A STUDY OF TECHNICAL INEFFICIENCIES OF MAIZE FARMERS WITHIN AND OUTSIDE THE NEW AGRICULTURAL EXTENSION PROGRAM IN THE HARARI REGION OF ETHIOPIA.

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Abstract

In 1994/95 Ethiopia launched a new agricultural intensification program based on the experience gained from the programs of the past and the success of the SG 2000 agricultural project in achieving higher yields in the subsistence sector. Stochastic frontier production functions were estimated for a sample of maize farmers within and outside the New Extension Program in order to study their technical inefficiencies and identify some of the factors contributing to variations in the productivity of maize farmers in the Harari Region of Ethiopia. It is found that there were technical change and changes in technical inefficiencies of maize farmers between 1994/95 and 1997/98. The average technical efficiencies of maize farmers were 73 per cent and factors such as agricultural extension, formal education, and off-farm incomes were important factors affecting the technical inefficiencies of maize farmers within the program. We concluded that policies enhancing the managerial and decision-making capacity of maize growers contributed, towards increasing their technical efficiencies and the objective of achieving increased maize production.

Key words: *Stochastic, Technical inefficiencies, Agricultural extension, Harari Region, Ethiopia*

Introduction

Ethiopia has a population of 66 million growing at an annual rate of 2.7 per cent and is expected to reach 86 million by 2010. Agriculture is the mainstay of Ethiopian economy. Agriculture contributes about 65 per cent of the GDP, 90 per cent of the total exports and about 85 per cent of the total employment. However, agricultural production is essentially subsistence and is characterized by low productivity. According to the FAO (1998), the average yield of maize, which covers 32 per cent of agricultural land and 28 per cent of agricultural production, is only 1.6 tonnes per hectare. Moreover, according to Ethiopian Ministry of Agriculture (1995), the average gross per capita food production is only 224 kg grain equivalent, which is 13 per cent below the average adult person nutritional requirement per year. Consequently, about 4.6 million people survive on humanitarian aid for some portion of an average production year.

Given the magnitude of the problem, Ethiopia has emphasized the importance of promoting agricultural intensification and extension programs aimed at stimulating rapid increase in productivity of food crops in subsistence agriculture. Examples of such programs include the Package Approaches (1957–1984); the Ethiopian Peasants Integrated Development program (1985–1990) and the Extension Management Training Program (1990–1994). In these programs public resources were directed to encourage farmers to adopt agricultural technologies developed locally and achieved higher yield at research and farm level trials. Yet, Belete (1989) noted that because of resource and government policy constraints they achieved little in meeting their objectives.

In 1994/95 Ethiopia actively promoted a New Extension Program (NEP) developed from the experiences gained from past extension programs and the success of the SG 2000[1] agricultural project in Ethiopia. The initiative involved the adoption of improved maize varieties, chemical fertilizers and pesticides, agricultural credit and extension advice in the subsistence sector. Preliminary analyses on the success of the program in Harari Region indicated that there were significant variations in maize yields among farmers within the New Extension Program. Yield of maize varied between 1.4 and 4.2 tonnes per hectare, with a mean yield of 2.8 tonnes per hectare and a standard deviation of 1.2 tonnes per hectare. The objectives of this paper are: (1) to examine whether yield variations were due to technical inefficiencies of maize farmers or other factors beyond their control; (2) to test for the existence of technical change and changes in technical inefficiencies of maize farmers; and (3) to identify some of the variables affecting the technical inefficiencies of maize farmers within and outside the New Extension Program in Harari Region of Ethiopia using stochastic frontier production function inefficiency models.

Farrell (1957) introduced the subject of estimating frontier production functions and measuring the economic efficiencies of firms involved in the production of certain

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[1] SG 2000 is an agricultural development initiative that envisaged agricultural policy reform in Ethiopia. The program tries to show policy makers in Ethiopia that productivity could be increased by two or three fold if locally produced research results are delivered to farmers at appropriate times and at reasonable prices (SG 2000 1995, 1996).

commodities. Following Farrell (1957), various frontier production functions involving various functional forms were proposed that accommodated different assumptions and applications. Reviews of these studies are given in Battese (1992) and Bravo-Ureta and Pinheiro (1993). The stochastic frontier model independently proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977) has been adapted and extensively applied in the analysis of technical efficiencies in agricultural production in developing counties particularly in south east Asia. Coelli and Battese (1996) specified stochastic frontier production inefficiency model, which Battese and Coelli (1995) proposed, to investigate factors affecting the technical inefficiencies of Indian farmers. Seyoum, Battesse and Fleming (1998) specified the above model to analyze the technical efficiencies of maize farmers within and outside the SG 2000 agricultural project in Ethiopia. The above study indicated that the frontier outputs and technical efficiencies of farmers within the SG 2000 project were greater than the frontier outputs and technical efficiencies of farmers outside the project, relative to their respective technologies. In this paper the model proposed by Battese and Coelli (1995) is used to study the technical inefficiencies of maize farmers within and outside the New Extension Program (NEP) in Harari Region. The remaining section of this paper consists of a discussion of the data and stochastic frontier inefficiency model, specified for Harari Region maize farmers and the empirical results and conclusions.

Panel Data on Harari Region Maize Farmers

Harari Region is located in eastern Ethiopia about 525 km east of the Ethiopian capital, Addis Ababa. According to Office of Population and Housing Census Commission report (1995), about 50 per cent of the population of the Harari Region is engaged in agriculture. Agricultural operation in the region consists of producing annual food crops such as maize, wheat and sorghum, and perennial crops (mainly coffee and "Khat"[2]) for private consumption and market. The major rainy season occurs between July and September, and the minor rainy season between March and April. On average, every fourth family has a member possessing functional literacy that is sufficient to take care of most financial or social needs. It is estimated that not more that seven per cent of farmers use modern agricultural technologies.

[2] Khat is a perennial crop mainly grown and consumed in Ethiopia and some parts of the Middle East. It is one of the major sources of off -farm income for farmers engaged in mixed crop production. It is *inter-cropped with other annual crops and adapts well in various climatic conditions.*

Human and oxen labour are the main sources of farming power and agricultural activities carried out on farm sizes between of 0.25 and four hectares.

The data used in this study were obtained from the surveys conducted by Harari Agricultural Bureau for the purpose of assessing resources and constraints of maize farmers and designing strategies to improve their farm management. The sampling process involved with grouping maize farmers into those within and outside the New Extension Program and then randomly selecting 20 per cent of maize farmers from the 262 farmers within and the 685 farmers outside the program in 1997/98. A sample size of 53 farmers within and 60 farmers outside the project were selected and then data on their farming operations were sought for the sample period between 1994/95 and 1996/97. A panel data on human labour hours, oxen labour hours, tractor hours and expenditures on chemicals were collected. Also obtained were data on the socio-economic variables such as, hours of agricultural extension advice, formal education, levels of off-farm income, farming experience and age of sample maize farmers. A total of nine observations from sample farmers within the project and 33 observations from sample maize farmers outside the project were missing because these farmers used their land for other agricultural operations or were not involved in the project for one or two of the previous years. The total number of observations involved in this study were 159 within the program and 180 farmers outside the program.

Stochastic Frontier Inefficiency Model for Maize Farmers

The stochastic frontier production function model, which we specified for the farming operations of maize farmers in Harari Region is given by

(1) $$\ln(y_{it}) = \beta_0 + \beta_T D_{Tit} + \beta_O D_{Oit} + \beta_1 x_{1it} + \beta_2 x_{2it} + \beta_3 x_{3it} + \beta_4 x_{4it,} + \beta_5 x_{5it} + v_{it} - u_{it}$$

where ln represents the natural logarithm (base e);

the subscripts, i and t , refer to the i-th sample farmer in the t-year of observation;

Y is the total level of maize output in quintals;[3]

x_1 is the logarithm of the total area of land used;

x_2 is the logarithm of the total amount of human labour hours used;

[3] A quintal is 100 kilogram

x_3 is the logarithm of the total amount of oxen labour hours used;[4]

x_4 represents the logarithm of the total value of other input costs (in Ethiopian Birr);[5]

x_5 represents the year of observation (coded as 1,2,3);

D_T is the dummy variable for tractor hours, which has value one if tractor power was used and zero otherwise

D_O is the dummy variable for oxen labour, which has value one if oxen labour was positive; and zero otherwise;

the v_{it}s are assumed to be identically and independently distributed $N(0,\sigma^2_v)$ random errors, independently distributed of the u_{it}s; which are assumed to be independently distributed non-negative truncations of the normal distributions with some variance, σ^2, such that the mean, μ_{it}, associated with the technical inefficiency effect, u_{it}, is defined by

$$(2) \qquad \mu_{it} = \delta_0 + \delta_1 z_{1it} + \delta_2 z_{2it} + \delta_3 z_{3it} + \delta_4 z_{4it}, + \delta_5 z_{5it} + \delta_6 z_{6it} + \delta_{0I} D_{Iit}$$

where z_1 is the years of formal schooling of the farmer;

z_2 represents the number of hours of extension services received;

z_3 denotes the number of years farming experience;

z_4 denotes the logarithm of the level of other income; [6]

z_5 is the age of the farmer;

z_6 is the year of observation (same as the x_5-variable in the production function specified on (1); and

D_I is a dummy variable which has values one, if other income is positive, and zero, otherwise.

The dummy variables, D_T and Do, permit different intercept of the production function to be estimated for farmers who used tractor power or oxen labour, respectively, for maize cultivation. The model for farmers within the program does not involve oxen dummy variable, D_O, because all of them used oxen. The experience variable in the inefficiency

[4] Some sample farmers outside the NEP did not use oxen hours. Thus the dummy variable D_o for oxen is used in the model as defined below, as proposed by Battese (1997).

[5] The exchange rate for one Ethiopian Birr is of $US 0.12 in 2004.

[6] Because some sample farmers did not have positive other income, the inefficiency variable, z_4, was actually the logarithm of the maximum of off-farm income and the dummy variable, $1-D_I$, where the D_I is the dummy variable for other income, defined below

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model for farmers within the program is omitted because it is linearly related to the year variable in the model for those farmers. The parameters of the model are estimated by maximum-likelihood methods using the computer program, FRONTIER Version 4.1, written by Coelli (1996), in which the variance parameters are expressed in terms of

(3) $\sigma^2_s \equiv \sigma^2 + \sigma^2_v$ and

(4) $\gamma \equiv \sigma^2/\sigma^2_s$.

Tests of hypotheses of interest are obtained using the generalised likelihood-ratio statistic defined by

(5) $LR = -2\{\ln[L(H_0)/L(H_1)]\}$

where $L(H_0)$ and $L(H_1)$ are the values of the likelihood function under the null and alternative hypotheses, H_0 and H_1, respectively. The generalised likelihood-ratio statistic is assumed to have asymptotic chi-square distribution (mixed chi-square) if the appropriate null hypothesis, H_0, is true. To perform these tests the stochastic frontier function under the null, H_0, is estimated by imposing the appropriate restrictions before estimating the model. The technical efficiency of the i-th farmer at the t-th year is defined as the ratio of the observed output to the frontier output in which the inefficiency effect is zero. Given the specification of the stochastic frontier model in equation 1, the technical efficiency of the i-th farmer in t-time period is given by

(5) $TE_{it} = \exp(-u_{it})$

Its values lie between zero and one, and are inversely related to the technical inefficiency effect.

Results and Discussions

The maximum-likelihood estimates of the parameters for the Cobb-Douglas frontier production functions for maize farmers within and outside the NEP are given in Table 1

Table 1: Maximum-likelihood Estimates for the Parameters of the Cobb-Douglas Stochastic Frontier Model for Maize Farmers Within and Outside the NEP

Variables	Parameters	ML Estimates[7]	
		Within	Outside
Stochastic Frontier			
Constant	β_0	3.0 (1.1)	-1.14 (0.88)
Land	β_1	0.50 (0.66)	0.27 (0.13)
Labour	β_2	0.02 (0.11)	0.63 (0.16)
Oxen	β_3	0.12 (0.34)	0.030 (0.098)
Other Inputs	β_4	0.08 (0.12)	0.046 (0.033)
Year	β_5	0.02 (0.12)	0.126 (0.055)
Tractor Dummy	β_T	-0.09 (0.22)	-0.088 (0.079)
Oxen Dummy	β_O	-	0.34 (0.32)
Inefficiency Model			
Constant	δ_0	4.5 (3.3)	-0.27 (0.90)
Education	δ_1	-0.093 (0.017)	-0.100 (0.046)
Extension	δ_2	-0.066 (0.083)	0.002 (0.033)
Experience	δ_3		-0.120 (0.050)
Other Income	δ_4	-0.33 (0.28)	-0.44 (0.23)
Age	δ_5	-0.0010 (0.0016)	0.120 (0.054)
Year	δ_6	-0.09 (0.11)	0.44 (0.15)
Income Dummy	δ_I	-2.2 (1.5)	-2.8 (1.4)
Variance Parameters			
Total of variances	σ^2_s	0.913 (0.018)	0.274 (0.050)
Gamma	γ	0.9999 (0.0029)	0.74 (0.10)
Log-likelihood Function		**62.154**	**-68.404**

[7] Figures in bracket are standard errors of the estimates, corrected to two significant digits.

The estimated coefficients generally have the expected signs. The estimated coefficients of stochastic frontier production functions are positive and measure elasticities of maize production with respect to inputs. The estimated elasticity of land was 0.50 for farmers within the program but it was 0.27 for maize farmers outside the program. This implies that maize output responds more to changes for an additional unite of land within the program than outside the program. The estimated elasticities of labour were 0.02 and 0.63 for maize farmers within and outside the program, respectively. The estimated elasticity of oxen labour was 0.12 for farmers within the program and the corresponding value for farmers outside the program was 0.03. The estimated elasticities of human and oxen labour within the program are statistically insignificant. The rate of technical progress in maize production within the program was 0.02 per cent per annum whereas the corresponding value for farmers outside the program was 0.13 per cent per annum. It is possible that some of the farmer outside the program have adopted the new technologies watching from farmers within the program.

The signs of the coefficients of the explanatory variables for the inefficiency model were also as expected except the variables for extension and year of observation for farmers outside the program. The negative sign for formal schooling shows that farmers with higher levels of schooling tend to have smaller technical inefficiencies in maize production. The estimated coefficient for agricultural extension is negative for farmers within the project but positive for farmers outside the program. This could be due to the fact that those using the extension advice are the ones who really need it. The negative sign for experience and off-farm income means that farmers tend to decrease their technical inefficiencies as they become more experienced and earn off-farm income. Presumably farmers having greater off-farm income might be more efficient as they gain experience because off-farm income might be a proxy for agricultural credit. The negative coefficient for age indicates that older farmers within the program tend to be less inefficient in maize production than younger one but the coefficient is not significant. The negative estimates for the year variable for farmers within the program indicates that they were reducing their technical efficiencies over the three years.

The maximum-likelihood estimate for the variance parameter, γ, for farmers within the project was 0.9999, correct to four digits behind the decimal place, with an estimated standard error of 0.0029, correct to two significant digits. The estimated γ-parameters for farmers within the program indicates that the random errors, v_{it}, are effectively zero, which suggests that the frontier production function for farmers within the program is deterministic rather than stochastic. This result is contrary to what was expected because the random errors and data noise plays a significant role in influencing agricultural production. The tests of hypotheses of interests on estimated stochastic frontier inefficiency model are presented in Table 2.

Table 2: Generalized Likelihood-ratio Tests of Hypotheses for Parameters of the Stochastic Frontier Production Functions for Sample Maize Farmers Within and Outside the NEP in Harari Region

Null hypothesis[8] (H_0)	Log-likelihood Function	Test Statistic	Critical Values	Decision on H_0
H_0: $\beta_{ij} = 0$, $i \leq j$, = 1,...,5 (Cobb-Douglas is adequate)				
Within program	62.16	21.02	25	Accept
Outside program	-68.40	15.95	25	Accept
H_0: $\beta_5 = 0$ (no technical change)				
Within program	56.590	11.13	3.84	Reject
Outside program	-70.328	3.850	3.84	Reject
H_0: $\gamma = \delta_0 = ... = \delta_6 = 0$ (no inefficiency effects)				
Within program	-17.273	158.86	14.85	Reject
H_0: $\gamma = \delta_0 = ... = \delta_7 = 0$ (no inefficiency effects)				
Outside program	-77.300	17.790	16.27	Reject
H_0: $\delta_1 = ... = \delta_6 = 0$ (z-variables not useful)				
Within program	-3.800	116.71	12.60	Reject
H_0: $\delta_1 .... \delta_7 = 0$ (z-variables not useful)				
Outside program	-75.010	13.22	14.07	Accept
H_0: $\delta_1 = 0$ (no schooling effect)				
Within program	44.320	35.67	3.84	Reject
Outside program	-70.20	3.58	3.84	Accept
H_0: $\delta_2 = 0$ (no extension effect)				
Within program	33.40	57.520	3.84	Reject
Outside program	-68.89	0.97	3.84	Accept
H_0: $\delta_6 = 0$ (no inefficiency changes over time)				
Within program	57.59	9.130	3.84	Reject
Outside program	-69.11	2.07	3.84	Accept

The null hypothesis, which specifies that the explanatory variables, education, extension, experience, other income, age and year of observation have no effect on the levels of the

[8] For the first null hypothesis, it is assumed that the alternative hypothesis is that the translog stochastic frontier applies. Because the Cobb-Douglas frontier production function is accepted as an adequate representation of the data

technical inefficiencies of maize production, are rejected for farmers within the program. The null hypotheses, H_0: $\delta_1 = 0$, and H_0: $\delta_2 = 0$, that the levels of formal education of farmers and extension advice to farmers (individually) had no effect on the technical inefficiencies was rejected for farmers within the program, but it is accepted for farmers outside the program.

The null hypothesis, H_0: $\delta_6 = 0$, which specifies the technical inefficiency effects are time-invariant or the maize farmers did not improve their technical inefficiencies over time, is rejected for maize farmers within the program. The technical efficiencies of sampled maize farmers were predicted using the equation expressed on 6 above and for the years of observations in the sampled years. The mean technical efficiency of farmers within the project was 0.74 and it was 0.73 for farmers outside the project. Individual technical efficiencies were as small as 0.50 and as large as 0.88 for farmers within the project and it was as small as 0.30 and as large as 0.99 for farmers outside the project.

The percentages of sample maize farmers within and outside the program with the technical efficiencies in the decile ranges are shown in Figure 1 and 2. The technical efficiencies of individual maize farmers fluctuated over the three years. The technical efficiency of a most maize farmers in 1995/96 and in 1996/97 was between 0.80 and 0.90 However, in any particular year on average 25 per cent of maize farmers within the program and only three per cent of maize farmers outside the program had technical efficiencies greater than 0.90. About 45 per cent of sample maize farmers within and 40 per cent of those outside the program had technical efficiencies between 0.70 and 0.80 and the remaining percentages of sample maize farmers in both groups had technical efficiencies less than 0.70.

(in the first test of hypotheses) then subsequent null hypotheses are tested assuming that the Cobb-Douglas model applies.

Figure 1: Percentage of Sample Maize Farmers Within the NEP with Technical Efficiencies in Decile Ranges for Three Years of Observation

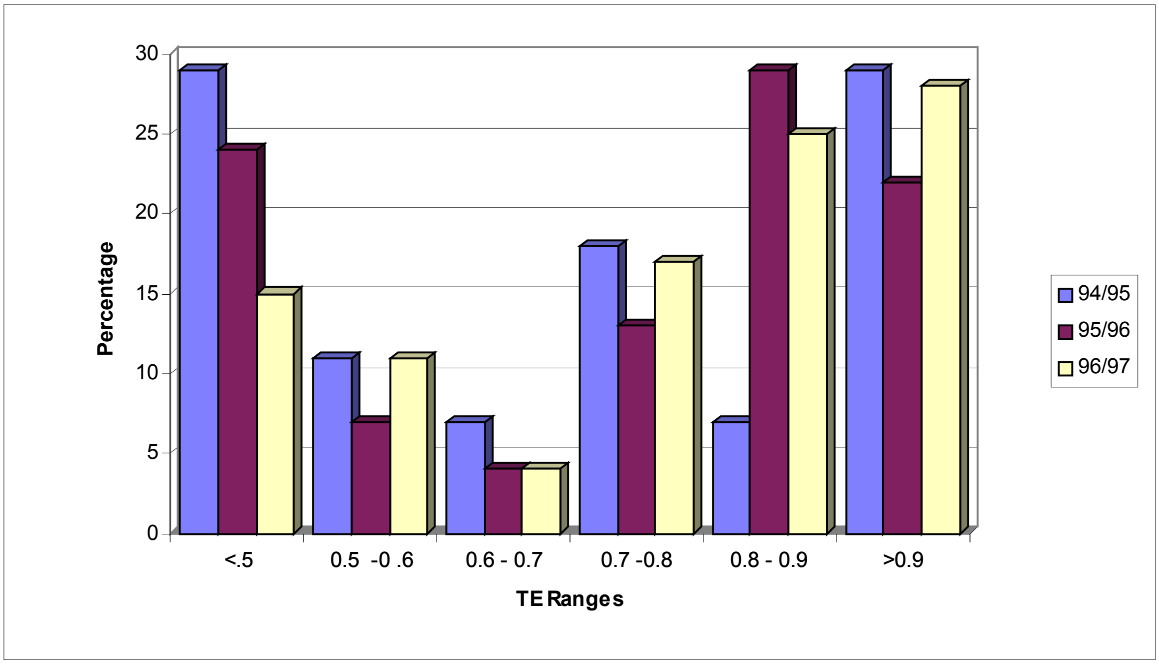
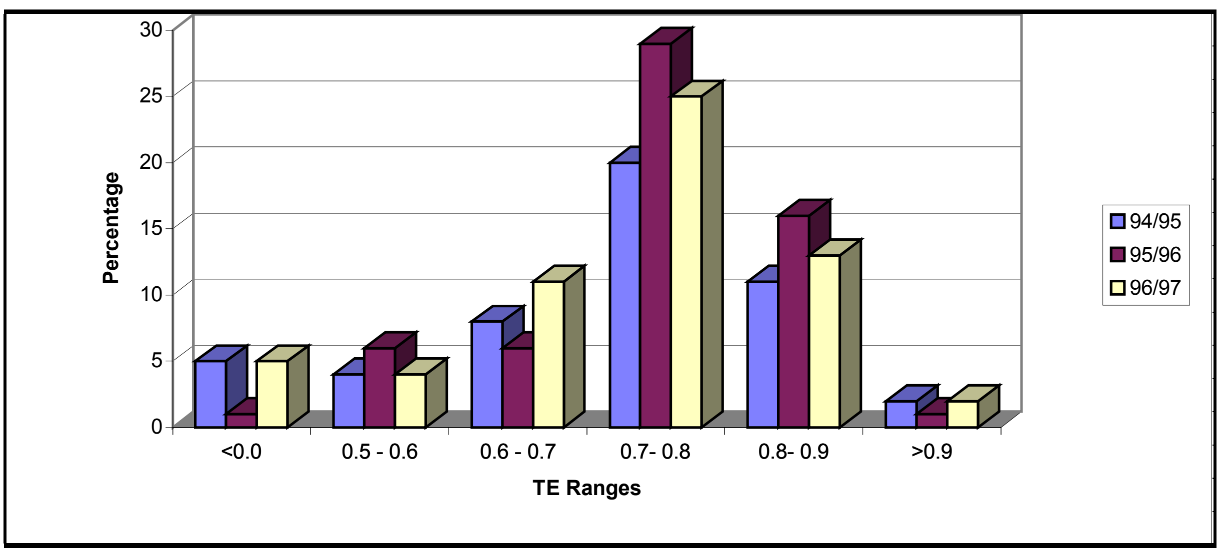


Figure 2: Percentage of Sample Maize Farmers Outside the NEP with Technical Efficiencies in Decile Ranges for the Three Years of Observation



Policy Implications

Over half of a century government efforts aimed at stimulating the productivity of Ethiopian agriculture have emphasized the adoption of modern agricultural technologies. In the process agricultural extension has played a major role in extending the new agricultural technologies to farmers. Other farmer specific variables such as the formal education, off-farm income and farming experience of maize farmers were given less emphasis in the planning and implementation processes of the agricultural intensification programs because of insufficient resources to address multiple problems on an integrated approach. The policy dilemma has always been whether the government is willing to channel limited resources on specific farmers to gain the advantage of increased productivity or to direct resources for extending the new maize technologies to other farmers. Past experiences showed that the former discriminated against the majority of farmers outside the programs and yet the later approach diffused resources rendering the initiatives to the highest degree ineffective and so far the balance between the two options has not been identified. Therefore, agricultural development planners need to look for effective policies that provide other means of relieving resource constraints and improving the efficiencies of maize farmers in the Harari Region of Ethiopia.

Conclusions

In this study it is showed that although there were positive technical changes and changes to technical inefficiencies over time for maize farmers within the New Extension Program, there were significant levels of technical inefficiencies of maize farmers in both groups in Harari Region. The mean technical efficiencies of both groups of farmers were about 73 per cent, but the technical efficiencies are not directly comparable because the two technologies are not the same. Agricultural extension advice, formal schooling, off-farm income and age of maize farmer were important factors affecting the technical inefficiencies of maize farmers within the program. Therefore, agricultural policy makers need to look for alternative means of strengthening the social and economic basis of maize farmers in order to address resource constraints and low productivity in maize production in the Harari Region of Ethiopia.

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