Technical and Economic Efficiency of Rice Production in Smallholder Farmers: The Case of Fogera District, Amhara Region, Northwestern Ethiopia.

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Abstract

In Ethiopia, rice is a recently introduced crop which is considered as the “Millennium crop” expected to hugely contribute food security. This paper seeks to measure the technical, allocative, and economic efficiency of rain-fed rice production and identify the factors that affect the efficiency of farmers in Fogera Districts of the Amhara Region. For the study, cross-sectional data were collected from a survey of 230 smallholder rice producers. The study used stochastic frontier production(SFA) and cost function to investigate the variations in the efficiency level of rice producers. The result indicated that the TE was higher as compared with the EE and AE. The average TE ranges between 24% and 93% with a mean of 70%. However, the mean of EE was 24.40 % and the AE 37.30%. Therefore, reduction of cost of production (such as improved input supply systems), warehouse facilities to keep produce and prevent the immediate sale of a product, introducing of a contract marketing system would improve the economic efficiency of the rice farming. Intervention on education and training on female-headed households, reducing family dependency, training of older farmers’ were vital to increase the EE of rice production.Similarly, improving the farmer’s education level to boost knowledge about new rice technology applications, and frequent training of farmers would enhance the TE of farmers in the study area.

Keywords: Allocative Efficiency, Economic efficiency, Technical efficiency, Amhra region.

1. INTRODUCTION

Rice (Oryza sativa L.) is a staple food and a common source of livelihood plays a major role in almost all Asian cultures and civilizations. It is also the most rapidly growing source of food in Africa and is of significant importance to food security and food self-sufficiency in an increasing number of low-income food-deficit countries such as Ethiopia. The crop is among the target commodities that have received due emphasis in the current effort to transform agricultural production and productivity. It is considered as the "Millennium crop" expected to contribute to food security in the country. Rice is considered to be a highly productive crop next to maize in the country (CSA, 2003). The estimated potential areas of rice production in Ethiopia were 30 million hectares.

The introduction and expansion of rice production in suitable agro-ecologies, therefore, could be an option to achieve food security and self-sufficiency. It is reported that the potential rice production area in Ethiopia is estimated to be about 20 million hectares and irrigated about 3.7 million hectares. In Ethiopia, about 88% of the production is obtained from rain-fed production, and only about 12% from irrigated water (MoARD, 2010). Despite the growing importance of the rice in Ethiopia, the traditional method of production such as plowing, planting, the chemical application has resulted in a huge reduction of potential production and productivity in the country(Atnaf, 2019).

Fogera district, one of the potential areas of rice production in Ethiopia with an estimated national rice product contribution of 42%(Tamirat et al., 2017), is challenged by several production and marketing challenges that hinder the benefit of the crop for farmers and consumers.

Like many other similar cereal productions in Ethiopia, rice production is characterized by low utilization of inputs, lack of technology, and inefficiency in utilizing resources (Schultz, 1964). However, to increase production and productivity of rice at the household level with the available resource endowments, efficient utilization of available inputs need to be fostered. With this respect, efficiency analysis is associated with harnessing the allocation of rice farming with a certain optimal level of output from a given bundle of resources or a certain level of output at the least cost. The reason behind the need to measure efficiency is that majority of rice farmers lack the tendency of making efficient use of existing technologies due to socioeconomic constraints.

On the other hand, the Ethiopian government growth and transformation strategy GTP (the 5-years plan) also indicated that increasing production and productivity/double of output/ per production seasons this is possible by using modern technologies or if farmers used their resources efficiently to the maximum level (GTP II(2015/16-2019/20).

According to, MoARD, (2010 and 2017), The average amount of paddy produced per household is estimated to be 21 quintals in 2009 and 22 quintals in 2010. In the Amhara region also paddy production was 25 qt/ha in 2010 and 23 qt in 2009 at the household level, but it is much lower at the research level (about 100qt /ha (Minilik et al, 2013). This shows that there is room to improve rice production to the maximum level but farmers produced below the production frontier line due to different factors. These entails the importance of identifying determinants that affect the farm level technical, allocative and economic efficiency differential at national level in general and in the study area in particular.

Most studies on efficiency focus on technical efficiency (Taddesse etal ,2016, Moges Dessale, (2017), Solomon,(2014) and Shumet (2011) and profit efficiency (Hyuha et al. 2007). Technical efficiency examines the capacity of producers to produce maximum output from the given level and combination of inputs. This doesn't show the whole source of inefficiency (technical and allocative efficiencies). This study, however, looks at both technical and allocative efficiency and the whole together (economic efficiency) of rice production. This, approach is in line with the evolving context of rice farming to commercialization(purchased input and eating of produce).

Cognizant of the stated importance of rice and existing untapped potential in terms of productivity and profitability in the study area, this research investigates the existing input-output relation of rice production and the gap due to the technical, allocative, and economic inefficiency of rice producer farmers. Moreover, it identifies the socioeconomic factors that affect the rice producer farmers in the study area. An understanding of the relationships between input-output relationship and efficiency of farm-specific practices would provide policymakers with appropriate information to design production and marketing program that can contribute to increasing food production and income of smallholder farmers.

2. Research Methodology

2.1. The Study Area.

The study was carried out in Fogera Districts of Amhara regional state of Ethiopia, where rice production is dominant in the region as well as in the country. Especially, borders of Fogera districts(the western part of Lake Tana) and its surrounding areas in North Gondar have the potential to grow rice since the area is characterized by its low altitude (about 800m above sea level) and high temperature with sufficient rainfall for production. In Ethiopia, a suitable rice-growing area is estimated to be about thirty million hectares and it remains a minor crop in Ethiopian Agriculture (Dawit, 2015, Tamirat and Jember, 2015). Rice production in Fogera district comprises of 40% (in 2008 and in 2010) of the national rice production (NRRDSE, 2010, APRA, 2019). The district comprises low land and upland rice production. The districts lie within latitude 40°411 South and 60°30I North and longitude 8°and 9°00I East of the Equator. (Figure 1).

2.2. Sample size and sampling design:

The data for this study was collected from randomly selected rain-fed lowland rice farmers in Fogera districts, during the 20015/20016 cropping season. A purposive sampling technique was used in the selection of rice-producing kebeles (lowest administrative units) in the Districts. The area classified as a low-land rice farming and upland rice farming system (Dawit, 2015). Among the fourteen rice-producing kebeles of the Districts, four kebeles (PA), from both farming systems were considered for the study (Table 1).

2.3. Type and sources of data

Both quantitative and qualitative data were collected through a survey using a structured questionnaire. Data on inputs used in production were fertilizer, seed, labor, capital, chemicals, herbicides as well as output office in quintal (1quintal = 100 kgs) were collected. data on socio-economic characteristics of the farmers were also obtained on the first visit with the use of questionnaires after a pre-test survey undertaken and corrections done on the questionnaire.

3. Method of Data Analysis

3.1. Efficiency and Stochastic Approaches.

The concepts of efficiency and productivity are commonly used to replace each other despite their different meanings. Productivity can be used as the ratio of output to the input of a given firm, where as efficiency is defined as the ratio of the maximum possible output on the frontier line to agiven level of inputs used fro production (Coelli, Rao, O'Donnell, &Battese, 2005). The estimation of efficiency began with the work of Farrell (1957), who explained the concept of a firm's efficiency considering multiple inputs. According to him, efficiency consists of two components: technical efficiency and allocative efficiency, A combination of technical and allocative efficiency presents a measure of economic or cost efficiency (Coelli, 1996a).

3.1.1. Estimation of Technical efficiency

The empirical stochastic frontier model used, was the Cobb-Douglass for the analysis of the technical efficiency of rice farms in the Fogera District. The major reasons researchers used using this functional form were due to its mathematical properties, simplicity of computation, and interpretation of the result was easy (Heady & Dillon, 1961). The Cobb-Douglas production function can provide a better approximation for the production processes for which factors of production are imperfect substitutes over the entire range of input values. Besides, the Cobb-Douglas production function is relatively simpler to estimate because of logarithmic transformation into linear form(Beattie & Taylor, 1985).

Technical inefficiency exists when it is possible to produce additional outputs with the fixed inputs used (output-oriented) or to produce the given level of outputs with fewer inputs (called input-oriented). In other words, technical efficiency (TE) can be stated as the ratio of the sum of weighted outputs to the sum of weighted inputs (Cooper et al., 2004). A general stochastic production following Aigner et al. (1977)and Meeusen and Van den Broeck (1977), the frontier can be expressed by

$$\ln Y_i = \alpha + \beta_i \ln X_i + V_i + U_i, \text{ where, i=1, 2...n} \quad (1)$$

Where: ln represents the natural logarithm, yi is the output produced by farm i, x is a vector of factor inputs, β is a vector of unknown parameters, Vi is the stochastic error term. The error term is assumed to be independently and identically distributed (N (0, 2). Ui is a one-sided, Vi non-negative random variable associated with the technical inefficiency in production. This one-sided term can follow such distribution as half-normal, exponential, truncated, and gamma. In our case, we specified it as a half-normal distribution.

To measure efficiency for the farmers we adopt the Coelli et al.,(1998) technical inefficiency model using cross-sectional data. The model is specified algebraically as follows;-

$$TE = Y_i/Y^* \quad (2)$$

$$\begin{aligned} TE_i &= Y_i / f(X_i;\beta)\exp(\varepsilon_i) \\ &= \frac{f(X_i;\beta)\exp(\varepsilon_i = v_i - u_i)}{f(X_i;\beta)\exp(v_i)} \\ &= \exp(-u_i) \end{aligned}$$

Where: ***TE_i*** is the ratio of the actual output to potential output. ***Y_i*** is the ratio of the actual output and Y* is the potential output, of technical efficiency of the farmer, and $f(X_i :\beta)\ exp\ (v_i\ )$ is stochastic frontier output.

$$u_i = Z_i\delta + w_i \tag{3}$$

Where; Z_i is a vector of explanatory variables associated with the technical inefficiency, δ is a vector of parameters to be estimated and w_i stands for unobservable random variables. If U =0, the farm is assumed to be efficient implying that the actual output is equal to the possible output. The farm will be lying on the production function, hence, technically efficient. The parametric model is estimated in terms of the variance parameters.

$$\delta^2 = \delta_v^{\ 2} + \delta_u^{\ 2} \tag{4}$$

$$\gamma = {\delta_v^{\ 2}}\Big/{\delta_u^{\ 2}} \tag{5}$$

Where: $0 \leq \gamma < 1$ and the variance measure fundamental in deterring whether a stochastic model is best over the traditional average production function in the case of cross-sectional data. According to Kumbhaker, Wang, and Horncastle (2015), the variance estimates methods of test statistics were not advisable and they recommend using the likelihood test statistics.

3.1.2. Estimation of Economic and Allocative Efficiency.

The stochastic cost frontier function was used to analyze economic efficiency (CE). The farm specific economic efficiency is defined as the ratio of the minimum total production cost (C*) to the actual observed total production of cost (C). The model for cost function is as follows;

$$C(Y_i^*, w) = HY_i^{*\mu} \prod_j W_j^{\alpha j} \tag{6}$$

where; $\alpha_j = \mu\hat{\beta}_j$, $\mu = (\sum \hat{\beta}_j)^{-1}$, $H = \frac{1}{\mu}(\hat{A} \prod \hat{\beta}^{\beta_j}{}_j)^{-\mu}$, $Y_i^* = \hat{A} \prod X_j^{\hat{\beta}_j}$ and $\hat{A} = \mathrm{Exp}(\hat{\beta}_o)$

Where; refers to the i^{thn} sample farm household; C_i is the minimum cost of production; W_i denotes input prices; Y_i* refers to farm output which is adjusted for noise, x_j refers to the inputs used, β's are the coefficients estimated from the production function and α's are parameters to be estimated.

By using the formula above it was calculated to find the minimum efficient cost (C^*), the output that should be produced (Y^*), the coefficients for the cost function α's, and the coefficient for output here is μ. Then, we have two costs: the actual cost that the farmer incurred (C) and the calculated minimum cost (C^*) and two outputs: the output that thefarmer actually produced (Y) and the output calculated (Y^*).

The farm specific economic efficiency is defined as the ratio of minimum calculated total production cost (C*) to actual total production cost (C).

$$EE = C^*/C \tag{7}$$

The allocative efficiency indexwas then derived as follows:

$$AE = EE/TE \tag{8}$$

After estimating the efficiency scores, the determinants of efficiency were estimated using the Tobit model as the efficiency scores are censored between 0 &1 (Battese and Coelli, 1995). Hence, the technical, allocative, and economic efficiency used as a dependent variable, and the corresponding inefficiency variables(considered as explanatory) were hypothesized.

Some authors argued that the socioeconomic variables should be incorporated directly in the production frontier model because such variables have a direct impact on efficiency and it has a persistence bias that will affect the estimates of efficiency (Wang and Schmidt, 2002). However, others defended this approach by contending that the socioeconomic attributes have around the effect on production and should be incorporated into analysis indirectly(Kalirajan, 1991 and Bravo–Ureta and Evenson, 1994). We adopted the latter one as justified above. The standard Tobit model was employed for the observation of farms (Maddala, 1983).

$$Y^* = X_i\beta_i + U_i \tag{9}$$

$$Y_i = Y^* \text{ if } Y^* < 0$$
$$Y_i = 0 \text{, otherwise}$$

Where; Ui ~N (0,), Xi, and βiare vector of explanatory variables and Unknown parameters, respectively, and Y* is the latent variable and Yi is the efficiency scores in Stochastic frontier (Amemia, 1984).

3.1.3. Variables Description of the Model.

Six explanatory variables were included in the stochastic frontier model to estimate the efficiency level of the farmers and about thirteen socioeconomic variables were included to identify the determinants of farmers' efficiency in rice production in the study area. The sign and the variables hypothesized to influence the efficiency of farmers in rice production were depicted (Table 2).3. Result and Discussion

3.1. Socioeconomic description of the respondents

Among the respondents, about 91% were male-headed households, whereas the rest 9% were female-headed headed households. The survey result indicated that the average age of 48 years old. The survey revealed that 19.13 % of the households were illiterate and 46.96 % were able to just read and write and 69.09 % were between school-age of one and ten. The average household size of the farmers was six members. The average farm experience in producing rice was 32 years of farming. The average extension frequency per month was about 2 with a minimum one and a maximum of eight times per month. Similarly, the average distance of farmers from the agricultural office, cooperative office, and the farmers' training center (FTC) to their homes were 87, 41, and 39 minutes respectively. The average distance from the nearest market center takes about 90 minutes (one hour and 30 minutes) (Table 1)

The average labor used for rice production such as for tillage, weeding, harvesting, and collection of rice was 123 man-days with a minimum of 24 and a maximum of 400 man-days. The average amount of rice seed used was about 362 kg(3.5 quintals) per household. The average land size allocated for rice production was about one hectare (4.27 timad). On average a farmer had 3 plots of land owned. The average yield of rice obtained was 4,533kg.The average fertilizer used for rice production of farmers was118 kg of Urea and 28 kg of DAP, respectively. Farmers also used several types of chemicals and the average amount of chemicals applied for rice production was about 0.08 litters per household. The average number of oxen farmers used for rice cultivation was about two oxen (a pair of oxen) which consists of about 46.96% and the maximum was about 5 oxen which were 1.30%. The average labor required for rice production was 10 oxen-days per Households (Table 3)

The average rice produced by the producers was 45 qt per household with a cost of 28,103.75 ETB. The average selling price of rice during the study year was 3059.5 ETB per quintal. The most significant cost of production was weed cost-covering (38% of the total cost of rice production). The cost of land was (land rent also considered as opportunity cost) and was found to be 46% of the total production cost(Table 4).

3.2.Estimation of Technical, Allocative and Economic Efficiencies

3.2.1. Technical efficiency model result.

The Wald Chi-square statistic was checked to test the overall significance of variables. The result implied that the model was significant at less than 1% level (LR chi2 (17) =187.79, and the explanatory power of the factors included within the model is satisfactory. The presence or absence of technical inefficiency was tested in the study using the important parameter of log-likelihood in the half-normal model $\lambda = \sigma u2/\sigma v2$. If $\lambda = 0$ there were no effects of technical inefficiency, and all deviations from the frontier were due to noise (Aigner et al. 1977). For rice analysis, the estimated value of λ =4.7292 significantly differed from zero. The null hypothesis that there is no inefficiency effect was rejected which means 47 % of the variation comes from the inefficiency.

The result of the model showed that seed, the area under rice cultivation, urea fertilizer, labor, and chemicals had a positive and significant effect on the level of rice production. This would mean an increase in those inputs results in an increase in the output of rice (Table 5). The summation of production inputs' coefficients was 0.939, indicating the one percent increase in inputs simultaneously leads to a 0.939% increment of production (CRS). This result inlined with the result of Desale, (2017).

The result of technical efficiency output indicated that the technical efficiency of rice production was 70.50%. However, the economic efficiency of the farmers was 24.40% and the allocative efficiency was 37.30%. The result indicated that the TE was better compared to the and AE. The lower mean AE and EE of rice production in the study area don't only imply the presence of a higher level of inefficiencies but also the presence of a huge possibility to improve the level of the same input level. For instance, the producer with an average EE level could reduce the current average cost of production by 76% to achieve the potential minimum cost level without reducing output levels (Table 6).

The result of the frequency distribution of the technical efficiency of rice farmers indicated that technical efficiency (TE) of the rice farmers in Fogera districts ranges from 71 percent to 25 percent, with an average of 70.52 percent. It indicates that there exists also a room to improve the technical efficiency of farmers without extra input use. In addition, the highest TE level ranging from 70 percent to 80 percent comprises 76 farmers, which is 33 percent of the total. The lowest TE score of less than 50 percent comprises 27 farmers, or 12 percent, indicating that almost all farmers in the study area able to improve their efficiency (Table 7).

3.2.3. Determinants of Technical, Economic, and Allocative efficiency of rice production.

The efficiency level of farmers is determined by various demographic, socio-economic, and institutional factors. We fitted a Tobit model with a dependent variable of technical, economical, and allocative efficiencies to determine factors that affect the efficiency of rice farming. The overall model was significant at the 1% level for technical but note economic and allocative efficiency. The result of the Tobit estimation function is presented in (Table 3).

The variables, age, dependency- ratio farm households were the important variables that affect the economic efficiency of the farmers at a 5% level of significance. However. It did not affect the technical and allocative efficiency of rice production. A similar study on rice farmers in Brunei, Darussalam indicated that experience, soil type, sex, and farm size has a positive effect on the economic efficiency of rice (Galawat and Yabe, 2011).

Household size also an impact on efficiency the result indicated that male household size has economic efficiency as compared to the female household size but has not any effect on the economic and allocative efficiency of rice production. The study by Abebe et al, (2016), indicated that household affects technical efficiency on rice production.

The education level of households is a necessary element to improve the technical efficiency of the rice farmers. It was Positively associated with the efficiency of rice production, implying that the farm family with a better education level is more efficient than families with less education level. That is a farmer with a better school produces more efficiently than lower-class schools. The result is similar to the study carried out by Tadesse et al, (2017), Boris etal.,(1993).

Another outcome of the efficiency model variable was the negative and significant effect of market distance on technical efficiency but did not have an effect on the economic and allocative efficiency of rice production. The farm family, who were distant from the market center were less efficient than the households who were nearer. Similarly, the coefficient of the cooperative office distance, variables were positive both on technical efficiency and economic efficiency but not had any relation to allocative efficiency. This implying that farmers who become nearer to the cooperative's office were more efficient. This expected result could be explained by technical assistance to the farmers, information sharing, and training courses by cooperatives. This result was consistent with the study by Tolga, (2009).

Farmer's experience in rice production has positively related to the technical efficiency of farm households. The farmer who has experience in rice production was efficiently a better position than the non-experienced farmers. This is because experience farmers, could be; improves the skill and technical capacity that enables to best match inputs. The result was consistent with many research outputs(Galawatand Yabe,2011, Tadesse et al.,2016)(Table 8).

4. Conclusion and Recommendation

The study investigated the farm level technical, allocative, and economic efficiency of rice production and its determinants in the Fogera District of Amhara regional state. The study was undertaken in a sample of 230 smallholder farmers. Using a stochastic frontier production function, the empirical evidence suggests the critical factor in explaining yield are education level of household, land size, Urea fertilizer, and chemicals application use. The technical efficiency of farmers in Fogera districts ranges from 71 percent to 25 percent, with an average of 70.52 percent. It indicated that there was room to improve the efficiency of farmers without extra input use. Besides, the highest TE level ranging from 70 percent to 80 percent comprises 76 farmers, which is 33 percent of the total. The lowest TE score of less than 50 percent comprises 27 farmers, or 12 percent, indicating that almost all farmers in the study area achieve a moderately efficient score.

Similarly, the education level of Household, market distance, distance from the cooperative office, and rice farming experience of households were particularly important determinants of farmer's efficiency of rice production in the study area. Hence, improving farmer's education level, knowledge about new technology applications. The government should focus on facilitating marketing infrastructure and encouraging experienced rice farmers to produce more efficiently were the recommendation forwarded.

The survey result also revealed that the economic efficiency of the farmers was 24.40% and the allocative efficiency was 37.30%. The result indicated that the TE was better compared to the EF and AE. The mean AE of farmers in the study area was 37.42% indicating there is a need to improve the present level of AE. The mean EE showed that there was a significant level of inefficiency in the production process. That is the producer with an average EE level could reduce the current average cost of production by 76% to achieve the potential minimum cost level without reducing output levels.

The main factors affecting technical efficiency were male-headed households, market distance, cooperative office distance, farming experience, and rice varieties. The factors that influence allocative efficiency were dependency ration, age of households, family size, and farmers' distance from the cooperative office. Similarly, soil type and rice variety were the main determinants that affect the economic efficiency of rice production.

Therefore, the minimum cost of production through the effective introduction of technologies and improved marketing system of households, Intervention on education and training on rice production for female-headed households, engaging unemployed household members to reduce dependency, training of older farmers' and improve infrastructures such as market facilities, roads, and input supplies were vital to increase the Economic efficiency of rice production.

Abbreviations: TE (Technical efficiency):**EE** (Economic Efficiency); **AE** (Farmers' training center); **PA**(Present Association); **CSA** (Central Statistical Authority);WAO(Woreda agricultural office); **ETB** (Ethiopia Birr);**SFA** (Stochastic Frontier Analysis); **DEA** (Data Envelop Analysis).

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Availabilityof data and materials; The author wants to declare that they can submit the data at any time based on publisher's request.

References.

Aigner, D.J., Lovell, C.A. and Schmidt, P. (1977) Formulation and Estimation of Stochastic Frontier Production Function Models. *Journal of Econometrics 6:21-37*.

APRA Brief Issue No. 16 March (2019) A Historical Analysis of Rice Commercialisation in Ethiopia: The Case of the Fogera Plain.

Amemiya, T. (1984) Tobit model, A Survey. *Journal of Econometrica. 24:3-63.*

Andreu, M.L., & Grunewald, O. (2006) Sources of inefficiency in Kansas farms. Paper presented at the Southern Agricultural Economics Association Annual Meetings, Orlando, Florida.

Atnaf, M. (2019) *Advances in Rice Research and Development in Ethiopia* (Issue December).

Banker, R.D. (1993) Maximum likelihood, consistence, and data envelopment analysis. A statistical foundation. Management Science, 39, 1265-1273

Battese G. E. and Coelli T. J. ,(1995) A model for technical inefficiency effects in a stochastic frontier production function for panel data, Volume 20, Issue 2, pp 325–332. Empirical Economics

Beattie, B.R., & Taylor, C.R. (1985) The economics of production. Malabar, FL: Robert E. Kreiger Publishing Company.

Boris E. Bravo-Ureta and Antonio E. Pinheiro, (1993) Efficiency Analysis of Developing Country Agriculture: A Review of the Frontier Function Literature.

Bravo-Ureta BE, EvensonEE, (1994) Efficiency in agricultural production the case of peasant farmers in Eastern Paraguay. Agricultural Economics 10;27-37

Coelli, T.J. (1996a) A guide to DEAP version 2.1: A data envelopment analysis (computer) program (CEPA Working Paper No. 8/96). Armidale, Australia: Department of Econometrics, University of New England.

Coelli, T.J. (1996b) A guide to Frontier version 4.1 : A computer program for stochastic frontier production and cost function estimation (CEPA Working Paper 96/07). Armidale, Australia: Department of Econometrics, University of New England.

Coelli, T.J., Prasada Rao, D.S. and Battese, G.E. (1998) An Introduction to Efficiency and Productivity Analysis. Kluwer Academic Publishers, London.

Coelli, T.J., Prasada Rao, D.S., O'Donnell, C.J. and Battese, G.E. (2005) *An Introduction to Efficiency and Productivity Analysis* (2nd Edition). New York, Springer Science Business Media Inc.

Cooper, W.W., Seiford, L.M. and Zhu, J. (2004) Data Envelopment Analysis: History, Models and Interpretations. Handbook on Data Envelopment Analysis. pp. 1-39.

CSA,(2003), Ethiopian Central statistical Ahutority of Ethiopia. 2003.

Dawit Alemu ,(2015) Rice in Ethiopia: Progress in Production Increase and Success Factors. 6th CARD General Meeting Novermbert, 2015

Fare, R., & Grosskopf, S. (1995) Non -parametric tests of regularity, Farrell efficiency and goodness of fit". *Journal of Econometrics, 69, 415-425.*

Farrell, M. J.(1957)The measurement of pro-ductive efficiency. *Journal of the Royal Statistical Society*, Series A (General), Part III, 120, 253-290.

Fekadu Gelaw and Bezabih Emana,(2008) Analysis of Technical Efficiency of Wheat Production",A Study InMachakel Woreda Ethiopia . *Eth. J. of Agric. Econ. 7(2)*

Forsund, E.R., Lovell, C.A., & Schmidt, P. (1980) A survey of frontier production functions and their relationship to efficiency measurement. *Journal of Econometrics, 13, 5-25.*

Galawat F. and Yabe M., (2011) Evaluation of Technical, Allocative, and Economic Efficiency in Rice Production, A Case Study on Rice Farmers in Brunei Darussalam.

Galawat F. and Yabe M., (2011) Evaluation of Technical, Allocative, and Economic Efficiency in Rice Production; A Case Study on Rice Farmers in Brunei Darussalam.

Hagos, A., & Zemedu, L. (2015)Determinants of Improved Rice Varieties Adoption in Fogera District of Ethiopia. *Science, Technology and Arts Research Journal*, *4*(1), 221. https://doi.org/10.4314/star.v4i1.35

Heady, E.O., & Dillon, J. (1961) Agricultural production functions. Ames: Iowa State University Press.

IPMS, (2005) Fogera Wereda pilot learning Site Diagnosis and program Design, Working paper.

Johansson, H. (2005)Technical, allocative, and economic efficiency in Swedish dairy farms: The data envelopment analysis versus the stochastic frontier approach. Poster background paper presented at the XIth International Congress of the European Association of Agricultural Economists (EAAE), Copenhagen, Denmark.

Kebede, E. (2011)Trends and Challenges in Rice Investment in Ethiopia. In K. Assefa, D. Alemu, K. Shiratori, & A. Kirub (Eds.), *Empowering Farmers' Innovation Series No. 2* (Issue 2, p. 67). Ethiopian Institute of Agricultural Research. http://www.eiar.gov.et

Khai and Mitsuyasu Yabe,(2011) Technical Efficiency Analysis of Rice Production In Vietnam . *J. Issaas Vol. 17, No. 1:135-146 (2011).*

Mesfin, A. H., & Zemedu, L. (2015) Improved Rice Seed Production and Marketing : Challenges and Opportunities ; the Case of Fogera District of Ethiopia. *J. Agric. Environ. Sci. 1(2):*, *1*, 1–21.

Maddala GS, (1983) Limited dependent and quantitative variables in Econometrics. New York, Cambridge University Press.

Meeunsen, W. and Van den Broeck, J. (1977) Efficiency Estimation from Cobb-Douglas Production Functions with composed error, *International Economics Review 18: 435- 444.*

Minilik Tsega, Dawit Alemu, Shiratori Kiyoshi(2013): Socioeconomic Characteristics of Smallholder Rice Production in Ethiopia, Research Report. EIAR.

Ministry of Agriculture and Rural Development (2009) National Rice Research and Development Strategy/NRRDS, Addis Ababa., Ethiopia

MoARD,(2010 and 2017) Ministry of Agriculture and Rural Development (MoARD) of the Federal Democratic Republic of Ethiopia.

MoARD. (2010) National rice research and development strategy of Ethiopia. Ministry of Agriculture and Rural Development.

Moges Dessale, (2017) Technical Efficiency in Teff Production. The Case Of Smallholder Farmers In Jamma District, South Wollo Zone, Ethiopia. Haramaya University, Haramaya.

MoRAD, (2017)Ministry of Agriculture and Rural Development (MoARD) of the Federal Democratic Republic of Ethiopia.

Schultz, T.W. (1964)Transforming Traditional Agriculture. Yale University Press. New Haven. CT.

Shumet Asefa (2011) Analysis of technical efficiency of crop producing smallholder farmers in Tigray",Ethiopia.

Solomon Bizuayehu,(2014) Technical efficiency of major crops in Ethiopia: Stochastic frontier model, *Academia Journal of Agricultural Research 2(6): 147-153, June 2014*

Subal C. Kumbhakar, Hung-Jen Wang, Alan P. Horncastle,(2015) A Practitioner's Guide to Stochastic Frontier Analysis Using Stata .USA.

Sumithra Muthayya, Jonathan D. Sugimoto, Scott Montgomery and Glen F. Maberly, (2014) An overview of global rice production, supply, trade, and consumption" , Ann. N.Y. Acad.Sci.1224(2014)7-14.

Tamirat Belayneh , Jember Tekle (2015) Review on adoption, trend, potential, and constraints of rice production to livelihood in Ethiopia vol.5 (iss.6): June, 2017

Tadesse Zenebe, Solomon Amare, and Fentahun Addis,(2016) Analysis of the Technical Efficiency of Rice Production in Fogera District of Ethiopia, A Stochastic Frontier Approach.

Tamirat Belayneh , Jember Tekle, (2017) Review on Adoption, Trend, Potential, And Constraints Of Rice Production to Livelihood In Ethiopia. International Journal of Research –Granthaalayah.

Tolga Tipi , Nural Yildiz , Mehmet Nargeleçekenler & Bahattin Çetinm (2009) Measuring the technical efficiency and determinants of efficiency of rice (*Oryza sativa*) farms in The Marmara region, Turkey.*New Zealand Journal of Crop and Horticultural Science, 2009, Vol. 37: 121-129*

Wang HJ, Schmidt P (2002) One-Step and two-step estimation of the effects of exogenous variables on technical efficiency levels, *J. Prod. Anal. 18:282-284.*

Figures

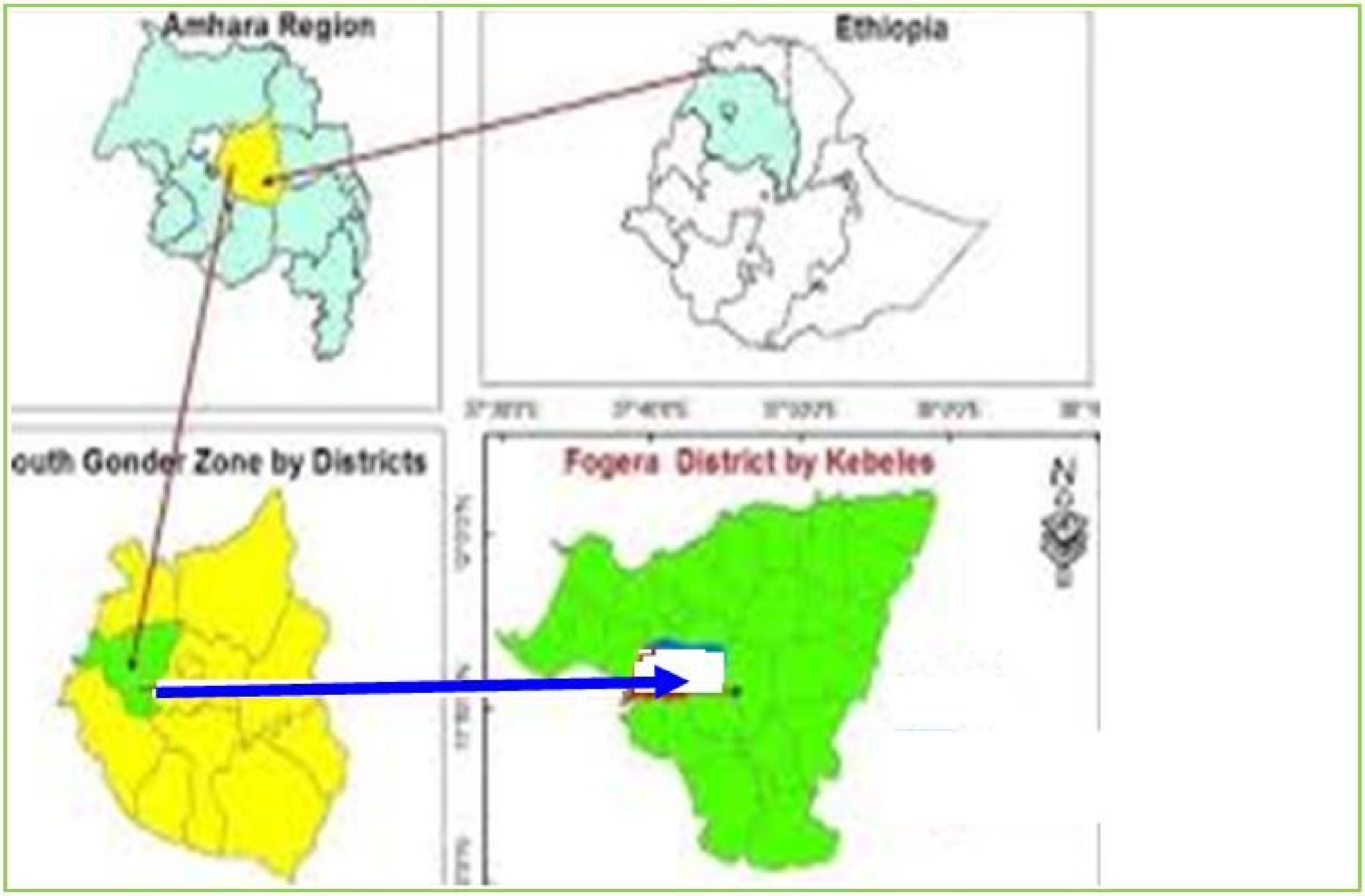

Figure 1

Location of research area, Amharic region, Ethiopia. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

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