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Impact of Policy Change on Technical Efficiency: Evidence from Small Scale Food Crop Farmers in Kellem Wollega, Ethiopia

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ABSTRACT

Background: An effort was made by the Ethiopian government to increase the level of technical efficiency of farmers across the country. However, due to climate change, smallholder farmers were facing challenges to increase technical efficiency in crop production. Adaptation to climate change is crucial to uphold and increase food crop productivity. This study analysis the impact of climate change adaptation and policy issues on food crop production efficiency in Kellem Wollega, Ethiopia.

Methods: The data was gathered from 400 randomly selected food crop smallholder farmers. The Cobb-Douglas production function was used by including the climate change adaptation measures as explanatory variables in technical inefficiency. Simulation was made to adaption measures that can be influenced by the policy variables to see their impact on the level of technical efficiency.

Result: The finding show that the use of adaptive practices (multiple crop type, improved crop varieties, adjusting planting dates and irrigation) had a significant and positive effect on technical efficiency whereas land fragmentation reduces efficiency level. Regarding simulation of policy variables the result show that the mean technical efficiency would increase with rising level of improved crop varieties, adjusting planting dates and irrigation practices. The results of the simulation of land fragmentation climate change adaptation variables show that the mean technical efficiency declines as a result of land fragmentation. Empirical results reveal that with appropriate policy intervention (climate change adaptation measures) the technical efficiency level of food crop farmers can be enhanced.

Key words: Adaptation, Climate change, Simulation, Technical efficiency.

INTRODUCTION

Climate change is endangering the agricultural productivity (Umunakwe *et al*., 2015) and due to constriants to adaptaion developing countries reamined vulnearbel to the impcat of climate change (Boko *et al*., 2007). But with adaptation the level of vulnerability can be moderated and/or enhance the positive impacts of climate change (Mendelsohn, Nordhaus and Shaw, 1994; Rosenzweig and Parry, 1994; Easterling, 1996; Mendelsohn and Dinar, 1999; Smith *et al*., 1999; Fankhauser, 2017).

Farmers especially food crop farmers can reduce the potential damage by making tactical responses to climate changes (Reilly, 1996; Smit *et al*., 2000; Smit and Skinner, 2002; Adger *et al*., 2003). The adaptation options range from management alterations by farmers themselves (changing timing of operations, adoption of conservation and diversification in production systems) to investment of funds by public agencies (in order to develop or improve irrigating schemes, modification of farm support programs and development of new plant varieties (Klein and Maciver, 1999; Adger *et al*., 2003; Bradshaw, Holly and Barry, 2004).

The stochastic frontier production function (Meeusen and van Den Broeck, 1977; Aigner and Chu, 1986) has been contributing to the econometric modelling of production and estimation of technical efficiency of firms. The econometric approach based on the deterministic parameter frontier (Aigner and Chu, 1986) has been used to develop stochastic frontier models. This stochastic frontier involved random components of technical inefficiency and random error (Aigner, Lovell and Schmidt, 1977; Meeusen and van Den Broeck, 1977; Oren and Alemdar, 2006; Ahmed *et al*., 2018).

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In literature, Stochastic Frontier Analysis is often used in agricultural economics because of the inherent nature of agricultural production that is the uncertainty and variability associated with agricultural production due to change in climate (weather, water, rain fall, pests, diseases, *etc.*) (Coelli, 1996; Coelli, Rao and Battese, 1998).

In this work, we investigate whether climate adaptation measures and simulation of the policy variables increase food crop production technical efficiency in Kellem Wollega, Ethiopia. It is expected that farmers who are more aware and better adapted to climate change will be able to make more efficient use of their resources and thus cope with any adversities. This study adds valuable information for agricultural policy design, as it provides evidence of the impact of alternative adaptation strategies to climate change and its impact on the level of technical efficiency.

MATERIALS AND METHODS

Study area and data

The study was conducted in Kellem Wollega Zone found in the Western part of Oromia Regional States of Ethiopia. It has ten rural districts and one administrative town. The zone is endowed with diverse socio-cultural settings and enjoys diversified climatic types. The area has good climate which is an opportunity to diversify agricultural practice and grow many varied type of crops and raise different livestock. For the purpose of this study 400 food crop producing farmers in production year 2019/20 were randomly selected from four districts. The data collection instrument focused on socioeconomic factors, production level, capital resource and agrochemicals used.

Analytical framework and empirical model

The data in this study was fitted into Cobb-Douglas function specified as:

$$ln\,(Y_i) = \beta_0 + \sum_{i=1}^{5} \beta_i\, ln\,(X_i) + v_i - u_i \qquad (1)$$

Where

ln is the natural logarithms, β's are coefficients of parameters to be estimated, Y_i is the total value output in US dollar. X_i's are factors of productions (farm size, labour, fertilizer and other agrochemical, farm equipment and oxen), v_i is the idiosyncratic error that arises from measurement errors in input use and/or yield of production independent and identically distributed as N (0,σv2) random variables and u_i is the non-negative random variables in measuring the technical inefficiency of individual household.

Technical inefficiency effects model:

$$U_i = \delta_0 + \sum_{i=0}^{n} \delta_i Z_{ji} \qquad (2)$$

Where

U_i= Inefficiency effect; δ_i= Coefficients of climate change adaptation strategies and socioeconomic factors; Z_{ji}= Climate change adaptation strategies and socio-economic factors (*i.e.* hypothesized efficiency changing variables).

The non-negativity assumption of the inefficiency term (u_i), the underlying distribution is non-normal and the error terms are asymmetrically distributed. Hence, the ordinary least squares (OLS) estimator is inefficient. (Coelli, 1995) argues that there are two main benefits of using frontier functions as the ones in equation Cobb-Douglas rather than OLS (average functions).

First, frontier functions are based on best performing producers and therefore can show the technology used in production, whereas average functions only shows technology of an average producer. Secondly, frontier functions show the best-practicing technology, whereas average functions show efficiency of producers within the whole group.

Lovell, (1993) also argued that MLE technique provides more efficient estimates than the OLS, besides its guarantee of non-negativity assumptions on the error terms. Thus, unknown parameters of frontier models are estimated using the maximum likelihood estimation (MLE) technique.

RESULTS AND DISCUSSION

Test for model specifications

Before estimating model parameters checking whether the stochastic production frontier is more appropriate than a conventional production function, *i.e.* testing whether there exist technical inefficiency in the production process or not is important. In this test the null hypothesis is given as: H0: γ = δ0 = δ1 =...δ9 = 0, which states that inefficiency effects are absent from the frontier model, was rejected for the food crop farmers (Table 1).

Maximum likelihood estimates for parameters of the two estimated models are presented in Table 2. The result shows that farm size, labour, fertilizer and other agrochemicals and oxen are highly significant at 1 per cent level of probability while farm equipment is significant at 5 per cent of significance. Similarly, the study of (Kidane and Ngeh, 2015; Mango *et al*., 2015; Sherzod, Kim and Lee, 2018) explained that farm area and fertilizer; (Sherzod, Kim and Lee, 2018; Wollie, 2018) labour and (Wollie, 2018) reported that ox are significant 1 per cent .

The estimated value for the γ for the food crop farmers was 0.669 and the values is significant at 1 per cent level of probability. These values indicate that technical inefficiency is highly significant in the food crop production activities in the study area. These results confirm the findings of (Ajibefun *et al.* 2006; Chiona *et al.* 2014; Kidane and Ngeh, 2015; Mango *et al*., 2015; Sherzod *et al.* 2018; Wollie, 2018) that technical inefficiency is significant in the food crop production activities.

Technical efficiency estimates

The technical efficiency shows the ability of farmers to derive maximum output from the inputs used in food crop production. The technical efficiency estimates are presented and discussed subsequently (Table 3). The results show high variability in technical efficiency among the food crop farmers in the study area. The computed technical efficiency varies from 0.38 to 0.92 with a mean of 0.79. The result of mean efficiency is similar to the finding of (Pradhan and Mukherjee, 2018). The variation in the level of the technical

Table 1: Generalised log likelihood-ratio tests of null hypothesis.

	Model 1	Model 2	λ	CV	Decision
Food Crop Famers	-143.42	-121.01	22.41	16.274	Reject Ho

*Critical value is obtained from Table 1 pp. 1246 in (Kodde and Palm, 1986), at 5 per cent level of significance and 9 degree of freedom (C^{x2}0.05,9).

Table 2: MLE of production function

Variables	Param.	Model 1		Model 2	
		Coef	SE	Coef	SE
Constant	β0	10.52***	0.56	11.08***	0.582
In (Farm size)	β1	0.366***	0.0381	0.464***	0.0314
In (Labour)	β2	0.49***	0.0532	0.501***	0.055
In (Fertilizer and agrochemical)	β3	0.0262***	-0.0205	0.0202***	0.00579
In (Farm equipment)	β4	0.0964**	0.035	0.989**	0.0278
In (Oxen)	β5	0.0433***	0.00879	0.0503***	0.00899
Total variance	δ^2			0.163***	0.0188
Gamma	γ			0.669***	0.126
No. of observation		400		400	

***p<0.01, **p<0.05, *p<0.1.

efficiencies in food crop production implies there is opportunity to improve the current level of technical efficiency by 21 per cent.

Impact of adaptation to climate change on technical efficiency

This section presents analysis of climate change adaptation strategies that influence technical efficiency in food crop production in the study area.

An inverse and statistically significant (at 1 per cent) relationship is found between crop diversification and technical inefficiency of food crop farmers (Table 4). This suggests that food crop farmers in study area who did not plant multiple type of crop experienced higher technical inefficiency. This is can be due to the reason that farmer engaged in multiple crop type is more efficient in allocating their resources like labour and land than his/her counterpart. Thus the adaptation of multiple crop type adaptation strategy would help the farmers to increase their level of technical efficiency.

The estimated coefficient for improved crop varieties is negative and significant at 5 percent (Table 4). This implies an increase in use of improved crop varieties tends to increase technical efficiency. Policy and programmes regarding the development and provision of improved crop varieties would help the farmers in the study area to left up the level of technical efficiency.

An inverse and statistically significant relationship is found between technical inefficiency and adjusting planting dates of the respondents (Table 4). This implies an increase in adjusting planting dates tends to increase technical efficiency (or decrease technical inefficiency). Adjusting planting dates helps farmers to reduce the loss due to changing climate. Thus farmers capable to adjust their planting dates experienced higher technical efficiency. The availability of information on climate change can help the farmers to adjust the time of planting dates *i.e.* increase the level of technical efficiency.

A negative and statistically significant relationship, at 10 per cent was found between irrigation practices and technical inefficiency in food crop production in the study area (Table 4). This implies that an increase in irrigation practices tends to increase technical efficiency. In the study area there is no functional irrigation technology. In the study area there is financial constraint that limits small scale famers to adopt irrigation technology. Government policy toward the development of irrigation schemes can help farmers in the study area to increase their level of technical efficiency.

Table 3: Distribution of technical efficiency estimates.

Efficiency Index	Freq.	Perc.
≤0.50	27	6.75
0.51≤0.60	53	13.25
0.61≤0.70	49	12.25
0.71≤0.80	64	16
0.81≤0.90	112	28
0.91≤1.00	95	23.75
Total	400	100
Mean	0.79	
Minimum	0.38	
Maximum	0.92	

Table 4: MLE of determinants of technical inefficiency.

Variables	Coef.	SE
Constant	9.75***	0.381
Multiple crop type	-0.0516***	0.00668
Improved crop varieties	-0.0283**	0.00775
Adjusting planting dates	-0.0773**	0.0336
Land fragmentation	0.0923***	0.0379
Irrigation practices	-0.443*	0.0301
Level of education	-0.0437**	0.0126
Climate change awareness	-0.0594***	0.00813
Farming experience	-0.0458*	0.0258
Nonfarm income	0.803**	0.339
Log likelihood function	-123.76	
No. of observation	400	

***p<0.01, **p<0.05, *p<0.1.

The result shows that the coefficient for land fragmentation is positive and significant at 1 per cent level of probability (Table 4). For the positive significant coefficient, it implies that an increase in land fragmentation tends to increase the level of the technical inefficiency (*i.e.* decrease technical efficiency). The finding shows that land fragmentation decrease level of technical efficiency in the study area. Land fragmentation is related to the use of time and other resource for agricultural production. In the study area farmers with more fragmented farm land are inefficient in using the agricultural resources. As policy intervention land consolidation farming can reduce the problem of land fragmentation and increase the level of technical efficiency.

Analysis of policy variables that affect technical inefficiency

The impact of selected climate change adaptation strategies (*i.e.* improved crop varieties, adjusting planting dates, land fragmentation, irrigation practices) on mean technical efficiency of food crop farmers in the study area after simulation is presented in Table 5. These variables are determinants of technical efficiency that could be influenced by policy implementation to improve the technical efficiency. The simulation is done with an increase in the value of these selected variables at 5 per ent, 10 per cent and 20 per cent. The results of the simulations are presented in Table 5.

The results of simulation of policy variables show that the level of mean technical efficiency would increase with rising level of improved crop varieties, adjusting planting dates and irrigation practices (Table 5). An increase in the availability of improved crop varieties from 5 per cent through 20 per cent raised the mean technical efficiency from 77 percent to 79 percent (Table 5). Thus in the study area government can play a great roll to increase the level of technical efficiency of farmers. By institutional arrangement either government or the private sector can provide improved crop varieties, climate change resisting and those crop having short time harvest, to influence current level of technical efficiency.

Information on changing climate helps farmers to adjust planting dates of crops. With increase in information regarding the climate and farming experience farmers adjust the planting time. Thus, with increase in practices of adjusting the planting dates from 5 percent through 20 per cent the mean technical efficiency raised from 79 per cent to 81 per cent.

Irrigation is one mechanism farmers practices in response to changing climate mainly rainfall. With increase in irrigation practices from 5 per cent through 20 per cent the mean technical efficiency raised from 79 per cent to 82 per cent. Training and facilitating the adoption of new technology regarding irrigation would increase the level of technical efficiency in the study area.

Table 5: Simulation results of variation in policy variables on mean technical efficiency.

Variable	Mean T.E=0.79		
	5%	10%	20%
Improved crop varieties	0.77	0.77	0.79
Adjusting planting dates	0.79	0.81	0.81
Land fragmentation	0.72	0.68	0.63
Irrigation practices	0.79	0.81	0.82
Level of education	0.80	0.80	0.83
Climate change awareness	0.80	0.82	0.84

The climate change awareness as one policy variable shows that an increase in climate change awareness from 5 per cent through 20 per cent raised the mean technical efficiency from 80 per cent to 84. The dissemination of information concerning climate change helps farms to adjust time planting crops. Thus, concerned body, the government, private sector and NGOs can provide information of changing climate that would increase the level of technical efficiency of farmers in the study area.

Education as one policy variable shows that, an increase in level of education from 5 per cent through 20 per cent raised the mean technical efficiency from 80 to 83 per cent. Thus providing training and technology on irrigation by concerned body would increase the level of technical efficiency of farmers in the study area.

The results of the simulation of land fragmentation climate change adaptation variables show with increase in land fragmentation from 5 per cent through 20 per cent the mean technical efficiency declined from 72 per cent to 63 percent. Thus to revert this value the government has to take some measures to reduce land fragmentation.

CONCLUSION

This study analyzed the effects of climate change adaptation measures and policy variables on technical efficiency of food crops producer in Kellem Wollega. Adaptation strategies such as multiple crop type, improved crop varieties, adjusting planting dates and irrigation have significant contribution on household food crop production technical efficiency in the study area. On the other hand, households that use land fragmentation adaptation strategy experience a reduction in technical efficiency in the study area. Policy/decision makers should therefore consider adaptation strategies that would improve household food crop production technical efficiency. The impact of selected climate change adaptation strategies on mean technical efficiency after simulation has shown that with appropriate policy the level of technical efficiency food crop farmers can be increased. The connection between productivity with the implementation of specific farm-level adaptive practices, as well as with actions that ease adoption barriers deserves additional analyses.

Conflict of interest: None.

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