Economics Bulletin

Volume 36, Issue 4

Does farm size matter? Investigating scale efficiency of peasant rice farmers in northern Ghana

Benjamin Tetteh Anang
University of Helsinki

Stefan Bäckman
University of Helsinki

Antonios Rezitis
University of Helsinki

Abstract

The study assessed the technical and scale efficiency of small-scale rice producers in northern Ghana as well as the effect of farm size on efficiency. Using survey data from 300 farm households, the study employed data envelopment analysis (DEA) to measure efficiency and a bootstrapped truncated regression in the second stage to assess the determinants of efficiency. The results indicated that respondents had overall technical efficiency of 46.6 percent, pure technical efficiency of 65.1 percent and scale efficiency of 69.5 percent. Farm size had a significantly positive effect on scale efficiency with majority of the farms operating at increasing returns to scale. The determinants of efficiency included farm size, gender of the household head, access to credit and irrigation, number of extension visits, the degree of specialization in rice production and location of the farm. Most of the inefficiencies are either technical or scale in nature hence there is justification to increase the scale of production of smaller farms in order to take advantage of unexplored economies of scale. The technically inefficient farmers also need to reduce waste in resource utilization by improving their efficiency of resource use. The authors prescribe other policy measures needed to improve rice production in northern Ghana.

The authors acknowledge the Nordic Africa Institute (NAI) in Uppsala, Sweden for funding the data collection. The authors also acknowledge the Kyösti Haataja Foundation in Finland for providing the first author with a study grant to conduct the research.
Citation: Benjamin Tetteh Anang and Stefan Bäckman and Antonios Rezitis, (2016) "Does farm size matter? Investigating scale efficiency of peasant rice farmers in northern Ghana", *Economics Bulletin*, Volume 36, Issue 4, pages 2275-2290
Contact: Benjamin Tetteh Anang - benjamin.anang@helsinki.fi, Stefan Bäckman - stefan.backman@helsinki.fi, Antonios Rezitis - antonios.rezitis@helsinki.fi.
Submitted: July 15, 2016. **Published:** November 28, 2016.

1. Introduction

The agricultural sector plays a crucial role in economic development in most developing countries including Ghana. Nevertheless, the agricultural sectors in most of these countries particularly in Sub-Saharan Africa continue to operate below their full potential in terms of productivity and efficiency levels thus failing to attain the goals of food security and poverty reduction. The potential of the agricultural sector in these countries can however be unleashed if the current levels of productivity and efficiency can be improved.

One notable feature of agriculture in most developing countries, which has implication for farm performance, is the predominance of smallholders who cultivate relatively small land areas. Singh et al. (2002) defined smallholder farmers as agricultural producers cultivating an average of 2.0 hectares. According to Namara et al. (2011), Ghanaian smallholders have an average landholding of about 1.2 hectares yet account for about 80 percent of the nation's total food production. Chamberlin (2007) also observed that more than 70 percent of Ghanaian farmers cultivate less than 3 hectares of land. According to the Ministry of Food and Agriculture (MoFA), an estimated 10 percent of Ghanaian smallholder farm households engage in domestic rice production with an average farm holding of 0.4 hectare (MoFA, 2009). Rice production in Ghana is therefore a small-scale economic activity.

From a neo-classical economics perspective, farmers can take advantage of the scale of production to enhance their productive and scale efficiencies. In principle, a farm may be technically efficient but not scale efficient. This means that a farm may be using the best practice but not taking advantage of economies of scale. The concept of scale efficiency is therefore important in smallholder agriculture where farms are generally small, and the likelihood of deriving gains from economies of scale may exist.

Even though smallholder farmers cultivate relatively small landholdings, there is often considerable heterogeneity in farm sizes due to unequal land resource endowment and access to agricultural land in most rural communities. The issue of heterogeneity in farm sizes adds to the debate on whether agriculture in developing countries should focus on large or small-scale farming. As noted by Akudugu (2016), a current debate is whether African agriculture should focus on large or small-scale agriculture. Larson et al. (2012) argue that an inverse relation exists between farm size and agricultural productivity hence the need to promote small-scale farming. This proposition receives further support from arguments linking economic transformation in developing countries to productivity growth in smallholder agriculture (see for example, McErlean and Wu 2003). In addition, Christiaensen et al. (2011) estimate that growth in agriculture engenders higher poverty reduction effects in Africa in comparison to other economic sectors like industry and the service sector. Since most of the poor in developing countries live in rural areas where agriculture is the main economic activity and source of livelihood, it seems logical to focus on the promotion of small-scale farming as a poverty alleviation strategy. For this reason, most governments and donor agencies tend to focus on the small farm sector in developing countries. Not only did large-scale agricultural projects in most developing countries in the past prove unsuccessful (Deininger et al. 2011) but smallholder farm units continue to supply the bulk of the food consumed in Africa and Asia (Nwanze 2011) as well as the production of most cash crops for export.

On the other hand, Collier and Dercon (2013) are of the view that promoting large-scale farming will lead to potential gains by way of economies of scale that can promote commercial agricultural production as pertains in many developed countries. Further arguments supporting this viewpoint are that large-scale farms can better manage risks and ensure faster spread of innovations at less cost as opposed to the slow spread of innovations among smallholder farmers (Alston et al. 2008). An argument used to oppose the idea that small farms are more productive than large farms is that innovations are scale neutral. This means that, in principle, a production technology should not perform better on small farms than on large farms.

However, it is worth noting that farmers' managerial ability may differ across different scales of operation. Hence, due to differences in resource endowments and managerial abilities, the size of landholding available to the farm household may influence its farm performance, including scale efficiency. Furthermore, a farmer may be technically efficient but not scale efficient, which may reflect differences in managerial ability. Controlling for differences in farm size may therefore highlight some scale effects in smallholder production in order to shed more light on the topic.

The foregoing arguments justify the need for further investigation into the scale efficiency of smallholder producers in order to understand how the scale of operation relates to efficiency. According to Dercon (2009) and Gollin et al. (2011), the question of whether transformation in agriculture rests solely on investing in small-scale farming remains unanswered.

The current study therefore employs a non-parametric efficiency analysis to investigate whether farm size matters to scale efficiency of peasant rice producers using northern Ghana as a case study. A farm is scale efficient when it operates at a size that is optimal such that changing its size makes the farm less efficient. Hence, the study seeks to find out whether at the current level of land allocation to rice production, smallholders are scale efficient in their production activities. The findings of the study will justify whether smallholder rice farmers need to adjust their landholdings to achieve higher efficiency of production.

The study uses a two-stage data envelopment analysis (DEA) to measure technical and scale efficiency and the determinants among peasant farmers in northern Ghana. The application of DEA to agriculture is very common in the literature on efficiency analysis. Authors such as Coelli et al. (2002), Hambrusch et al. (2006), Rahman and Awerije (2015) and Watkins et al. (2014) used DEA to estimate measures of farm performance notably technical, allocative, economic and scale efficiency in agriculture. In addition, authors such as Bjurek et al. (1990), Førsund (1992) and Wanke (2012) have applied parametric and non-parametric approaches to study scale efficiency in various fields.

DEA models rely on input and output data and the basic models include the CCR (Charnes, Cooper and Rhodes) and the BCC (Banker, Charnes and Cooper) models. The CCR model proposed by Charnes et al. (1978) relies on the assumption of constant returns to scale (CRS) while the BCC model proposed by Banker et al. (1984) assumes variable returns to scale (VRS) of activities. The efficiency measures in DEA are defined in three ways namely overall technical efficiency, pure technical efficiency and scale efficiency. Overall technical efficiency refers to technical efficiency using the CCR model (that is, technical efficiency under constant returns to scale) while pure technical efficiency relates to technical efficiency using the BCC model (that is, technical efficiency under variable returns to scale). The pure technical efficiency measure accounts for the influence of managerial ability on farmers' productive efficiency, which is relevant to the discussion of smallholder agricultural production. The overall technical efficiency measure indicates how farmers allocate resources judiciously in the production process. It deals with how effectively producers turn inputs into outputs in relation to the data-driven frontier of the best-practice farms in the sample. Scale efficiency is the ratio of overall technical efficiency to the pure technical efficiency. This efficiency measure assesses whether the producers are operating at an optimal scale and therefore provides insight into whether or not the scale of production can be adjusted to enhance efficiency.

The focus of the current paper is determination of scale efficiency. However, since this efficiency measure derives from pure technical efficiency and overall technical efficiency measures, we include the discussion of these efficiency measures in the article. The authors also observe that in most of the published articles on scale efficiency, a concurrent discussion is usually made of these three efficiency measures.

2. Materials and Methods

2.1 Model specification

The current study assesses the technical and scale efficiency of small-scale rice production in northern Ghana and the effect of farm size on efficiency. The study uses a non-parametric approach namely data envelopment analysis (DEA) under constant and variable returns to scale assumptions. The DEA approach generates a data envelopment surface by linking points in the input-output space in a way that no longer permits the production of more output using the same input level or production of the same output using less input. The data envelopment surface serves as a benchmark for measuring the relative efficiency of the rest of the firms outside the envelopment surface (Marwa and Aziakpono 2016). All efficient farms in the sample are linked by a continuous locus to form an efficient frontier to which the efficiency score for every DMU is measured by how far its deviates from the efficient frontier. The frontier in the case of the constant returns to scale is linear while that for the variable returns to scale is convex hull (Favero and Papi 1995).

We decompose the efficiency analysis into three dimensions in order to understand the possible sources of inefficiency. The first dimension relates to overall technical efficiency, the second relates to pure technical efficiency while the third relates to scale efficiency. The estimation of overall technical efficiency involves measuring the ratio of the distance between inefficient points to the constant returns to scale (CRS) efficient frontier while estimation of pure technical efficiency involves measuring the ratio of the distance between inefficient points to the variable returns to scale (VRS) efficient frontier. Scale efficiency (SE) is the ratio of overall technical efficiency (OTE) and pure technical efficiency (PTE). The study employs the input orientation in the estimation because producers have more control on input than output.

The formulation of DEA can follow either a constrained maximization or minimization objective function using linear programming. The study employs the minimization formulation because of its mathematical tractability (Coelli et al. 2005). Consider that the data covers N farms or decision-making units (DMUs), K inputs and M outputs. We represent an individual DMU by the vectors x_i and q_i respectively. For all N DMUs, let X represent the KxN input matrix and Q, the MxN output matrix. The expression of the minimization formulation for the constant returns to scale (CRS) assumption according to Coelli et al. (2005) is as follows:

$$\begin{aligned} &\min_{(\theta,\lambda)} \theta \\ \text{s.t.} \quad & -q_i + Q\lambda \geq 0 \quad i = 1, 2, 3, \ldots, N. \\ & \theta x_i - X\lambda \geq 0 \\ & \lambda \geq 0 \end{aligned} \tag{1}$$

where θ stands for the efficiency score for the i^{th} farm, q represents a column vector of outputs, Q is an MxN output matrix, x is a column vector of inputs, X is a KxN input matrix for all DMUs and λ is an Nx1 vector of constants (weighting coefficients). The value of θ ranges from 0 to 1 where 1 indicates a technically efficient DMU operating on the efficient frontier. Values of θ less than 1 operate below the efficient frontier.

We formulate the variable returns to scale (VRS) linear programming problem by adding the convexity constraint to the VRS specification as follows:

$$\begin{aligned} &\min_{(\theta,\lambda)} \theta \\ \text{s.t.} \quad & -q_i + Q\lambda \geq 0 \quad i = 1, 2, 3, \ldots, N. \\ & \theta x_i - X\lambda \geq 0 \\ & N1'\lambda = 1 \\ & \lambda \geq 0 \end{aligned} \tag{2}$$

where N1 represents an Nx1 vector of ones and the rest of the variables maintain their previous definitions.

Furthermore, we derive scale efficiency (SE) as follows:

$$SE = \frac{CRS_{DEA}}{VRS_{DEA}} \tag{3}$$

where CRS_{DEA} represents the efficiency score obtained from the CRS assumption and VRS_{DEA} is the score from the VRS model.

To determine whether a DMU is operating in an area of increasing, decreasing or constant returns to scale, we impose the non-increasing returns to scale (NIRS) assumption as follows:

$$\begin{aligned}
&\min_{(\theta,\lambda)} \theta \\
&\text{s.t.} \quad -q_i + Q\lambda \geq 0 \quad i = 1, 2, 3, \ldots, \text{N}. \qquad (4)\\
&\qquad \theta x_i - X\lambda \geq 0 \\
&\qquad N1'\lambda \leq 1 \\
&\qquad \lambda \geq 0
\end{aligned}$$

where the variables have their usual definitions.

The authors observe that many of the previous studies used a two-stage DEA analysis where the efficiency scores from the first stage were regressed on socio-economic variables that had influence on the efficiency estimates using either Tobit or truncated regression analysis. The argument for using these approaches is that the efficiency scores are censored or truncated. Hence, Hoff (2007) asserts the sufficiency of the Tobit procedure in representing the second stage DEA models. However, authors like Simar and Wilson (2007) have questioned these procedures on the basis that the efficiency estimates from DEA are prone to complex correlations while the procedure lacks a well-defined data generation mechanism. McDonald (2009) is also of the view that the process of generating the DEA scores does not follow a censoring process hence inappropriate to use Tobit analysis in the second stage. Simar and Wilson (2007) therefore proposed a bootstrapping technique for generating reliable standard errors and confidence intervals for the second stage analysis.

The Simar and Wilson (2007) approach attempts to construct and simulate a data generating process by generating artificial bootstrap samples from which standard errors and confidence intervals are constructed. This procedure is an implementation of the truncated regression model with bootstrapping of the efficiency scores using simulation. The current study followed this approach and implemented the procedure in Stata version 14 using the “simarwilson” user-written command (algorithm #1). Detailed explanation of the procedure is presented in Appendix A.

2.2 Data and descriptive statistics of the respondents

Data for the study was collected by the authors in 2014 for the 2013-2014 farming season and covered 300 rice-producing farm households. A multistage stratified random sampling was used to select the farmers. Administratively, northern Ghana comprises of the Upper East, Upper West and Northern Regions. The Upper East and Northern Regions were purposively selected because of their importance in rice production in Ghana. Smallholder farmers were selected from three major irrigation schemes in the study area: Vea and Tono Irrigation Schemes in the Upper East Region, and Botanga Irrigation Scheme in the Northern Region. Equal numbers of irrigation-users and rain-fed producers were included in the sample.

We present the descriptive statistics of the continuous variables used in the study in Table 1a and the discrete variables in Table 1b. The respondents are small-scale producers judging from the small farm sizes averaging less than a hectare[1]. The respondents also used relatively low amounts of inputs in production suggesting that they are resource-poor farmers. The level of education and number of contacts with extension agents were also very low, which are likely to affect the managerial ability of the farmers. The farmers are in their productive ages and have cultivated rice for more than 15 years. The farmers also allocate about 45 percent of their total land to rice production. This figure is high considering that smallholder farmers typically produce crops consumed by the household and trade the extra output for cash. Hence, one may classify rice production as an important cash cropping system among the respondents. Majority of the respondents were males with 40 percent using credit in production. Furthermore, two-third of the respondents planted improved rice varieties. According to the sampling design, equal number of irrigators and non-irrigators were included in the study with two-third of the respondents coming from the Upper East Region. The distribution of major irrigation schemes in the study area meant that we selected two irrigation schemes in the Upper East Region and one in the Northern Region for the study.

Table 1a: Descriptive statistics of the variables in the study[2]

Variable	Mean	Std. Dev.	Minimum	Maximum
Output (kg)	1649	2102	25	13000
Farm size (ha)	0.86	0.68	0.08	4.86
Labor (man-days)	64.3	45.1	10	363
Seed (kg)	158	155.3	2.5	1000
Fertilizer (kg)	292	308.6	0	3000
Expenditure (Ghana Cedi)	186.1	190.1	0	1560
Capital (Ghana Cedi)	128.3	151.4	0	1140
Age (Years)	41.2	12.3	19	75
Years of rice farming experience	15.4	10.8	1	60
Years of formal education	3.93	5.35	0	20
Share of land under rice (%)	45.4	25.1	3.6	100
Number of adult working members	6.18	6.26	1	63
Number of extension contacts	3.31	5.21	0	30

Table 1b: Descriptive statistics of discrete variables in the study

Variable	Frequency	Percent
Sex (1=Male, 0 otherwise)	235	78.3
Access to credit (1 = access, 0 otherwise)	121	40.3
Rice variety (1=Improved, 0 otherwise)	200	66.7
Access to irrigation (1= access, 0 otherwise)	150	50.0
Regional dummy (1=Northern Region, 0 otherwise)	100	33.3

[1] Traditionally, smallholders are defined as those farmers operating less than 2 hectares. In sparsely populated semi-arid areas, the land size could be up to 10 hectares for smallholders (Dixon et al., 2003).

[2] The data reveals discrepancy in the minimum and maximum of the input and output variables, partly reflecting the variability in farm size. However, diagnostic tests did not reveal the presence of outliers. Furthermore, we estimated the model without farms exceeding 2.5 hectares but the result did not change.

3. Results and Discussion

3.1 Analysis of scale efficiency of smallholder rice farmers

We present the efficiency scores obtained from the DEA analysis in Table 2. The technical efficiency estimates under constant as well as variable returns to scale are reported alongside the scale efficiency scores. Mean technical efficiency under constant returns to scale (CRS-TE) was 47 percent as against 65 percent under the variable returns to scale assumption (VRS-TE). The mean scale efficiency (SE) was 70 percent. The results show that 10 percent of the DMUs were scale efficient, meaning that these farms were located on the efficient frontier. About 9.3 percent of the DMUs were technically efficiency under constant returns to scale. For the technical efficiency under variable returns to scale, the result showed 20 percent DMUs operating on the efficient frontier. Hence most of the inefficiencies are either technical or scale in nature meaning that smaller farms may need to increase their scale of production in order to enhance their efficiency. The results also indicate very high variability in the efficiency scores. This suggests that some of the respondents are very inefficient in their resource utilization or operating at sub-optimal scale of production. The technically inefficient farmers therefore need to improve their efficiency of resource use in order to reduce wasting resources in their production activities.

Table 2: Frequency distribution of the efficiency scores

Efficiency range	OTE (CRS-TE)	PTE (VRS-TE)	SE
0.00 – 0.10	18	0	6
0.11 – 0.20	43	4	10
0.21 – 0.30	45	25	17
0.31 – 0.40	42	31	16
0.41 – 0.50	33	42	25
0.51 – 0.60	31	39	33
0.61 – 0.70	23	40	33
0.71 – 0.80	19	24	34
0.81 – 0.90	9	21	29
0.91 – 1.00	37	74	97
Mean	0.47	0.65	0.70
Minimum	0.01	0.16	0.02
Maximum	1.00	1.00	1.00
Number of efficient DMUs	28	62	30

Note: OTE, overall technical efficiency; PTE, pure technical efficiency; SE, scale efficiency

Table 3 presents the distribution of farms across different categories of returns to scale in the study area. The results indicate that 81.3 percent of all farms operate at increasing returns to scale with 8.7 and 10.1 percent operating at decreasing and constant returns to scale, respectively. Thus, majority of the farms are operating at the inefficient part of the production function.

Table 3: Returns to scale summary statistics

Scale Classification [a]	Number	Percent
CRS	30	10%
DRS	26	8.7%
IRS	244	81.3%
Total	300	100%

[a] CRS, constant returns to scale; DRS, decreasing (diminishing) returns to scale; IRS, increasing returns to scale

We illustrate the relationship between scale efficiency and farm size in Figure 1. A positive linear relationship is shown indicating higher scale efficiency with increase in landholding. The result indicates that increasing landholdings is beneficial to smallholder farmers in the study area, by taking advantage of scale effects in production. Encouraging farmers to increase their share of land under rice can therefore boost rice production in Ghana. Hence, efforts to facilitate access to land for rice cultivation can bring the desired results of increasing domestic rice production in Ghana as enshrined in the National Rice Development Strategy (NRDS).

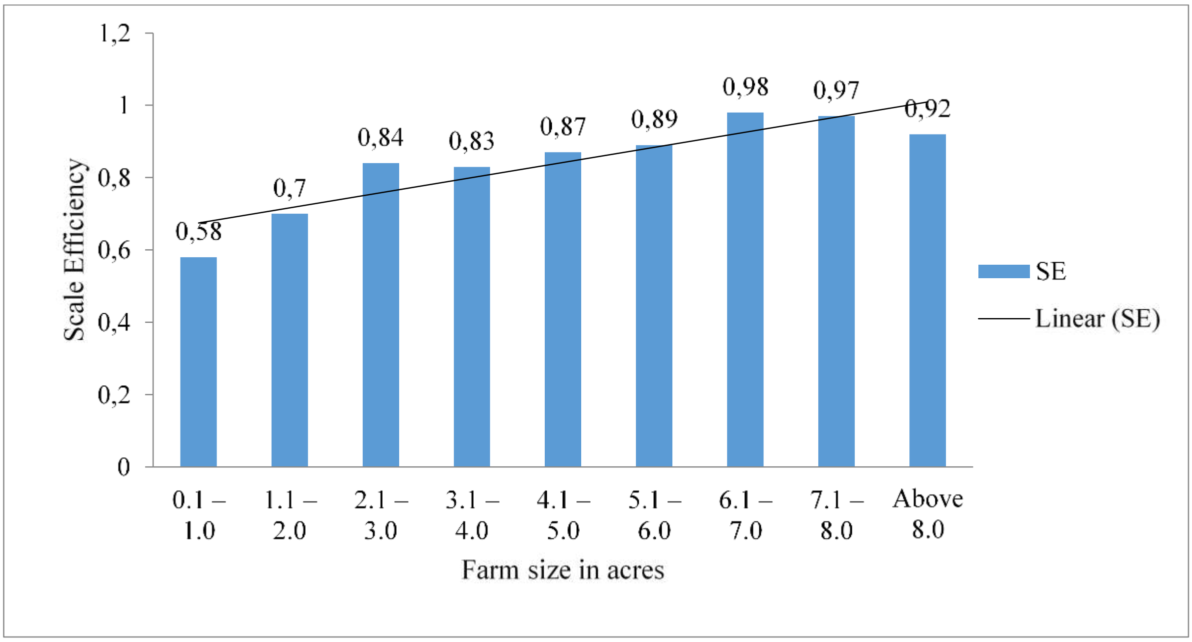

Figure 1: Graph of scale efficiency and farm size

3.2 Factors explaining efficiency

We present the results of the bootstrapped DEA analysis of the determinants of efficiency using the Simar and Wilson (2007) approach in Table 4. The variable of interest in the study, that is, farm size had a positively significant effect on scale efficiency at the 1 percent level, implying that larger farms achieve higher scale efficiency. The result agrees with Karagiannis and Sarris (2005) who found a positive and statistically significant association between scale efficiency and farm size among Greek tobacco farmers. The result indicates that farmers with smaller farm holdings can improve their scale efficiency by increasing their land area. As indicated by Coelli and Battese (1996), farmers with smaller farms may have alternative sources of income, which they may consider more important hence devoting less attention to farming. However, the quadratic term had a negatively significant effect on scale efficiency at the 10 percent level. The result indicates that scale efficiency increases at a decreasing rate with an increase in farm size. On the other hand, we found the farm size variable to have a significant and negative association with pure technical efficiency indicating that an increase in farm size decreases the pure technical efficiency of the farmers. Since pure technical efficiency relates to managerial efficiency of the producers, we conclude that smallholder farmers become less managerially efficient when farm size increases. The quadratic term had a positive and significant coefficient indicating that smaller farms become relatively less efficient when farm size increases. However, the effect of farm size was insignificant in the case of overall technical efficiency.

The result of our study agrees with Watkins et al. (2014) in their analysis of rice production in Arkansas in the United States. The authors found a positively significant effect of land size on scale efficiency but a negatively significant effect of land size on pure technical efficiency. They also found the effect of land size on overall efficiency to be negative and insignificant. Taraka et al. (2010) also support our findings according to their study that found technical efficiency to be lower on larger rice farms in Thailand. In the view of Ross et al. (2009), misallocation of resources on larger farms is a factor that accounts for the decline in technical efficiency on these farms. Matchaya (2007) also reported an inverse relation between farm size and farm productivity in Malawi. What the result of this study seems to suggest is that scale and technical efficiency may differ in their relationship with farm size. Thus, in relation to farm size, technical and scale efficiency may seem to be separate goals to the farmer, the attainment of which may depend on different combination of factors.

The second-stage DEA analysis using the Simar and Wilson approach showed that the regional dummy variable, access to irrigation and the degree of specialization in rice production had significant effect on all three efficiency measures. The result indicates that access to irrigation, the degree of specialization in rice farming, and being located in the Northern Region lead to higher efficiency of smallholder rice farmers in northern Ghana. Hence, expanding access to irrigation, promoting the specialization in rice production and addressing the factors impeding the productivity of producers in the Upper East Region, will contribute to higher rice production efficiency in northern Ghana leading to higher incomes from farming. The result of our study agrees with Karimov (2013) who found access to irrigation water to enhance the technical efficiency of Nigerian farming households. Anang et al. (2016) also found the degree of specialization to enhance the production efficiency of smallholder farmers in northern Ghana.

Table 4: Second-stage analysis of factors explaining efficiency

Variable	Coefficient	Std. Error	95% Confidence Int.	
			Lower	Upper
Scale efficiency				
Farm size	0.404***	0.104	0.202	0.607
Farm size squared	- 0.062*	0.035	-0.130	0.007
Regional dummy	0.227***	0.056	0.118	0.336
Access to irrigation	0.351***	0.047	0.258	0.444
Sex of household head	0.087*	0.048	-0.006	0.180
Age of household head	0.005	0.011	-0.016	0.026
Age of household head squared	- 0.0001	0.0001	-0.0003	0.0002
Access to credit	0.116**	0.045	0.028	0.205
Extension visits	0.008*	0.004	0.0002	0.016
Degree of specialization	0.002**	0.001	0.0002	0.004
Constant	- 0.027	0.228	-0.473	0.419
Sigma	0.246***	0.017	0.213	0.279
Pure technical efficiency				
Farm size	– 0.269***	0.063	– 0.393	-0.145
Farm size squared	0.052***	0.019	0.015	0.089
Regional dummy	0.118***	0.036	0.048	0.188
Access to irrigation	0.066**	0.031	0.006	0.126
Sex of household head	0.023	0.036	– 0.048	0.094
Age of household head	– 0.007	0.008	– 0.022	0.009
Age of household head squared	0.0001	0.0001	0.0001	0.0002
Access to credit	0.004	0.029	– 0.052	0.061
Extension visits	0.004	0.003	– 0.003	0.010
Degree of specialization	0.002***	0.001	0.001	0.003
Constant	0.689***	0.164	0.367	1.010
Sigma	0.195***	0.010	0.176	0.215
Overall technical efficiency				
Farm size	– 0.062	0.058	– 0.176	0.051
Farm size squared	0.013	0.015	– 0.016	0.041
Regional dummy	0.144***	0.034	0.079	0.210
Access to irrigation	0.169***	0.026	0.119	0.219
Sex of household head	0.048	0.032	– 0.015	0.111
Age of household head	– 0.003	0.007	– 0.017	0.011
Age of household head squared	0.0001	0.0001	0.0001	0.0002
Access to credit	0.043*	0.026	– 0.008	0.093
Extension visits	0.006**	0.003	0.0001	0.011
Degree of specialization	0.002***	0.001	0.0004	0.003
Constant	0.216	0.156	– 0.089	0.521
Sigma	0.208***	0.010	0.189	0.227

* signifies statistical significance at the 10% level.
** signifies statistical significance at the 5% level.
*** signifies statistical significance at the 1% level.

We also observed that access to microcredit improved scale efficiency as well as overall efficiency but the effect was not significant in the case of pure technical efficiency. The result of our study is contrary to Ly et al. (2016) who found access to credit to decrease both scale efficiency and pure efficiency of pig producers in Vietnam but supported by Mugera and

Featherstone (2008) who found credit to increase scale efficiency, overall efficiency and pure efficiency of hog producers in the Philippines. Karimov et al. (2013) also found access to credit to enhance the technical efficiency of farming households in Nigeria. Since credit enables farmers to hire in labor and acquire important production inputs, we anticipated efficiency gains from its use in production. Concerning the weak relationship between microcredit and pure technical efficiency, we argue that this might reflect farmers' low managerial ability since the pure technical efficiency measure accounts for the managerial ability of farmers.

The study also found access to extension services to enhance the scale efficiency and overall technical efficiency of farmers but the effect was not significant in the case of pure technical efficiency. The result is consistent with Karimov et al. (2013) who found access to extension to enhance the technical efficiency of farming households in Nigeria. Taraka et al. (2010) also found extension contact to increase the technical efficiency of rice farmers in Central Thailand. Extension services equip farmers with the technical knowhow to enhance their level of efficiency. The low level of extension contacts, averaging three visits per production season might play a role in its weak effect on pure technical efficiency.

Finally, gender of the farmer had a significant effect on scale efficiency but not on the technical efficiency measures. Scale efficiency is therefore higher for men than women in the study area. The result agrees with other studies in developing countries where men tend to dominate decision-making and have greater access to production resources (Anang et al., 2016). The result alludes to the fact that male farmers are usually the custodians of production resources in many rural communities and the control of these resources tend to enhance their efficiency of production. Mugera and Featherstone (2008) also found male hog producers in the Philippines to be 21 percent more scale efficient than their female counterparts. The result of our study is however at variance with Dhungana et al. (2004) in their study of economic efficiency of rice farmers in Nepal.

4. Conclusion and Recommendations

The study employed data envelopment analysis to estimate the technical, pure technical and scale efficiency of rice farms in northern Ghana, using data from a cross-section of 300 farmers. The results indicated technical efficiency of 46.6 percent, pure technical efficiency of 65.1 percent and scale efficiency of 69.5 percent among the respondent smallholder farmers. Majority of the farms operated at increasing returns to scale while a positive linear relationship existed between scale efficiency and farm size.

The second-stage DEA analysis showed the determinants of scale efficiency to include gender, farm size, contact with extension agents, access to credit and irrigation, degree of specialization in rice production and location of the farm. Scale efficiency was higher for the following: farmers with larger farms, producers with more extension visits, irrigation users, farmers who specialize more in rice production, farmers with access to credit, and farmers located in the Northern Region. For the determinants of pure technical efficiency, we found farm size, location of the farm, access to irrigation, and the degree of specialization in rice production to be the influential factors. Pure technical efficiency increased with all these variables with the exception of farm size. Concerning overall technical efficiency, we found the location of the farm, access to irrigation and credit, number of extension visits and the degree of specialization in rice production to be the influential factors. The overall technical efficiency increased with all these factors with farmers in the Northern Region having higher technical efficiency. The farm size variable was however not significant in its effect on overall technical efficiency of the farmers.

The result shows that most of the inefficiencies are either technical or scale in nature. However, the effect of farm size varies for the two efficiency measures. Hence farm expansion will enable farmers to exploit economies of scale but (due to lack of managerial abilities) technical efficiency will decline. Therefore at the current level of technology, farmers cannot exploit economies of scale and technical efficiency gains at the same time. However, if the farmers use improved techniques of production and gain managerial skills, they could expand farm size and derive both scale and technical efficiency gains.

From a policy perspective, we recommend the expansion of irrigation access to smallholder farmers to enhance their efficiency of production. Furthermore, promoting specialization in rice production will raise the efficiency levels of producers, thereby increasing farm incomes. In addition, the study recommends further investigation into the causes and possible remedies to the factors impeding farmers' productive and scale efficiencies in the Upper East Region. Furthermore, since most of the inefficiencies are either technical or scale in nature, the study calls for an increase in the scale of production for smaller farms in order to take advantage of unexplored economies of scale. This may however conflict with the goal of technical efficiency as smaller farms in the sample are more technically efficient. Hence, a more realistic approach could be for farmers to specialize more by increasing the area under rice cultivation and foregoing the production of other crops. The technically inefficient farmers on the other hand need to reduce waste in resource utilization by improving their efficiency of resource use.

A lack of managerial and technical know-how may also hinder the exploitation of economies of scale by smallholder farmers. Since most smallholders depend on public extension services for production advice and information, the provision of extension services can go a long way to improve farmers' managerial ability thus influencing their efficiency of production. There is therefore the need to improve extension service delivery to farmers as well as tailor training needs to those farmers who lack the requisite managerial skills. The availability of credit to farmers is also important if producers are to take advantage of unexplored economies of scale. From the study, access to credit positively influenced scale efficiency. Hence, policy measures that enhance smallholder farmers' access to credit for agricultural production are needed.

References

Akudugu, M. A. (2016) "Agricultural productivity, credit and farm size nexus in Africa: a case study of Ghana" *Agricultural Finance Review* **76**, 288 - 308

Alston, J. M., Pardey, P. G., and Ruttan, V. W. (2008) "Research lags revisited: Concepts and evidence from U.S. agriculture" University of Minnesota staff working paper number P08-14.

Anang, B. T., Bäckman, S., and Sipiläinen, T. (2016) "Technical efficiency and its determinants in smallholder rice production in northern Ghana" *The Journal of Developing Areas* **50**, 311-328.

Banker, R. D., Charnes, A., and Cooper, W. W. (1984) "Some models for estimating technical and scale inefficiencies in data envelopment analysis" *Management Science* **30**, 1078-1092.

Bjurek, H., Hjalmarsson, L., and Forsund F. R. (1990) "Deterministic parametric and non-parametric estimation of efficiency in service production. A comparison" *Journal of Econometrics* ***46***, 213-227.

Chamberlin, J. (2007) "Defining Smallholder Agriculture in Ghana: Who are smallholders, what do they do and how are they linked with markets?" Ghana Strategy Support Program (GSSP). Background Paper No. GSSP 0006. http://www.ifpri.org/sites/default/files/publications/gsspwp06.pdf. Accessed 1 May 2016.

Charnes, A., Cooper, W. W., and Rhodes, E. (1978) "Measuring the efficiency of decision making units" *European Journal of Operational Research* **2**, 429-441.

Christiaensen, L., Demery, L., and Kuhl, J. (2011) "The (evolving) role of agriculture in poverty reduction – an empirical perspective" *Journal of Development Economics* ***96***, 239-254.

Coelli, T. J., and Battese, G. E. (1996) "Identification of factors which influence the technical inefficiency of Indian farmers" *Australian Journal of Agricultural Economics* **40**, 103 – 128.

Coelli, T. J., Pradasa Rao, D. S. P., O'Donnell, C. J., and Battese, G. E. (2005) "An Introduction to efficiency and productivity analysis" 2nd Ed., Springer: New York, NY, USA.

Coelli, T. J., Rahman, S., and Thirtle, C. (2002) "Technical, allocative, cost and scale efficiencies in Bangladesh rice cultivation: A non-parametric approach" *Journal of Agricultural Economics* ***53***, 607-626.

Collier, P., and Dercon, S. (2013) "African agriculture in 50 years: Smallholders in a rapidly changing world?" Stanford Symposium Series on Global Food Policy and Food Security in the 21st Century. Centre on Food Security and the Environment: Stanford University.

Deininger, K., Byerlee, D., Lindsay, J., Norton, A., Selod, H., and Stickler, M. (2011) "Rising global interest in farmland. Can it yield sustainable and equitable benefits?" Washington DC: The World Bank.

Dercon, S. (2009) "Rural poverty: Old challenges in new contexts" The World Bank Research Observer 2009.

Dhungana, B. R., Nuthall P. L., and Nartea, G. V. (2004) "Measuring the economic efficiency of Nepalese rice farms using data envelopment analysis" *The Australian Journal of Agricultural and Resource Economics* **48**, 347 – 369.

Dixon J., Tanyeri-Abur, A. and Wattenbach, H. (2003). "Context and Framework for Approaches to Assessing the Impact of Globalization on Smallholders", In Dixon J., K. Taniguchi and H. Wattenbach (ed.), Approaches to Assessing the Impact of Globalization on African Smallholders: Household and Village Economy Modeling, Proceedings of Working Session Globalization and the African Smallholder Study. Rome, Italy: FAO and The World Bank.

Favero, C. A., and Papi, L. (1995) "Technical efficiency and scale efficiency in the Italian banking sector: a non-parametric approach" *Applied Economics* **27**, 385-395.

Førsund, F.R. (1992) "A Comparison of parametric and non-parametric efficiency measures: The case of Norwegian ferries" *Journal of Productivity Analysis* **3**, 25-43.

Gollin, D., Lagakos, D., and Waugh, M. E. (2011) "The agricultural productivity gap in developing countries" New York University working papers number 11-14.

Hambrusch, J., Kirner, L., and Ortner, K. M. (2006) "Technical and scale efficiency in Austrian dairy farming" *Economic Science for Rural Development* **10**, 42 – 49.

Hoff, A. (2007) "Second stage DEA: Comparison of approaches for modelling the DEA score" *European Journal of Operations Research* **181**, 425–435.

Karagiannis, G. K., and Sarris, A. (2005) "Measuring and explaining scale efficiency with the parametric approach: the case of Greek tobacco growers" *Agricultural Economics* **33**, 441-451.

Karimov, A. (2013) "Productive efficiency of potato and melon growing farms in Uzbekistan: a two stage double bootstrap data envelopment analysis" *Agriculture* **3**, 503-515.

Karimov, A., Awotide, B. A., and Amos, T. T. (2013) "Production and scale efficiency of maize farming households in South-Western Nigeria" *International Journal of Social Economics* **41**, 1087 – 1100.

Larson, D. F., Otsuka, K., Matsumoto, T., and Kilic, T. (2012) "Should African rural development strategies depend on smallholder farms? An exploration of the inverse productivity hypothesis" Policy Research working paper number 6190.

Ly, N. T., Nanseki, T., and Chomei, Y. (2016) "Technical efficiency and its determinants in pig production in Vietnam: A DEA approach" *The Japanese Journal of Rural Economics* **18**, 56 – 61.

Marwa, N., and Aziapkono, M. (2016) "Technical and scale efficiency of Tanzanian saving and credit cooperatives" *The Journal of Developing Areas* **50**, 29-46.

Matchaya, G. (2007) "Does size of operated area matter? Evidence from Malawi's agricultural production" *International Journal of Agriculture and Rural Development* **10**, 114-125

McDonald, J. (2009) "Using Least Squares and Tobit in second stage DEA efficiency analyses" *European Journal of Operations Research* **197**, 792–798.

McErlean, S., and Wu, Z. (2003) "Regional agricultural labor productivity convergence in China" *Food Policy* **28**, 237-252.

MoFA (2009) "National Rice Development Strategy (NRDS) (Draft)" Ministry of Food and Agriculture. Republic of Ghana.

Mugera, A. W., and Featherstone, A. M. (2008) "Backyard hog production efficiency: Evidence from the Philippines" *Asian Economic Journal* **22**, 267–287.

Namara, R. E., Horowitz, H., Nyamadi, B., and Barry, B. (2011) "Irrigation development in Ghana: Past experiences, emerging opportunities, and future directions" Ghana Strategy Support Program (GSSP), GSSP working paper number 0027, March 2011.

Nwanze, K. F. (2011) "Smallholders can feed the world. Viewpoint" President of the International Fund for Agricultural Development. http://www.ifad.org/pub/viewpoint/smallholder.pdf. Accessed 30 May 2016.

Rahman, S., and Awerije, B. O. (2015) "Technical and scale efficiency of cassava production system in Delta State, Nigeria: an application of Two-Stage DEA approach" *Journal of Agriculture and Rural Development in the Tropics and Subtropics* **116**, 59 – 69.

Ross, K., Dalton, T. J., and Featherstone, A. M. (2009) "A nonparametric efficiency analysis of bean producers from North and South Kiwu" Selected paper for the Southern Agricultural Economics Association annual meeting, Atlanta, Georgia, January 31 – February 3, 2009.

Simar, L., and Wilson, P. W. (2007) "Estimation and inference in two-stage semi-parametric models of production processes" *Journal of Econometrics* **136**, 31–64.

Singh, R. B., Kumar, P. and Woodhead, T. (2002) "Smallholder farmers in India: Food security and agricultural policy" RAP Publication number 2002/03.

Taraka, K., Latif, I. A., and Shamsudin, M. N. (2010) "A nonparametric approach to evaluate technical efficiency of rice farms in Central Thailand" *Chulalongkorn Journal of Economics* **22**, 1 – 14.

Tauchmann, H. (2015) "Simarwilson: DEA based two-step efficiency analysis" 2015 German Stata Users Group Meeting, Nuremberg, IAB. www.stata.com/meeting/germany15/abstracts/materials/de15_tauchmann.pdf. Accessed 1 January 2016.

Wanke P. F. (2012) “Determinants of scale efficiency in the Brazilian third-party logistics industry from 2001 to 2009” *Brazilian Administrative Review* **9**, 66-87

Watkins, K. B., Hristovska, T., Mazzanti, R., Wilson Jr., C. E., and Schmidt, L. (2014) “Measurement of technical, allocative, economic, and scale efficiency of rice production in Arkansas using data envelopment analysis” *Journal of Agricultural and Applied Economics* **46**, 89–106.

Appendix A:

The Simar and Wilson (2007) Procedure (algorithm #1)[3]

Step 1: Estimate the efficiency scores θ_i using DEA (i = 1, …N)

Step 2: Fit $\hat{\theta}_i = \beta z_i$ using truncated regression by maximum likelihood estimation and obtain estimates for $\hat{\beta}$ and $\hat{\sigma}_\varepsilon$.

- Exclude efficient DMUs j ($\hat{\theta}_j = 1, j = 1,...M$)
- $\varepsilon_i \equiv \varepsilon_i + \varsigma_i$ with $\varsigma_i \equiv \hat{\theta}_i - \theta_i$
- $\hat{\theta}_i^{in} \in (0,1]$ for input orientation (right truncation at 1).

Step 3: Loop over the next 3 steps B times (where b = 1, …, B)

- We draw ε_i^b from $N(0, \hat{\sigma}_\varepsilon)$ with right truncation for the input orientation (otherwise left truncation for the output orientation) at $(1 - \hat{\beta} z_i)$ for $i = M+1,...,N$
- Compute $\theta_i^b = \hat{\beta} z_i + \varepsilon_i^b$ for $i = M+1,...,N$
- Use the artificial efficiency scores θ_i^b as the dependent variable to estimate $\hat{\beta}^b$ and $\hat{\sigma}_\varepsilon^b$ by truncated regression.

Step 4: The final step is to construct standard errors for $\hat{\beta}$ and $\hat{\sigma}_\varepsilon$ (confidence intervals for β and σ_ε) from simulated distribution of $\hat{\beta}^b$ and $\hat{\sigma}_\varepsilon^b$.

[3] The Simar and Wilson approach described here is adapted from Tauchmann (2015).