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Meta regression analysis of economic efficiency in farm households in Ethiopia

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Abstract

The focus of this review paper was to analyze the economic efficiency in farm households in Ethiopia by using meta-regression analysis of previous studies conducted so far on the specified issue. For this purpose, a total of 20 (twenty) frontier studies conducted in different parts of the country on economic efficiency in farming households were compiled and a total of 22 observations were identified for data extraction. The extracted data were analyzed through descriptive statistics as well as econometric models (Tobit model). The descriptive statistics shows that the mean economic efficiency and technical efficiency estimates for the observation were 0.422 and 0.792 respectively. On the other hand, the mean technical efficiency score for reviewed empirical studies for grain crops and other crops were 0.764 and 0.700 respectively. The t-test statistics shows that, the mean economic efficiency score for reviewed empirical studies in different grouping variables (study product type, location of study and method of efficiency analysis) does not have significant difference whereas the test shows the existence of significant difference in mean technical efficiency score for grain crops and other crops indicating that the mean technical efficiency score for grain crops is higher than other crops. The econometric model result shows that out of six explanatory variables included in the model study product type, location of study area and method of efficiency analysis does not have significant influence on the mean economic efficiency score of empirical studies whereas sample size, number of explanatory variables and mean technical efficiency score have significant influence on the mean economic efficiency score of empirical studies at 5, 1 and 5% level of significance respectively. Sample size and mean technical efficiency score have negative influence whereas number of explanatory variables has positive influence. It is obvious that, for clear policy recommendation, accurate estimates of economic efficiency especially for commercial crops are crucial. In such issues, meta-analysis has paramount importance. Therefore, though the findings of this analysis shows and identifies the relationship between different explanatory variables and economic efficiency, it is better if further analysis covering large number of studies, wide geographic area and different agricultural commodities is conducted.

Keywords: Economic efficiency, Meta-regression analysis, Farm households.

Introduction

Agriculture is the main stay for the majority of Ethiopians and it is the largest contributor for GDP of the country next to service sector. The contribution of agriculture and service sector to GDP is 36.3 and 39.3% respectively[1].

The economic theory suggests that the aggregate performance of a given country is the sum of the individual firms' performance which operates within that country. Therefore, sound micro-foundations of efficiency analysis are critical for the integrity of productivity and efficiency analysis at macro level[2]. Efficiency Analysis is a challenging issue for measuring the performance of various sectors and Efficiency of the firms also makes substantial changes in the economy of a given country[3].

The issue of Efficiency consists of two main components namely technical and allocative efficiency. When a decision making unit achieves maximum output from a given set of inputs, it is said to be technically efficient. On the other hand, if the decision making unit is able to choose the optimal combination of inputs, given the level of input prices and production technology, it is allocatively efficient. Given technical and allocative efficiency, their product gives an overall efficiency which is achieving maximum output from a particular input level, with utilization of inputs at least cost[4].

The concept of efficiency is one of the most important topics of economic theory that shows the relationship between the actual amount a decision making unit produces from a given input and the feasible potential of the input, under the assumption of full utilization of the resources available[5]. Due to the potential importance of efficiency as a means of fostering production, a substantial number of studies focusing on agriculture have been conducted sofar[6].

Specifically, in Ethiopia's agriculture context where a lot of factors affect the efficiency (Economic efficiency) of farmers, studies related to efficiency has paramount importance. Due to this, different scholars have been conducted research on economic efficiency analysis in farm households involved in different farm activities like crop farming, livestock farming, vegetable farming and others. Hence, the main objective of this paper is to perform review of empirical estimates of economic efficiency (EE) in Ethiopian agriculture by using a meta-analysis and test the influence of specific characteristics (crop considered, study area, sample size, number of explanatory variables included) of the data for systematic differences in estimated average economic efficiency score.

Methodology

Overview of Efficiency Analysis Methodologies: If decision making units effectively use variable resources in such a way that profit is maximum with the given best production technology available, it is possible to say that the decision making unit is efficient. The concept of efficiency is composed of two components; namely technical and allocative efficiency. Technical efficiency refers to the ratio of actual output to the maximum attainable level of output, for a given level of production inputs. Allocative efficiency refers only to the adjustment of inputs and outputs to reflect relative prices, having chosen the production technology. Minimizing the use of inputs and improving output per unit of input is an important issue in policy formulation and management of decision making units. Due to this, measuring the existed level of efficiency is an important first step[7].

Generally, two measurement approaches of efficiency measurement were suggested during the first popular work done by Farrell on measurement of productive efficiency. These are categorized as parametric and non-parametric[7]. Following his seminal work, during the past few decades a lot of influential studies have been developed along these paradigms. Of these, the econometric (parametric) approach has been motivated to develop stochastic frontier models based on the deterministic parameter frontier specification of Aignerand Chu[8]. The Stochastic Frontier Analysis (SFA) is one of the most popular efficiency analysis methods that recognizes the random noise around the estimated production frontier and was developed by Aigner *et. al*[9] and Meeusen and van den Broeck[10].

The main, strength of the stochastic frontier analysis is that it can deal with stochastic noise and provides a room for different hypothesis tests where its requirement of specifying the underlying technology and an explicit distributional assumption are the main weaknesses of the SFA. The non-parametric approach or mathematical programming method developed by Charnes *et.al*[11] mainly focuses on the development of piece-wise linear function using Data Envelopment Analysis (DEA). The main merit of DEA of efficiency is that no explicit functional form is imposed on the data, and it can easily accommodate multiple outputs. Both SFA and DEA have been used in different fields such as hospitals, agriculture, education and industry to compare various systems.

Data Source: The most important issues that need series consideration in doing meta-regression analysis and reporting includes the exact databases or other sources used, a full disclosure of the rules for study (or effect size) inclusion/ exclusion, a complete list of the information coded for each study or estimate and others[12].

Considering this issue, a comprehensive collection and compilation of both published and unpublished empirical studies conducted on farming activities on economic efficiency were made. Hence, a total of 20 empirical studies were found and 22 observations were extracted for this analysis. The numbers of observations are higher than the numbers of studies reviewed because there were some studies that reported more than one economic efficiency estimate. Out of the total empirical literatures found, 81.8 and 18.2 % were published and unpublished (specifically thesis) sources. An overview of the materials the materials used for this analysis is presented in Table-1.

Data type and definition: For this particular analysis both continuous as well as dummy variables were used. The continuous variables used include economic efficiency (EE) score, sample size (SS) considered by the empirical study, number of explanatory variables (NEV) used in the model and technical efficiency (TE) score. Whereas the dummy variables considered for this analysis include type of the product (TTP) the empirical study was considered, location of study area (LSA) and method of efficiency analysis (EEA).Given these variables, the data were extracted and coded as presented in Table-2.

Methods of Data Analysis: For analysis of data extracted from different studies conducted so far, both descriptive as well as econometric model was employed for analysis. The descriptive statics includes mean, standard deviation and percentage and t-test were used for testing mean difference.

The main objective of this paper is to see the effect of different attributes like type of the product (TTP), location of study area (LSA), sample size (SS), number of explanatory variables (NEV) in the model, technical efficiency (TE) score and method of efficiency analysis (EEA) on the variation in the economic efficiency (EE) indices reported in the literature.

The value of efficiency scores are between zero and one where a value of zero indicates existence of full inefficiency and a value of one indicates absence of inefficiency. Given the bounded value of efficiency score between zero and one, two-limit Tobit model specified in the econometrics analysis book of Greene[33] were used to see the effect of selected explanatory variable on estimated average economic efficiency score. Hence, for an empirical investigation of this issue, the following model is estimated:

$$EE = (\ TTP, LSA, SS, NEV, TE, MEA) \tag{1}$$

Where, EE: represents mean economic efficiency, TTP: is type of the product, LSA: is location of study area, SS: is sample size, NEV: is number of explanatory variables, TE: is mean technical efficiency score and with this specified explanatory variables, the two-limit Tobit model is specified as:

$$EE_i^* = \beta_0 + \sum \beta_i X_i + \mu_i$$

Where (2)

$$EE_i = \begin{cases} 1, \text{ if } EE_i^* \geq 1 \\ EE_i^*, \text{ if } 0 < EE_i^* < 1 \\ 0, \text{if } EE_i^* \leq 0 \end{cases}$$

The variable X_i and β_i represents list of explanatory variables specified above and parameters to be estimated and μ_i is the disturbance term.

Results and discussion

Descriptive Statistics Results: In this part of the paper, the results of descriptive statistics for both dependent and independent continuous and dummy variables are presented.

As presented in Table-3, the descriptive result shows that, the minimum and maximum economic efficiency score for the reviewed empirical studies were 0.101 and 0.640 respectively with average economic efficiency score of 0.422 and standard deviation of 0.131. Similarly, the minimum and maximum technical efficiency score were 0.604 and 0.849 respectively with average technical efficiency score of 0.729 and standard deviation of 0.076. As it can be seen from the table, the standard deviation for economic efficiency is higher than that of technical efficiency showing that there is relatively high variation in farm households mean economic efficiency as compared with technical efficiency. In addition to this, the average number of explanatory variables included in the model and sample size for the reviewed empirical studies were 6.27 and 212.91 with a standard deviation of 1.12 and 16.30 respectively.

Similarly, as it can be seen in Table-4, out of the total (N=22) empirical studies on economic efficiency in farm households reviewed 45.5% were conducted on grain crops like Maize, Wheat, Barley and Sorghum whereas 54.5% were conducted on other farm activities like pulses, vegetables and others. On the other hand the majority of the studies were conducted in Oromia region and most of the studies (81.8%) were used stochastic frontier methods for their efficiency analysis.

In addition to this, the mean economic efficiency score for reviewed empirical studies in different grouping variables (study product type, location of study and method of efficiency analysis) were computed and presented in Table-5. As it can be seen in the table, the average economic efficiency score for studies conducted on grain crops and other farming is 0.416 and 0.426 respectively. Similarly, the average economic efficiency score for those empirical studies conducted in Oromia region and other regions were 0.419 and 0.426 respectively. Moreover, average economic efficiency score for those empirical studies which employs stochastic frontier analysis and data envelopment analysis for efficiency estimates were 0.424 and 0.412 respectively. Finally, the t-test statistics shows that there is no significant difference between the average economic efficiency score in different grouping variables.

In the same fashion, the average technical efficiency score for reviewed empirical studies in different grouping variables (study product type, location of study and method of efficiency analysis) were computed and presented in Table-6. As it can be seen in the table, the average technical efficiency score for studies conducted on grain crops and other farming was0.764 and 0.700 respectively and the t-test statistics shows that there is significant difference between the average technical efficiency scores. This may be due to the reason that, farmers especially in developing countries produce grain crops mainly for consumption and not for marketing. Similarly, the average technical efficiency score for those empirical studies conducted in Oromia region and other regions were 0.735 and 0.721 respectively. Moreover, average technical efficiency score for those empirical studies which employs stochastic frontier analysis and data envelopment analysis for efficiency estimates were 0.734 and 0.706 respectively and the t-test statistics shows that there is no significant difference between the average technical efficiency score inlocation of study and method of efficiency analysis.

Econometric Results: In this subsection of the analysis, the econometric results of the data are presented. Before the final analysis of the data was made, multicollinearity and heteroskedasticity problem was tested. The test result shows that there is no series multicollinearity problem in the data set as well as the variance for the residual term is constant which shows there is no heteroskedasticity problem. The analysis was made using both SPSS 16 and STATA 14 statistical soft wares. Hence, the Maximum likelihood estimation results of Tobit regression is presented in Table-7.

To compare the maximum likelihood estimation results of Tobit regression with ordinary least square (OLS) estimates, the results of both Tobit and OLS regression are presented. Though, the final interpretation was made based on Tobit regression result, the OLS results are presented in Table-8 for comparison purpose only. The findings of the analysis indicate that, the OLS estimates are similar to the Tobit model which was estimated using maximum likelihood procedures. As it can be observed in the tables given below, the estimates of the coefficients under OLS and Tobit models are very close to each other. But though the estimates are close to each other, the results shows that there are very small differences in terms of standard errors which have a direct effect on the significance power of the parameter estimates and test of hypothesis. The fact that the dependent variable is indeed truncated suggests that the ML results are better and the interpretation was made based on the ML estimation results.

Table-1: Overview of empirical studies used for analysis.

First author	Product type	Year	Study Area	Sample Size	TE (%)	EE (%)
Daniel Hailu[13]	Potato	2016	Oromia	196	62.60	54.20
Hika Wana[14]	Sesame	2018	Oromia	124	75.16	53.95
Berhan Tegegne[15]	Onion (Irrigation)	2015	Amhara	200	79.70	47.75
Mustefa Bati[16]	Maize	2017	Oromia	240	80.52	28.44
Hassen Beshir[17]	Mixed crop-livestock	2012	Amhara	252	62.00	29.00
Getachew Wollie[18]	Barley	2018	Amhara	123	70.90	48.80
Kifle Degefa[19]	Maize	2017	Oromia	124	82.93	54.00
ESSA CHANIE[20]	Teff, Wheat and Chickpea	2011	Amhara and Oromia	700	79.00	31.00
Gosa Alemu[21]	Sorghum	2016	Amhara	130	74.00	32.00
Solomon Bizuayehu[22]	Wheat sead	2012	Amhara	150	79.90	37.30
Musa Hassen[23]	Maize	2015	Oromia	138	84.87	31.62
Mustefa Bati[24]	Coffee	2017	Oromia	200	71.71	10.12
Desale Gebretsadik[25]	Sesame	2017	Tigray	126	71.00	64.00
Sisay Debebe[26]	Maize	2015	Oromia	385	62.30	39.00
Jema Haji[27]	Vegetable	2008	Oromia	150	68.00	43.00
Jema Haji	Vegetable	2008	Oromia)	150	66.00	43.00
Ali Beshir Melkaw[28]	Farm households	2014	Amhara	118	60.40	37.60
Musa Hasen Ahmed[29]	Maize	2018	Oromia	480	82.24	28.29
Ermiyas Mekonnen[30]	Sesame	2015	SNNPR	120	67.11	45.14
Arega D. Alene[31]	Traditional maize	2005	Oromia	47	68.00	56.00
Arega D. Alene	Hybrid maize	2005	Oromia	51	78.00	61.00
Beneberu Teferra[32]	Wheat, faba bean and lentil	2018	Amhara	480	77.00	53.00

Table-2: Description of dependent and independent variables.

Variables	Description and Measurement	Expected sign
Economic Efficiency(EE): Dependent	Average level of EE obtained from each reviewed study and measured as continuous variable	
Independent Variables		
Sample size (SS)	Total number of observation considered under the reviewed study and measured as continuous variable	+
Number of explanatory variables (NEV)	Total number of explanatory variables used in the model under the reviewed study and measured as continuous variable	+
Technical efficiency (TE)	Average level of TE obtained from each reviewed study and measured as continuous variable	+
Type of the product (TTP)	The product type considered by the reviewed study and is measured as dummy variable, (1, Grain crops and 0 others)	+
Location of study area (LSA)	The location where the reviewed study was conducted and measured as dummy variable (1, Oromia and 0 Others)	+
Method of efficiency analysis (EEA)	The method used by the reviewed study for efficiency analysis and is measured as dummy variable (1, SFA and 0 DEA)	+

Table-3: Descriptive summary of continuous variables.

Variables	N	Minimum	Maximum	Mean	Std. Deviation
Mean economic efficiency score	22	0.101	0.640	0.422	0.131
Mean technical efficiency score	22	0.604	0.849	0.729	0.076
Number of explanatory variables	22	5	8	6.27	1.120

Table-4: Descriptive summary of dummy variables.

Variables		N=22	
		N	%
Study product type	Grains	10	45.5
	Others	12	54.5
Location of study area	Oromia region	12	54.5
	Other regions	10	45.5
Method of efficiency analysis used	SFA	18	81.8
	DEA	4	18.2

Table-5: Comparison of mean economic efficiency score in different grouping variables.

Grouping variables		Economic efficiency score		t-value
		Mean	Std. Deviation	
Study product type	Grains (n=10)	0.416	0.123	0.174
	Others (n=12)	0.426	0.143	
Location of study	Oromia region (n=12)	0.419	0.151	0.117
	Others (n=10)	0.426	0.112	
Method of efficiency analysis	SFA (n=10)	0.424	0.141	0.171
	DEA (n=12)	0.412	0.093	

Table-6: Comparison of mean technical efficiency score in different grouping variables.

Grouping variables		Technical efficiency score		t-value
		Mean	Std. Deviation	
Study product type	Grains (n=10)	0.764	0.073	2.133**
	Others (n=12)	0.700	0.067	
Location of study	Oromia region (n=12)	0.735	0.082	0.432
	Others (n=10)	0.721	0.072	
Method of efficiency analysis	SFA (n=10)	0.734	0.074	0.657
	DEA (n=12)	0.706	0.089	

**represents significant at 5%.

Table-7: Maximum likelihood estimation results of Tobit regression.

Variables	dy/dx	Std. Err.	Z	P>|z|	95% Conf. Interval	
Study product type	0.0961	0.0627	1.5300	0.1260	-0.0269	0.2190
Location of study area	0.0162	0.0467	0.3500	0.7280	-0.0752	0.1077
Sample size	-0.0003**	0.0002	-1.9900	0.0460	-0.0006	-0.0000
Method of efficiency analysis	-0.0462	0.0692	-0.6700	0.5040	-0.1818	0.0893
Number of explanatory variables	0.1032***	0.0306	3.3700	0.0010	0.0431	0.1633
Mean technical efficiency score	-1.1637**	0.5046	-2.3100	0.0210	-2.1526	-0.1748

** and *** represents significant at 5 and 1% respectively.

Table-8: OLS estimation results.

Variables	Coefficients	Std. Error	t	Sig.
(Constant)	0.656	0.279	2.351	0.033**
Study product type	0.084	0.072	1.167	0.261
Location of study area	0.019	0.054	0.349	0.732
Sample size	0.000	0.000	-1.715	0.107
Method of efficiency analysis used	-0.041	0.080	-0.517	0.613
Number of explanatory variables included in the model	0.098	0.035	2.783	0.014**
Mean technical efficiency score	-1.087	0.580	-1.873	0.081*

Note: * and ** represents significant at 10 and 5% respectively.

The results of the econometric model shows that, out of six (6) explanatory variables included in the model three (3) of them were significant. As it can be seen in Table-6, Sample size and Mean technical efficiency score were significant at 5% level of significance whereas Number of explanatory variables included in the model were significant at 1% level of significance.

The tobit estimation result shows that the coefficient of study product type is positive and insignificant. This may indicate that farm households grow grain crops mainly for the purpose of consumption as compared to other commercial crops like vegetables and oil crops. Similarly, location of study area has positive coefficient though it is not significant and this may show that regional differences does not create significant difference in economic efficiency of farm households in the country.

In addition to this, the coefficient for method of efficiency analysis used was negative and insignificant. This result shows that using either SFA or DEA does not create significant difference in economic efficiency score though using SFA yields 0.0462 lower mean economic efficiency score than DEA and this result is in line with the finding of the study conducted by Thiam *et al.*[34], Brons *et al.*[35] and Fatima and Yasmin[36].

However the coefficient of sample size is negative and significant at 5%. This value shows that increment in sample size by one will decrease the economic efficiency score by 0.00003.

This may be due to the fact that as the sample size increases the probability that the sample becomes representative increases. Hence, in developing countries including Ethiopia, most of the farmers are subsistence where their main target is producing crop for food which directly affects their level of economic efficiency indirectly. This finding contradicts with the finding of the study jointly conducted by Iršováand Havránek[37] where the finding of their meta-analysis on measuring bank efficiency results a positive and significant coefficient for efficiency and this difference may be due to the reason that the two sectors are different because the bank sector is totally commercial sector whereas the farming sector is not.

Similarly, number of explanatory variables included in the model has positive and significant influence on mean economic efficiency score estimates at 1% level of significance and the result is in line with the result of Fatima and Yasmin[36] but in their finding though the coefficient is positive it is insignificant. Finally, mean technical efficiency score has negative and significant influence on the mean economic efficiency estimates of farm households at 5% level of significance. This may be due to the reason that, almost half of the empirical studies reviewed for this analysis were conducted on grain crops where farmers produce them purposely for consumption rather than marketing. Hence, their primary interest may be increasing their output given inputs rather than maximizing their profit. And again this result implies that attaining high technical efficiency does not have direct contribution on economic efficiency showing that separate intervention is needed to improve both economic as well as technical efficiency of farm house holds in the country.

Conclusion

For this meta-analysis, a total of 20 frontier studies conducted in different parts of the country on economic efficiency in farming households were compiled and a total of 22 observations were identified for data extraction. The numbers of observations are higher than the numbers of studies reviewed because there were some studies that reported more than one economic efficiency estimate.

The descriptive statistics shows that the mean economic efficiency and technical efficiency estimates for the observation were 0.422 and 0.792 respectively. The t-test statistics shows that, the mean economic efficiency score for reviewed empirical studies in different grouping variables (Study product type, Location of study and Method of efficiency analysis) does not have significant difference.

On the other hand, the mean technical efficiency score for reviewed empirical studies for grain crops and other crops were 0.764 and 0.700 respectively and the t-test statistics shows that there is significant difference between them indicating that the mean technical efficiency score for grain crops is higher than for other crops.

The econometric result shows that out of six explanatory variables included in the model study product type, location of study area and method of efficiency analysis does not have significant influence on the mean economic efficiency score of empirical studies.

On the other hand, sample size, number of explanatory variables and mean technical efficiency score have significant influence on the mean economic efficiency score of empirical studies at 5, 1 and 5% level of significance. Sample size and mean technical efficiency score have negative influence whereas number of explanatory variables has positive influence.

Finally, for clear policy recommendation, accurate estimates of economic efficiency especially for commercial crops are crucial. In such issues, meta-analysis has paramount importance. Therefore, though the findings of this analysis shows and identifies the relationship between different explanatory variables and economic efficiency, it is better if further analysis covering large number of studies, wide geographic area and different agricultural commodities is conducted. This would lead to a better understanding of the association between estimates of mean economic efficiency and the explanatory variables extracted from the reviewed studies. Over all, the analysis shows the mean economic efficiency for the reviewed studies is very small and the issue needs series attention.

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