rate of global population growth is declining, the food demand is expected to increase to 9.1 billion by 2050. Most of this increase is projected to occur in South Asia and Sub-Saharan Africa, where a large share of the world's food insecure population resides (FAO, 2009). Ethiopia is among the poorest countries in the region, with over 85% of the population depending on agriculture (Getachew and Ranjan, 2012). Agriculture in the country is mostly small-scale, rainfall dependent and of subsistent nature with limited access to technology and institutional support.

In the country, extreme poverty is widespread; more than 38% of rural households fall below the food poverty line and 47% of children under five suffer from stunting (WFP, 2010). As indicated by Goshu et al. (2012), the depth and intensity of food insecurity in the country are high. Despite all these problems, the population of the country is increasing nearly by 3% annually (UNDP, 2009). This growing population requires better economic performance than ever before at least to ensure food security. This could demand increase in agricultural production through either introduction of modern technologies or by improving the production efficiency of the existing technology. Irrigation has been considered as one of the viable technology for achieving food security (Gebrehaweria et al., 2012). As indicated by Awulachew

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et al. (2007) the country's perennial dependence on food aid is attributed largely to an over-reliance on rain-fed smallholder agriculture. In the country, one drought event in 12 years lowers GDP by 7 to 10% and increases poverty by 12 to 14% (IWMI, 2011).

Nevertheless, investing in irrigation alone may not increase production and productivity, as there is always a time lag between the adoption of a new technology and achieving efficient use of that technology due to farmers' high degree of unfamiliarity with new technology caused by poor extension, infrastructure and education services (Arega and Manfrez, 2005). Therefore, it is important to determine if the actual production process follows the economic rationality criterion and, if not, by how much farmers are operating off the efficiency frontier. Specifically, in Ethiopia, the idea of boosting agricultural production through improvement in TE is supported by tremendous empirical studies, including Ahmed et al. (2014) and Gelaw (2013).

Although efficiency and productivity analysis is one of the most researched areas in Ethiopia, most of the studies emphasized on cereals and very few studies have analysed the productivity of root crops though they present an opportunity in reversing the trends in poverty and nutritional insecurity in the country.

Ethiopia has good climatic and edaphic conditions for higher potato production and productivity (Endale et al., 2008). Potato production in Ethiopia has exponentially expanded from 44,000 ha in 1994 to 67,362 ha of land in 2014 and the yield improved from 0.7954 tonne/ha to 13.6847 tonne/ha within this period (FAOSTAT, 2015). Potato has significant impact on the livelihood of smallholder farmers in Ethiopia. As indicated in CSA (2014) about 1,437,697 farmers were engaged in production of potato at 2013/14 Meher[1] production season. However, the supply of potato in Eastern Ethiopia is neither sufficient nor constant to satisfy the demand for the market (Mahlet et al., 2015).

Therefore, in countries like Ethiopia, where food deficit is prevalent due to recurrent droughts, the adoption of modern technologies like irrigation and improving the efficiency of production is expected to increase production and productivity. Despite such expectations that irrigation can shift the production frontier upward, there has been no empirical study to investigate the efficiency of irrigated agriculture in the study area. That means to what extent the irrigation users are better off in TE and the variability in productivity among irrigation user and non-user farmers is not well known. Therefore, this study investigated the level of TE of irrigated and rain fed potato farms and identified the factors that limit the level of TE.

The results of this study indicate an entry point for policy interventions to improve the efficiency of smallholder farmers through efficient utilization of available production inputs under irrigation and rain-fed agriculture. The result also enables less efficient farmers to derive lessons about better production practices from more efficient farmers. Identification of factors that are causing efficiency difference among farmers might have a substantial contribution in assisting policy makers as well as development workers to focus on those factors in order to improve farm efficiency. Therefore, the results would be important in designing potato extension packages in particular and the extension service in general that probably enhance the living standard of smallholders, mitigate the problem of food insecurity and improve competitiveness of the farmers.

METHODOLOGY

Description of the study area

This study was undertaken in Eastern Ethiopia, explicitly in Kombolcha district. The district is found in East Hararghe zone of Oromia Regional State with an area of 446.61 km^2. Attitudinally, it extends between 1200 and 2460 masl. Out of the 19 Kebeles[2] in the district, seven of them are located in the lowland and the remaining kebeles are located in the middle altitude. The annual rainfall of District ranges from 600 mm to 900 mm. The district's farming economy is characterized by small and fragmented land holdings. The rain-fed production system is most dominant and is practiced by the majority of the farmers. However, horticultural crops are often produced using irrigation. Farmers produce different crops like sorghum, maize, wheat, haricot bean, and fruits and vegetables. The district is one of the major producers of vegetables (Bezabih and Hadera, 2007). In addition, *chat*[3] is the dominant cash crop widely produced in the areas.

[1] Main season of the production year usually refers to the period from September up to February.

[2] Kebele is the smallest administrative hierarchy in Ethiopia.

[3] Chat (Catha edulis or Khat) is an evergreen plant used commonly for mastication and its sympathomimetic actions.

Method of sampling

A combination of purposive and random sampling techniques was employed to draw a sample of farmers for the study. First, Kombolcha district was selected since it is one of the major potato producing areas in Eastern Ethiopia. From the district, six kebeles were selected based on access to irrigation and households residing in selected kebeles were stratified as user and non-user of irrigation. This is because, in the same locality, some individuals irrigate while others do not due to awareness problem and accessibility of irrigation water. Accordingly, data were collected randomly from both strata using the same interview schedule at the same time. To give an equal chance in the selection of the study units from each concerned strata, probability proportional to size was applied. Consequently, the total sample size of 130 households was drawn via sampling frame (70 irrigation users and 60 non-users) using a simple random sampling technique.

Measurement of efficiency

The efficiency of a firm is its ability to produce the greatest amount of output possible from a given amount of inputs and an efficient firm is the one with a given state of technical know-how, can produce a given quantity of goods by using the least quantity of inputs possible (Raymond, 1981). Productive efficiency comprises technical and allocative efficiencies. TE reflects the ability of the firm to maximize output for a given set of resource inputs (Bradley et al., 2014). Allocative efficiency, on the other hand, is the ability of a firm to choose its input in a cost minimizing way (Farrell and Fieldhouse, 1962).

There are two approaches of measuring efficiency: output oriented (primal approach) and input oriented approach (dual approach). In the primal approach, the interest is by how much output could be expanded from a given level of inputs. Whereas in the input oriented approach the concern is the amount by which all inputs could be proportionately reduced to achieve the efficient level of production (Coelli et al., 2005). Parametric and non-parametric techniques are the two methods that can be delineated to the measurement of production efficiency. Data Envelope Analysis (DEA) method, which was initiated by Farrell (1957) and transformed into an estimation tool by Charnes and Rhodes (1978), is widely used non-parametric technique. It builds a linear, piecewise function from of empirical observations of inputs and outputs based on linear programming technique, which estimates a production frontier through a convex envelope curve formed by line segments joining observed efficient production units. No functional form is imposed on the production frontier and no assumption is made on the error term. As Del Gatto et al. (2011) pointed out this method, however, lacks the statistical procedure for hypothesis testing, it does not take measurement errors and random effects into account rather, it supposes that every deviation from the frontier is due to the firm's inefficiency. Moreover, it is very sensitive to extreme values and outliers.

Parametric approach, on the other hand, is based on econometric estimation of a production frontier whose functional form is specified in advance. In this approach, the stochastic frontier approach (SFA) is the most popular. It accounts for the effect of random factors such as errors of measurement, unspecified variables, or hazard factors. However, the need for imposing an explicit parametric form for the underlying technology and explicit distributional assumption for the inefficiency term are the main limitations of this approach (Sharma et al., 1999).

This paper has used SFA. This technique was selected for its ability to distinguish inefficiency from deviations that are caused by factors beyond the control of farmers. Agricultural production studies may be affected by measurement and variable omission errors (Chakraborty et al., 2002). As smallholder farmers in Ethiopia are characterized by low levels of education, most available data are likely to be subject to measurement errors.

The stochastic frontier production function was independently proposed by (Aigner et al., 1977; Meeusen and Van den Broeck, 1977). The original specification involved a production function specified for cross-sectional data that had an error term with two components, one to account for random effects and another to account for technical inefficiency. This model can be expressed in the following form.

$$Y_i = F(X_i;\beta)\exp(V_i - U_i) \quad i = 1, 2, 3,... n \qquad (1)$$

where Y_i is the production of the i^{th} farmer, X_i is a vector of inputs used by the i^{th} farmer, β is a vector of unknown parameters, V_i is a random variable which is assumed to be $N(0,\sigma_v^2)$ and independent of the U_i which is nonnegative random variable assumed to account for technical inefficiency in production.

As SFA require prior specification of functional form, Coelli et al. (1995) presented three common functional forms: Cobb Douglas, Translog and Zellner-Revankar generalized production functions. A log likelihood ratio test indicated that Cobb-Douglas production function is the best functional form for this study (Table 2). However, as indicated by Yin (2000) this production function is not free from critics. It has restrictive assumptions of unitary elasticity of substitution and constant returns to scale and input elasticities. Translog production function also has its own limitations such as being susceptible to multicollinearity and degrees of freedom problems. The linear form of Cobb Douglas production function is represented in Equation 2.

$$\ln Y_i = \beta_0 + \ln \sum_{j=1}^{n} \beta_j X_{ij} + \varepsilon_i \qquad (2)$$

where $\varepsilon_i = v_i - u_i$;

ln denotes the natural logarithm, j represents the number of inputs used, i represents the i^{th} farmer in the sample, Y_i represents the observed potato production of the i^{th} farmer, X_{ij} = denotes j^{th} farmer input variables used in potato production of the i^{th} farmer, β stands for the vector of unknown parameters to be estimated, ε_i is a composed disturbance term made up of two elements (v_i and u_i), v_i is the disturbance error term, independently and identically distributed as $N(0,\sigma_v^2)$ intended to capture events beyond the control of farmers; and u_i is a non-negative random variable, independently and identically distributed as $N^+(\mu,\sigma_u^2)$ intended to capture technical inefficiency effects in the production of potato measured as the ratio of observed output to maximum feasible output of the i^{th} plot. u_i is assumed to follow half-normal distribution with mean μ_i and, σ^2, such that:

$$\mu_i = Z_i\delta \qquad (3)$$

where, μ_i is inefficiency effects. δ is a 1xPvector of parameters to be estimated, which would generally be expected to include an intercept parameter and z_i is a Px1 vector of explanatory variables associated with firm specific inefficiency effects and are fixed constants.

A single stage estimation procedure was followed to analyze determinates of TE from a stochastic frontier production function. As indicated by Battese and Coelli, (1995), the two-step approach has serious limitations. The inefficiency effects assumed to be independently and identically distributed in the first stage in order to use Jondrow et al. (1982) approach to predict the value of technical inefficiency effects are assumed to be a function of several variables in the second stage. Unless all the coefficients of the inefficiency factors are at the same time equal to zero, the second assumption contradicts with the first assumption.

Propensity score matching (PSM)

PSM was used to select irrigated farms that are comparable to rain-fed farms in their biophysical characteristics.This technique helps to adjust for initial differences between a cross-section of irrigated and rain fed farms by matching each unit based on similar observable characteristics. It conveniently summarizes the conditional probability of adoption given pre-treatment or exogenous characteristics (Rosenbaum and Rubin, 1983). To do this, Caliper, Kernel and Nearest Neighbor matching estimators were used in matching the rain-fed and irrigated farms in the common support region. The final choice of the best matching estimator was guided by three criteria: balancing test, pseudo-R^2 and matched sample size (Caliendo and Kopeining, 2008). The balancing test refers to the test of equality of means of covariates after matching (Dehejia and Wahba, 2002). The pseudo-R^2 indicates how well the regressors explain the participation probability. After matching there should be no systematic differences in the distribution of covariates between both groups and, therefore the pseudo-R^2 should be low. A matching estimator that results in the largest number of matched sample size is preferred. Based on the criteria set above, caliper 0.25, with balancing test = 12, pseudo-R^2 = 0.024 and Matched sample size =108 (40 rain-fed plots and 68 irrigated plots) was found to be the best matching algorithm for the data we have.

EMPIRICAL RESULTS

Socioeconomic characteristic

The mean age of sample respondents was about 36 (Table 1) with a range of 20 to 75 years and they had been engaged in potato farming for about eighteen years. The mean educational level attended by sample respondents was about three. The family size of the sample farmers ranged from one to 10 with a mean of 4.33 person per adult equivalent per household. Seventy-five of the farms were in the woinadega[4] agro-ecological zone and

[4] Woinadega lies in the altitude of 1500–2300/2400 mm, rain--fall of 800–1200 mm/year and average annual temperature of 20.0–17.5/16°C and kolla's altitude is from 500–1500/1800 mm with rainfall of 200–800 mm/year and annual temperature of 27.5–20°C (MoA, 2000).

Table 1. Characteristics of respondents
Tabela 1. Charakterystyka respondentów

Variable Zmienna	Mean Średnia	Standard deviation Odchylenie standardowe	Min Min.	Max Maks.
Age – Wiek	35.88	10.41	20.00	75.00
Education (level of schooling) Wykształcenie (poziom wykształcenia)	2.85	3.29	0.00	12.00
Landholding (ha) Obszar gospodarstwa (ha)	0.36	0.19	0.06	1.00
Family sizes (adult equivalent) Wielkość rodziny (odpowiednik osoby dorosłej)	4.33	1.56	1.00	10.00
Experience (years) Doświadczenie (w latach)	17.81	10.13	1.00	55.00
Farm income (ETB per annum) Roczny dochód farmy	21 488.05	21 009.79	10.00	164 825.00
Livestock size in TLU Ilość inwentarza żywego	3.17	2.08	0.00	12.38
Off/nonfarm income (ETB) Dochód z działalności pozarolniczej	1 201.26	4 003.50	0.00	36 500.00
Agro-ecology (1 = woinadega, 0 = kolla) Ekologiczne działania rolnicze (1 = klimat ciepły umiarkowany, 0 = półsuchy)	0.75	0.43	0.00	1.00
Distance to market (km) Odległość od rynku (km)	7.41	7.15	0.00	22.00
Distance to main road (km) Odległość od drogi głównej (km)	3.96	6.35	0.00	22.00
Extension contact (no. of contacts) Kontakt z ośrodkami doskonalenia (liczba kontaktów)	10.93	15.07	0.00	60.00

Source: own computation (2015).
Źródło: obliczenia własne (2015).

the remaining 15% are located in kolla. On average, the respondents have 0.36 ha of land and 3.17 units of livestock in tropical livestock units (TLU). Annually, respondents were getting 21488ETB[5] from farm activities and they obtained 1201ETB from non/off farm activities. Sample respondents were 7.41 and 3.96 km away from the nearest market and the main road, respectively. The mean frequency of extension contact was about 10.93 days per year.

Test of hypothesis

One attractive feature of SPF method is its ability to test various hypotheses using maximum likelihood ratio test, which were not possible in non-parametric models. Subsequently, before proceeding to the estimation of the parameters from which individual level of efficiencies are estimated, it is essential to examine various assumptions related to the model specification. To do this, three hypotheses were tested. The first test was to choose the functional form that can better fit to the data at hand. This was done by testing the null hypothesis that the coefficients of all interaction terms and square

[5] ETB – Ethiopian birr; at the time of data collection, one USD was equivalent to 20.05 ETB.

Table 2. Generalized likelihood ratio tests of hypothesis for the parameters
Tabela 2. Uogólnione testy współczynnika prawdopodobieństwa hipotezy dla parametrów

Null hypothesis Hipoteza zerowa	Calculated Wyliczone χ^2	Degree of freedom* Stopień swobody*	Critical value Wartość krytyczna χ^2_{df}, 0.95	Decision Decyzja
For irrigated farms Dla farm nawadnianych sztucznie				
$H_0 = \beta_{ij} = 0$	6.856	15	24.9958	Accept H_0 Zaakceptować H_0
Inefficiency parameter Wskaźnik niewydajności H_0: $\gamma = 0$	14.004	1	3.84146	Reject H_0 Odrzucić H_0
H_0: $= \delta_0 = \delta_1 = \ldots = \delta_{12} = 0$	39.408	12	21.0261	Reject H_0 Odrzucić H_0
For rain-fed farms Dla farm nawadnianych naturalnie				
$H_0 = \beta_{ij} = 0$	12.851	15	24.996	Accept H_0 Zaakceptować H_0
Inefficiency parameter Wskaźnik niewydajności H_0: $\gamma = 0$	4.086	1	3.8415	Reject H_0 Odrzucić H_0
H_0: $= \delta_0 = \delta_1 = \ldots = \delta_{12} = 0$	38.622	12	21.0261	Reject H_0 Odrzucić H_0

* Degree of freedom (df) is equal to the number of restrictions (number of parameter equated to zero).
Source: model output.
* Stopień swobody (df) jest równy liczbie ograniczeń (liczba parametru utożsamionego z zerem).
Źródło: wynik działania modelu.

specifications in the translog functional forms are equal to zero (or checking weather Cobb Douglas is adequate representation). The second test was to verify whether there exists considerable inefficiency among farmers. The other test was to check whether the explanatory variables in the inefficiency effect model contribute significantly to the explanation of the technical inefficiency variation for the potato-growing farmers. The test was done based on the log likelihood ratio test (Table 2) which can be specified as:

$$LR = \lambda = -2[\ln L(H_0) - \ln L(H_1)] \quad (4)$$

where, $L(H_0)$ and $L(H_1)$ are the values of the log-likelihood function under the null and alternative hypotheses, respectively. This generalized likelihood-ratio test, LR, has asymptotic distribution, which is a mixture of χ^2 distribution, namely $\frac{1}{2}\chi_0^2 + \frac{1}{2}\chi_1^2$ (Coelli, 1995).

The calculated χ^2 value obtained from the log likelihood functions of the average response function and the stochastic production function was found to be greater than the critical value[6]. Hence, the null hypothesis that the average response function is an adequate representation of the data was rejected. The other hypothesis were also tested in the same way by calculating the likelihood ratio value using the value of the log likelihood function under the stochastic frontier model without explanatory variables of inefficiency effects (H_0) and the full frontier model with variables that are supposed to determine the inefficiency level of each farmer (H_1). The λ value obtained was again higher than the critical χ^2 value at the

[6] The critical value for a test of size α is equal to the value, $\chi^2(\alpha)$, where this is the value, which is exceeded by the χ_1^2 random variable with probability equal to 2α (Coelli et al., 1998).

degree of freedom equal to the number of restrictions. Hence, these variables simultaneously explain the difference in inefficiency among farmers.

Estimation of production function

The dependent variable of the estimated model was potato output (kg) produced. The input variables used in the analysis were area under potato (ha), organic fertilizer (quintal), labor (man-day in man-equivalent), quantity of seed (kg) and inorganic fertilizers specifically DAP and urea (kg). The result is presented in Table 3. The estimated value of γ indicates that 73.55% of total variation in irrigated farm output is due to technical ineffficacy. Whereas 69.26% of differences between the observed and maximum production frontier outputs in rain fed agriculture were due to the factors that were under farmer's control. The coefficients of area under potato, seed and amount of organic fertilizer were positive and statistically significant in irrigation agriculture. On the other hand, seed, urea, labor and area were also found to be significant in rain fed agriculture. However, the coefficient of Urea is found to be negative in rain fed agriculture indicating yield response to Urea under moisture stressed area is poor which is in line with the finding of Abdoulaye and Sanders (2005). Nevertheless, since the major concern of this study is to compare the level of TE of potato growing farmers under rain-fed and irrigation and the major factors determining the TE differential in the study area, in-depth discussions on the structure of production function and coefficients of input variables will not be made.

Technical efficiency scores

The mean TE of potato growing farmers under irrigation was 50.22% with the minimum and maximum scores of 19.90% and 88.24%, respectively (Table 4). For rain-fed agriculture, the mean TE score is 75.62% with minimum score of 20.70% and maximum of 99.93%. This shows that there is a wide disparity among farmers in their level of TE, which may in turn indicate that there is a room for improving the existing level of production through enhancing the level of TE. The mean TE tells us that the farmers who are using irrigation have opportunity to reduce inputs used for potato production

Table 3. Maximum likelihood estimates of the stochastic production frontier for irrigation and rain-fed production functions

Tabela 3. Maksymalne wartości prawdopodobieństwa stochastycznej granicy produkcji dla funkcji nawadniania sztucznego oraz naturalnego

Variables – Zmienne	Irrigation Sztuczne nawadnianie		Rain-fed Naturalne nawadnianie	
	cofficient współczynnik	standard error błąd standardowy	cofficient współczynnik	standard error błąd standardowy
Seed – Nasiona	0.667***	0.12	0.621***	0.13
Organic fertilizer – Nawóz organiczny	0.049**	0.02	0.039	0.03
Urea – Mocznik	0.026	0.03	-0.068**	0.03
Dap – Ftalan allilu	0.002	0.02	0.031	0.02
Labour – Praca	0.046	0.07	0.145**	0.07
Area – Obszar	0.604***	0.11	0.291**	0.11
Cons – Argumenty przeciw	5.344***	0.76	5.266***	0.8
$\sigma_v^2 + \sigma_u^2$	0.6630		0.8459	
$\gamma = \sigma_u^2/(\sigma_v^2 + \sigma_u^2)$	0.7356		0.6926	

*** and ** significant at 1%, and 5% probability level, respectively.
Source: model output.
Gwiazdkami *** i ** oznaczono poziom prawdopodobieństwa, odpowiednio 1% i 5%.
Źródło: wynik działania modelu.

Table 4. Summary of technical efficiency scores for irrigated and rain-fed farms
Tabela 4. Podsumowanie wyników technicznej wydajności farm nawadnianych sztucznie i naturalnie

Type of Farmers Farmerzy	Minimum Minimalnie	Maximum Maksymalnie	Mean Średnia	Standard deviation Odchylenie standardowe
Irrigation users Korzystający ze sztucznego nawadniania	0.1990	0.8824	0.5022	0.2311
Rain-fed Korzystający z naturalnego nawadniania	0.2070	0.9993	0.7562	0.2292

Source: model output.
Źródło: wynik działania modelu.

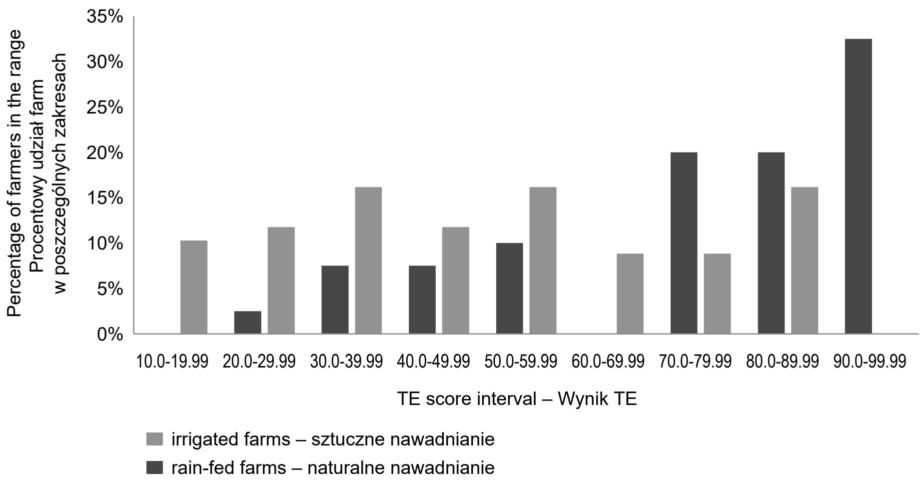

Fig. 1. Frequency distribution of technical efficiency indices for irrigated and rain-fed farms
Source: model output
Rys. 1. Rozkład występowania indeksów wydajności technicznej dla farm nawadnianych sztucznie i naturalnie
Źródło: wynik działania modelu.

proportionally by nearly 50% to produce the current level of output if appropriate measures are taken. There is also possibility of reducing inputs used in rain fed agriculture by 24.38% without affecting the current level of output. The results indicate that if the average farmer in the irrigated farm was to achieve the TE level of its most efficient counterpart, s/he could realize 43% input savings. A similar calculation can be made for technically average farmers in rain fed and the result revealed that 24.33% of input saving can be realized. For the most technically inefficient rain-fed dependent farmers, the result reveals that there is input savings of 79.29% if s/he was to achieve the TE level of its most efficient counterpart.

The frequency distribution of TE levels are presented in Figure 1. The figure indicates that rain-fed agriculture operates close to its production frontier, while irrigated agriculture produces towards the left of the spectrum. More than 50% of plots under rain fed were operated above the efficiency score of 80%. However, only 16.20% of irrigated farms were operated above the 80% of efficiency level. Whereas 50% of

Table 5. Average production of irrigated and rain-fed frontiers
Tabela 5. Średnia produkcja z granicznych obszarów nawadnianych sztucznie i naturalnie

Type of input Rodzaj nakładu	Irrigation (N = 68) Sztuczne nawadnianie (N = 68)		Rain-fed (N = 40) Naturalne nawadnianie (N = 40)	
	amount of inputs used wielkość zastosowanych nakładów	average product średnio na produkt	amount of inputs used wielkość zastosowanych nakładów	average product średnio na produkt
Total average product Całkowity – średnio na produkt	–	3 476.832	–	2537.73
Seed – Nasiona	234.2647	14.8415	201.25	12.6098
Organic fertilizer – Nawóz organiczny	65.3089	53.2367	52.1251	48.6854
Urea – Mocznik	13.9250	249.6826	12.5513	202.1893
Dap – Ftalan allilu	14.3000	243.1348	7.9575	318.9093
Labor – Praca	6.0055	578.9399	7.6563	331.4586
Area – Obszar/areał	0.0941	36 941.044	0.0891	28 468.8458

Source: model output.
Źródło: wynik działania modelu.

plots under irrigation were operated below efficiency score of 50%, yet the corresponding value for rain fed agriculture was only 17.50%. Thus, productivity of farms under irrigation can be raised through increasing the level of TE at the existing level of technology and inputs; while rain fed farms need the introduction of new technologies to increase productivity significantly.

Average productivity under irrigation and rain fed

Table 5 presents the average productivity of inputs used in the stochastic frontier production models of irrigated and rain-fed potato farmers. The results reveal that irrigated agriculture requires 0.0941 ha of land, 234.26 kg of seed, 6man-days of labor, and 65.309 kg of organic fertilizer, 13.9 kg of UREA and 14.3 kg of DAP to produce 3476.8 kg of potato. On the other hand, to produce 2537.73 kg of potato, rain-fed agriculture required 0.089 ha of land, 52.13 kg of organic fertilizer, 201.25 kg of seed, 7.66 man-days of labor and 7.96 kg of DAP and 12.55 kg of urea.

Determinants of technical inefficiency of irrigated and rain fed potato producers

Having the information about the existence of technical inefficiency and measuring its magnitude, scrutinizing the major factors causing this inefficiency level is the next step of the study. To see this, efficiency levels of sample farmers were regressed on factors that were expected to affect efficiency levels[7] (Table 6).

Households' landholding was positively and significantly related to technical inefficiency of potato growers in both irrigated and rain-fed agriculture. This could be due to the fact that as the farm size increases the managing ability of the farmer will decrease, given the level of technology. Farmers may not also have adequate cash to purchase improved inputs for all farms as the size increase, leading to less expenditure on improved

[7] One important point to be considered here is that the dependent variable is the inefficiency component of the total error term estimated in combination with the production frontier. Hence, the coefficients should be read as the effect of each variable on the level of inefficiency instead of efficiency.

Table 6. Maximum-likelihood estimates for parameters of technical inefficiency for irrigated and rain-fed potato production
Tabela 6. Maksymalne wartości prawdopodobieństwa dla parametrów braku technicznej wydajności w produkcji ziemniaków nawadnianych sztucznie i naturalnie

Variables – Zmienne	Irrigation Sztuczne nawadnianie		Rain-fed Naturalne nawadnianie	
	coefficient współczynnik	standard error błąd standardowy	coefficient współczynnik	standard error błąd standardowy
Age – Wiek	–8.48E-05	0.0062	–0.0055	0.0035
Agri-ecology Ekologiczne działania rolnicze	–0.3262	0.2076	–0.1330	0.1050
Distance to main road Odległość od głównej drogi	–0.0002	0.0075	0.0024	0.0050
Landholding (ha) Obszar gospodarstwa (ha)	0.3404**	0.1598	0.3230***	0.1018
Non/off income Dochód z działalności pozarolniczej	1.30E-06	1.53E-05	1.0E-05***	3.69E-06
Distance to market (km) Odległość od odbiorcy (km)	–0.0034	0.0122	0.0010	0.0057
Education – Poziom wykształcenia	–0.0073	0.0093	0.0097	0.0059
Experience – Doświadczenie	0.0009	0.0067	0.0020	0.0034
Family size – Wielkość rodziny	0.0297**	0.0130	–0.0002	0.0104
Farm income Dochód z gospodarstwa	–1.59E-06	1.34E-06	–6.35E-06***	1.12E-06
Livestock size (TLU) Liczebność żywego inwentarza	–0.0047	0.0210	0.0287***	0.0097
Extension – Doskonalenie	–0.008911***	0.0027	-0.0024***	0.0009
Cons – Argumenty przeciw	0.0842	0.4875	0.4433	0.2794

*** and ** significant at 1% and 5% probability level, respectively.
Source: model output.
Gwiazdkami *** i ** oznaczono poziom prawdopodobieństwa, odpowiednio 1% i 5%.
Źródło: wynik działania modelu.

production technology and practices, which in turn make the farmers less efficient.

On/off farm income of household head was also related positively to technical inefficiency in rain-fed agriculture. More income from off/non-farm will attract the farmer and if farmer spends more time on off/non-farm activities relative to farm activities, the farm practices will receive less attention and less management, this could negatively affect agricultural activities and hence efficiency.

Family size was also found to be a significant variable in determining farm efficiency. As indicated in Table 6, family size was positively and significantly related to technical inefficiency of potato farmers in irrigation agriculture. Increase in the family size would increase expenditure for home consumption that can affect the efficiency of farmers negatively by creating farm financial constraints. As discussed earlier irrigation agriculture requires higher level of inputs than the rain-fed.

Extension contact was negatively related to technical inefficiency in both irrigated and rain-fed potato farms. The higher the linkage between farmers and development agents, the more the information flows and the technological (knowledge) transfer from the latter to the former. Those farmers who have frequent contacts with development agents are likely to produce better than others.

Livestock size was also found to have positive effect on technical inefficiency of rain fed agriculture. Farmers who possess more number of livestock will allocate much of their time in livestock husbandry practices and give less time for crop farm activities, which in turn affect crops production efficiency. Meaning, its supplementary effect could diminish and it is likely to become competitive. In the study area, livestock also have other social benefits, which could be the sign of wealth and source of respect.

Farm income also found to have negative relation with technical inefficiency in rain fed agriculture. Increase in farm income will alleviate financial constraints so that farmers with good farm income will have better capacity to purchase the recommended amount of improved agricultural inputs at the required time that would improve productivity.

CONCLUSION AND RECOMMENDATION

In this paper, a single-step stochastic frontier analysis was used to estimate both the frontier and inefficiency models simultaneously. The study has revealed that variation in the output across potato farms in the region is partly due to difference in their technical efficiency levels. The level of technical efficiency was also found to differ significantly between irrigated and rain-fed farms. The result indicated that by proper management and prudent allocation of the existing resources and technology, sufficient potential exists for improving the productivity of potato. Especially, the potential to increase production by improving efficiency is enormous in irrigated agriculture. Therefore, the attention of policy makers to mitigate the existing level of food deficiency and poverty by improving agricultural production should not stick only to the introduction and dissemination of inputs but also they should give due attention towards improving the existing level of efficiency.

The study also identified factors causing efficiency disparity among farmers and landholding is among significant variables that affect the level of technical efficiency in both irrigated and rain-fed agriculture. Thus, provision of technologies that would help to carry out such operations more efficiently would improve the technical efficiency level of the farmers. The negative impact of off-farm employment of the household on the level of technical efficiency of rain fed agriculture indicates its competitive nature with the activities related to the production of potato. In this regard, the authors are not against the opportunity that farmers would get from the off-farm employment. This is because; it is not the off-farm engagement that is affecting the level of TE. Rather it is the overlapping of both operations in time as well as their competitive nature for the labour input. Hence, it is pertinent to suggest that less efficient farmers properly allocate their family labour between farm and off-farm activities. The negative impact of livestock ownership on TE of rain fed agriculture also indicates the complementarity between them and the result has to be seen in the same way as the off-farm activity. Family size also found to contribute negatively to the improvement of efficiency. Thus, family planning programs should be strengthened to reduce the average family size in the long run. The result indicated that extension contact has positive and significant contribution to technical efficiency in both irrigated and rain fed farms. Therefore, proper and sufficient extension services should be provided. This could be done by designing suitable capacity building program to train additional development agents to reduce the existing higher ratio of farmers to development agents in the country.

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PORÓWNAWCZA ANALIZA STOCHASTYCZNA GOSPODARSTW Z UPRAWĄ ZIEMNIAKÓW NAWADNIANYCH SZTUCZNIE I NATURALNIE WE WSCHODNIEJ ETIOPII

Streszczenie. Rozwój systemów nawadniania jest powszechnie uważany za jedną z najistotniejszych strategii zapewniających bezpieczeństwo żywnościowe. Zwiększenie zasobów wodnych i odpowiednie ich wykorzystanie to kwestie szczególnie istotne dla rządu Etiopii. Dotychczas nie zbadano jednak dokładnie korzyści stosowania nawadniania sztucznego na tle nawadniania naturalnego pod względem efektywności technologicznej. Niniejsze opracowanie zawiera zatem porównanie efektywności technologicznej tych dwóch grup producentów ziemniaków na obszarze wschodniej Etiopii. Przy wyborze porównywalnych gospodarstw do badania zastosowano metodę PSM (Propensity Score Matching), co umożliwiło określenie rzeczywistych różnic między podmiotami z obu grup. Dopasowano funkcję produkcji Cobba-Douglasa, stosując porównawczą analizę stochastyczną produkcji dla obu przypadków – z nawadnianiem i bez. Wykazano, że gospodarstwa nawadniane są znacznie mniej efektywne w porównaniu z drugą grupą. Wskazuje to na ogromny potencjał zwiększenia ich produkcji dzięki poprawie efektywności. W gospodarstwach nawadnianych za czynniki mające hipotetycznie największy wpływ na poziom efektywności technologicznej uznano: wielkość gospodarstwa, liczebność rodziny i kontakty z ośrodkami doskonalenia, natomiast w gospodarstwach nawadnianych naturalnie były to: wielkość gospodarstwa, dochód z działalności pozarolniczej i rolniczej, liczebność żywego inwentarza i kontakty z ośrodkami doskonalenia. Okazuje się więc, że w każdej z tych dwóch grup gospodarstw zupełnie inne czynniki wpływają na efektywność technologiczną. Przy opracowywaniu strategii mających na celu jej poprawę trzeba zatem uwzględnić specyfikę obu badanych grup.

Słowa kluczowe: nawadnianie, nawodnienie naturalne, efektywność technologiczna, porównawcza analiza stochastyczna, PSM, ziemniaki

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