PRODUCTIVITY AND EFFICIENCY OF AGRICULTURAL EXTENSION PACKAGE IN ETHIOPIA

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Abstract

In an objective to assess the impact of extension package program on productivity and efficiency of Ethiopian agriculture, the study used data collected in 2001 by the Ethiopian Development Research Institute (EDRI). The estimated total factor productivity using Tornqvist total factor productivity index shows that the total factor productivity of maize, teff and wheat extension farmers on average exceed that of non-extension while there are no clearly discernable differences in efficiency. Determinants of both total factor productivity and technical efficiency are identified. Most importantly, the role of agro-ecologies in influencing both total factor productivity and efficiency is significant, implying the need for considering agro-ecology differences in introducing extension package technologies.

1. Introduction

1.1. Background

It is always claimed that Agriculture remained to be the mainstay of Ethiopian economy despite the dismal performance of the sector. Various factors were held responsible for poor performance, despite the attempts were made to modernize it. In an effort to change the living standard of the population and to transform agriculture, the government declared the Agricultural Development Led Industrialization (ADLI) in 1993, recognizing the country's economic problem is deep rooted in agriculture. The measure is expected to improve the manufacturing sector simultaneously.

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One of the major public programs in Ethiopian agriculture is the extension package that provides modern agricultural technologies and intensifies agricultural productivity. The major outcome of the *free market economy* after 1991 is Ethiopian peasants can produce from their holdings and sell at the price they choose. Despite the introduction of new technologies in the 1970s and 1980s, the fact that farmers were discouraged to market their output freely constrained output and productivity. Todaro and Stephen (2003) indicated that technology in agriculture might not attain its target goal unless the land tenure, social, institutional, cultural and commercial, etc grounds are appropriate. In this regard, the objective of the extension package is given the land tenure, institutional and commercial grounds, it is possible to provide and direct the farmers with the appropriate technology and skill so that the level of productivity will rise and bring better income. Otherwise food self-sufficiency is difficult to achieve both in the long and short-term. Given an irreversible trend of declining size of cultivated land, the only feasible way to raise production is to increase land productivity if China doesn't want to rely on large-scale imports to feed her huge and still growing population (Yao and Liu, 1998). Similarly, due to land shortage, cropping systems in Africa is in transition from farm abundant to land constrained (Reardon et al 1996). Evidences, therefore, suggest the need for rising productivity and the adoption of various alternative strategies.

Since 1995/96-cropping season when PADETS became operational, fertilizer and improved seeds have witnessed widespread and increasing rates of adoption, despite the removal of all input subsidy since 1997/98. Between 1995 and 1999, the consumption of fertilizer increased from 35,272 to 2,168,756 quintals. In the same period, improved seed application rose from 11,043 to 177,783 quintals. The number of participating farmers leaped from 31,256 to 3,731,217 covering nearly 40% of the farming population. The value of credit, which began at 8.1 million, has reached 150.2 million. Demonstration plots in the fields of farmers covered by the package rose to at 3,807,658. In terms of its spread in hitherto unknown areas, adoption rates of new varieties and fertilizer, diffusion and increased yield rates resemble green revolution in cereals (Tenkir, et al., 2004).

The coming into the scene of the level of technology has to change the production frontier of farmers. While some indicators of adoption levels have been treated to some extent its effect on the level of productivity has not, however, been sufficiently treated by researchers. This study therefore fills the gap thereby looking into the impact of the technology packages on the productivity and technical efficiency of the farmers.

1.2. Objective of the Study

The study has the following general and specific objectives.

1) To assess the total factor productivity of the performance of extension participating farmers in comparison to non-extension farmers.
2) To estimate the technical efficiency for both extension and non-extension farmers[1] and identify determinants.

2. Conceptual Frameworks

2.1. Total Factor Productivity (TFP)

The economic theory of production has provided the analytical framework for most empirical research on productivity. The cornerstone of the theory is the production function, which postulates a well-defined relationship between output and factor inputs. Productivity can be achieved from two sources; first, through technological change of using improved practices of production such as ploughs, fertilizers, pesticides, improved seeds, etc which pushes the production frontier upward; and second, if the farmer has got further skills in using the existing techniques of production, productivity will increase.

Measuring productivity is conceptually better understood when total factor productivity (TFP) is measured empirically. Total factor productivity is the ratio of aggregate outputs to aggregate inputs. Some studies use interspatial measures of total factor productivity based on *Divisia Index* as defined by Denny and Fuss (1983), where efficiency is estimated for different kinds of land contracts. The TFP approach is found to be suitable for cases where the complexity and diversity of smallholder farming, like in Ethiopia, is large; it also makes comparison possible among different farming systems. The superiority of the method of TFP over the conventional method of measuring land and labor productivity emerges from the fact that the later is misleading if there is high substitutability between inputs (Gavian and Ehui, 1996). Within the TFP methods, there are different kinds of measurements that need to be seen from various methodological perspectives.

[1]Technical efficiency is the ability of a firm to obtain maximal output from a given set of inputs while alocative efficiency is the ability of a firm to use inputs in optimal proportions, given their respective prices (Coelli, 1995).

Most of the empirical literature focused on productivity of individual factor productivities in Africa such as labor and land productivities and some of those studies got strong evidence that fertilizer and improved seeds are associated with higher yields; and considerable yield variability across fields within a given technology type (Howard et al, 1999). Reardon et al 1996, for instance, discussed returns per labor day and output per hectare of wheat maize and soybeans are generally low for some African countries and the yields differ by crop, zone, technology and farm size; determinants of productivity according to this evidence are many.[2] Moreover, they indicated that policy reform (exchange rate, interest rate and market liberalization) is necessary but not a sufficient condition to spur productivity.

Another study in Ethiopia found that tenure difference in terms of “rented-in” and “owned” has significant effect on sorghum and wheat output while there is no significant impact on teff and maize output (Abebe and Negussie, 2005). The same study revealed that at regional level land fragmentation (number of parcels) and land conservation has positive relationship with the sample crops yields, remarking a possible difference at zonal level in the case of land fragmentation. An empirical study using discriminant analysis of participants and non-participants in extension package program in Oromia region indicates that the yields of maize and wheat from plots of National Extension Package participants as compared to non-participants in the study area is found to be as high as 50% for maize and 39% for wheat compared to yields of the same crops from the non- participant farmers, with insignificant difference for teff and sorghum (Samia and Habekirstos, 2005). However, most of those studies conducted in Ethiopia, have focused on the technical efficiency, and not so much focused on factor productivity which requires employing the Tornqvist quantity index-, one of the indexes of measurement of TFP as, shown below:

Tornqvist quantity index:

Q_{st}= $\prod_{i=1}^{N}\left[\frac{q_{it}}{P_{it}}\right]^{\frac{\omega_{is}+\omega_{it}}{2}}$ **, is the Tornqvist quantity index where:**

$\bar{\omega}_i$ = arithmetic mean of output shares;

[2]Major important ones are fertilizer, seed, animal traction, organic inputs and conservation investments, farm size and land tenure, non-cropping income (including credit), land preparation efforts and well-functioning input and output markets.

$\bar{\upsilon}_j$ = arithmetic mean of input shares; P_{it} and Q_{it} are price and quantity of commodity **i** at time **t** respectively.
The estimated value of the index tells us the direction of change of TFP (Colelli, et al 1998). In this study, after estimating the TFP, we will run linear regression model to identify factors influencing TFP; as in many studies in Ethiopian agriculture (Gezahegn, 2002).

2.2. Technical Efficiency

In estimating the frontier, we use the model derived by Battese and Coelli (1995):

$$\mathbf{Y_i = F(X_i; \beta) + \varepsilon_i;\ \varepsilon_i = V_i - U_i;\ where\ U_i \geq 0}$$

Where, Y_i: output of the farm i=1,2,…N
F (…): is the production technology
X is vector of N inputs
β is vector of unknown parameter to be estimated
ε_i is the error term with two components of:
V_i : is non-negative error term(due to the decision or action of the farmer);
U_i: the technical inefficiency component (factors out of control of the farmer / decision maker.
$U_i = \sum\delta Z_i + \omega_i$, $U_i \geq 0$; where Z_i factors affecting the technical efficiency of the farm and δ is parameter.

The symmetric random error Vi accounts for random variations in output because of factors, such as, measurement error, exogenous shocks; etc, which is not under the control of the farmer and it is assumed to be independently and identically distributed as N $(0,\sigma^2_{vi})$. Moreover, the asymmetric non-negative random error, U_i measures technical inefficiency relative to the Stochastic Frontier and is assumed to be independently and identically distributed non-negative truncations (at zero from below) of the N (μ, σ^2_{ui}) distribution. The variance parameter of the model is parameterized as:

$$\sigma^2_\varepsilon = \sigma^2_u + \sigma^2_v \quad \textbf{and } \gamma = \sigma^2_u / \sigma^2_u;\ \mathbf{0<\gamma<1:}$$

$\tilde{y} = y_i - u_i = f(x_{i;}\ \beta) - v_i$, after finding the estimates of u_i and $v_{i;}$

Where,

$\tilde{y}$: is the observed output of the i^{th} farm household adjusted for the stochastic random noise captured by $u_{i;}$ this equation is used to derive the technically efficient input vector and to derive algebraically.

The model we use matters in measuring the efficiency of firms (Liu, 2005). There are two common functional specifications the Cobb-Douglas stochastic frontier and the translog. Cobb-Douglas production function is criticized for its rigidity flexible despite the multi-colinearity problem. The functional form of the stochastic frontier is determined by testing. Thus, the frontier models estimated are defined as:

$$y_{it} = \beta_o + \sum_{j=1}^{n} \beta_i X_i + V_{it} - U_{it} \qquad \text{(Cobb-Douglas) ; and}$$

$$y_{it} = \beta_o + \sum_{i=1}^{p} \beta_i X_i + \sum_{j=1}^{p} \sum_{i=1}^{p} \beta_{jh} X_i X_{hj} + V_{it} - U_{it} \quad \text{(Translog)}$$

We select the appropriate model specification through tests. Wald tests are commonly used to test the null hypothesis of no inefficiency, i.e., that the variance of the one-sided process is zero. However, additional Monte Carlo experiments show that the size properties of this test are very weak (STATA, 2003). The estimation of truncated-normal distribution stochastic frontier model and the log likelihood test makes continuous iteration and attaches the maximized iteration, which is used to calculate the log likelihood statistics. The likelihood-ratio test statistic λ = -2{log [Likelihood (H_o)]– log [Likelihood (H_1)]} has approximately a χ_q^2 distribution with q equal to the number of parameters assumed to be zero in the null hypothesis; it is compared with the critical values of the χ_q^2 _distribution and decided between the two models. The power of the LR test is increased by testing jointly the null hypothesis that γ = δi =0, for all i, meaning that neither the constant term nor the inefficiency effects are present in the model; since γ takes values between 0 and 1, any LR test involving a null hypothesis which includes the restriction that γ = 0 has been shown to have a mixed χ^2 distribution, with appropriate critical values (Kodde and Palm, 1986) quoted in Piesse, et al (2002).

The technical inefficiency effect term is distributed N (μ_i, σ^2_v) where μ_i can be specified and defined as:

$\mu_i = \beta o + \sum_{j=1}^{n} \delta_o Z_{ij}$; where Z_j are socioeconomic and infrastructure variables which are identified in the literature or taken from the observation of the researcher.

The estimation of the inefficiency model has two approaches. The first is simultaneous equation modeling (Battese and Colelli, 1995) and the two-stage modeling (discussed above). The advantage of the simultaneous equation technique over the two stages is that it incorporates farm specific factors in the estimation of the production frontier because those factors may have a direct impact on efficiency (Wadud, 2002). The estimates for u_i and v_i are found from the SF model and the technical efficiency predictors by replacing parameter by their maximum likelihood estimates. We use the maximum likelihood estimation to identify the determinants, considering the choice of model is controversial (Batsse and Colelli, 1995).

3. Analysis

3.1. The Data Set

For this study, the May 2001/02 survey data generated by EDRI was combined with the survey data collected during the same period by the Central Statistical Authority's (CSA) on Ethiopian Agricultural Sample Enumeration extension package data, mainly overlaid for the yield data[3] employed in the analysis.

The sampling method used is multistage sampling, involving a random selection of farm households at some stage in the order of zones selected purposively from the four major regions of the country, which represents over 85% of the population. Two woredas were selected from each zones purposively depending on the level of adoption of modern input technology. Within the woredas, PAs were selected through systematic sampling, and then farm households are selected randomly from sampled households. As the objective of this study is to estimate Total Factor Productivity (TFP) and Technical Efficiency (TE), we included the sample drawn for each crop cut

[3] The yield data from CSA is based on a more accurate measure of yield index using crop-cut samples.

samples from the national sample of 1921 farm households (Agricultural Extension Survey of EDRI of the 2001/02); until we exhausted complete data set on the variables which enabled us to estimate TFP differential between extension and non-extension farmers *(Tornquvist index)*, continuously matching the sample size and finally for each crop i.e. 115 for maize, 56 for wheat and 112 for teff. For technical efficiency estimation, however, the sample size is relatively larger i.e. 186 for maize & 244 for teff because of non-matching sample size requirement for efficiency estimation unlike TFP estimation.

3.2. Data Analysis

3.2.1. Descriptive Analysis

Table 3.1 depicts the socioeconomic characteristics of sampled households. Household size has no significant effect between extension and non-extension farmers, though higher mean for extension farmers was observed in case of wheat and teff, which are relatively more labor and technology intensive commodities. The number of livestock the households own has mixed features; first, for maize and wheat farmers, the average number of livestock is higher for adopters, which may show the need for higher wealth income to purchase the input packages. On the other hand, the number of livestock in case of teff is higher for non-extension farmers, but outliers affect (standard deviation is 12.10 for Extension farmers compared to 35.44 to that of non-extension farmers). The higher mean livestock ownership in some cases implies there is disincentive to adopt modern technologies.

Form the table one can infer the following important features; first, the proportion of female household head for the crops producers for the largest sample size (maize and teff) is higher in the non-extensions (15% for maize and 13% for teff) against 9% and 12% for extension farmers respectively. The implication is there are less number of females participants in extension than male counter part. The national average rate of female participants for all crops in the extensions and non-extension farmers stands close to 8.4% and 12% respectively. In the sample, the proportion of illiterate farmers is about 56%, 47% and 56% for maize, wheat and teff extensions respectively while it is 73%, 80% and 67% for non-extension farmers of the same crops. This shows that less number of extension farmers are illiterate which is true for more of non- extension farm households. This reflects that there is an overall tendency for educated farmers to adopt new technologies, which is consistent with the findings of previous studies (EDRI, 2004). Demographically, most of the farm households included in the sample are followers of orthodox Christian religion (average of 65% for all crops); which is nearly twice the national average figure in the national sample (i.e. 31.5%).

Table 3.1: Extension and Non-extension Farmers: Quantitative Variables

Corp/variable	Extension			Non-extension farmers		
Maize (Maximum N=115)	**Mean**	**SD**	**Median**	**Mean**	**SD**	**Median**
Age of Head	41.94	14.33	40.00	44.00	14.00	40.00
Household size	6.28	2.17	6.00	6.0	2.00	6.00
No of Male	3.50	1.93	3.00	3.00	1.00	3.00
No of Female	2.97	1.66	3.00	3.00	1.00	3.00
No of livestock	5.44	4.68	4.00	4.48	3.48	3.00
Wheat (Maximum N= 55)						
Age of Head	43.21	13.89	44.00	45.64	16.72	43.00
Household size	5.75	2.09	6.00	5.32	1.65	5.50
No of Male	3.14	1.53	3.00	3.00	1.29	3.00
No of Female	2.63	1.45	2.00	2.32	1.11	2.00
No of livestock	5.40	4.17	5.00	4.33	3.00	3.07
Teff (Maximum N=112)						
Age of Head	**47.0**	**13.00**	45.00	45.00	14.00	46.00
Household size	6.00	2.00	6.00	5.00	2.00	5.00
No of Male	3.00	2.00	3.00	3.00	2.00	3.00
No of Female	3.00	1.00	3.00	3.00	1.00	2.00
No. of livestock	8.51	15.19	6.00	12.50	5.09	5.00

Source: Own Summary from Extension Data

Table 3.2: Extension and Non-extension farmers: Qualitative Socioeconomic Variables

Crop/variable	Adopters		Non-extension farmers	
Maize (N= 115)	**Sample Highest Share**	**Sample Lowest shares**	**Sample Highest Share**	**Sample Lowest shares**
Sex of Head (1=M **and**2=F)	M=106 (92%)	F=9 (8%)	M=96(83.5%)	F=28(16.5%)
Marital Status[3]	1=107(93%)	3=5,4=1,5=1	1=94(82)	All others=21
Religion[4]	1=57 (50%)	2=35, 4=20, 3=2	1=42(37%)	2=40;3=1;4=32
Education of Head[5]	1=61(50%)	2=13,3=17,4=24	1=83(72%)	2=6;3=19;4=7
Means of livelihood[6]	Farming=114	Education =1	Farming=115	Education =0
Wheat (N=56)				
Sex of Head	M=54(96%)	F=2(4%)	M=54(96%)	F=2(4%)
Marital Status	1=54(96%)	5=1;6=1	1=50	2=1;3=2;4=2;5=1
Religion	1=31(55%)	2=25	1=34	2=21;3=1
Education of Head	1=29(52%)	2=14;3=9;4=4	1=43	2=7;3=4;4=2
Means of livelihood	Farming=56	-	Farming=56	-
Teff (N=112)				
Sex of Head	100(89%)	F=12(11%)	M=96(87%)	F=16(14%)
Marital Status	1=101(90%)	3=5; all others 6	1=92(82)	3=10; all others=12
Religion	1=88(79%)	2=14,3=4;4=4;	1=79(71)	2=22;4=11
Education of Head	1=66(59%)	2=17;3=18;4=11	1=78(70)	2=12;3=15;4=7
Means of livelihood	Farming=110	2=1; 6=1	Farming=111	3=1

Source: Own Summary from Extension Data

3.2.1.1. Maize

The average land size allocated for maize by adopters' is about 0.37 ha (max: 2.0 and a min: 0.06 ha). In comparison, the average land size of the non-extension farmers is 0.34 ha ranging within a maximum of 1.5 ha and a minimum of 0.12 ha (Table 3.3).

[3] 1 =Married; 2= Unmarried; 3= Widow; 4= Widower; 5= Divorced; 6= Migrant HH; 7= other 8=unknown
[4] 1=orthodox; 2=Muslim; 3=Catholic; 4= Protestant
[5] 1= Illiterate; 2= Grade 1-6; 3= Grade 7-12; 4= above grade 12
[6] 1= trade; 2= education; 3=hired out labour; 4= living with relative; 6=others

Table 3.3: Input Usage by Sample Maize Extension and Non-extension Farmers

Item		Extension					Non-extension				
		N	Min	Max	Mean	Std	N	Min	Max	Mean	Std
Land Size		115	0.06	4.0	0.46	0.5	115	0.12	1.50	0.34	0.2
Total Urea and DAP (Kg)		115	4.00	400	71.82	65.5	115	0	0	0	0
Improved Plus Local Seed	Total	88[7]	0.25	50.0	9.0	7.4	115	0.25	90.00	8.9	6.8
	Only Selected seed	71(62%)	0.25	50	8.4	8.3	115	0	0	0	0
	Only Local seed	28	5	19	6.9	4.2	115	0.25	90.00	8.9	6.8
	Both (sum) users	11	5	27.5	15.9	7.1	115	0	0	0	0
Natural Fertilizer (Kg)		18	0.50	200	93.7	67.6	1	2.00	2.00	2	0
Chemical Expenditures		46	10.00	78	13.7	19.9	115	0	0	0	0
Receive Advice Offered?		Y=65, n=14	-	-	-	-	Y=14	-	-	-	-
Total No of OXEN		115	0.00	5	1.51	1.16	115	1.00	5.00	1.11	0.7
Total *OTD*s		115	0.74	64	11.6	11.0	115	0.75	38.00	8.9	6.8
Labor in man-days		115	2.00	228	48.8	42.0	115	3.50	113.75	34.06	22.4

Source: Own computation from Extension Data

There is variation in terms of fertilizer use among extensions. It varies with a maximum of 400 and a minimum of 4 kg, with an average of 71.8 kg per land holding. Among the adopters, there are 18 (only 15.6%) who utilize natural fertilizers in addition to the artificial ones. When we see the seed input-use by the sample extension maize producers 71(61%) responded to have used improved seed, 65(24%) of them use only local seeds 9.5% of them use a mixture of both types of seeds. Obviously, the non-extension maize producers use local maize seeds. It is believed that farmers use chemicals for pesticides, weeds, etc; however, in the sample there are 46(40%) extensions and no non-extension farmers using chemicals in maize production. The other component is advises and follow-up offered by the local extension agents on inputs, cultural practices, chemicals and others. To the question asked on whether the adopter is getting advice offered with respect to all crops, 65 extension farmers (56.5%) responded to have used input/advice and advice on cultural and other practices while 50(43%) of them didn't receive any extension service advice. This is similar for all of the three crops extension adopters, but varies for the non-extension farmers (10%, 21% and 16 % for maize, teff and wheat non-extensions).

[7] The remaining are reported as missing data

The traditional crop production involves use of draught power input of oxen. In this regard, the number of oxen the farmers own affects their production. In the maize sample respondent extension and non-extension, 49 among N=78 (63%) and 37 among N=84 of them (44%) have two or more oxen respectively. The larger percentage of more than two oxen extension farmers owners as compared to non-extension consistent with the sample size of 186. This shows that more extension participating farmers have the required number of oxen for land ploughing and adopting technologies compared to the non-extension farmers. The number of farmers with no oxen ownership is also greater for the non-extension 46(40%) than that of Extension 37(32%) farm households. In terms of the total Oxen-Timad-Days (*OTD)*[♣] used, for extension and the non-extensions the mean is 11.6 (*min: 0.74 and max: 64)* and *8.9 (min: 0.75 and max: 38)* respectively, which depicts that more intensive land cultivation requirement for extensions participants for higher oxen day requirement than the non-extension farmers. The characteristics of labor input indicates similar trend. The average labor input for extension farmers is 48.8 in adult equivalent (AE) which lies within a range of 2.0 to 289 man-days while for the non-extension the mean is 30.9 in the range of 3.5 to 113.8 man-days, which remarks the need for higher labor input in adopting modern technologies.

Two more variables included in this descriptive analysis are the credit and market access. Theoretically it is believed that better access to market motivates farmers to be more productive and efficient. Among the 115 non-extension maize farmers, 5 (4%) use all, 19 (17%) use primary and secondary while 91(79%) use only primary maize markets, which is lower market visit than the case of non-extension. The non-extensions farmers on average attend less number of markets (primary, secondary and tertiary), but more frequently than the extension. Most of the non-adopter maize farmers use the primary market with the average attendance frequency of 1.4. On average, extensions attend primary, secondary and tertiary markets at a rate of 1.44, 1.36 and 1.39 times per week; while the non-extensions do 1.44, 2.10 and 1.46 per week respectively (Table 3.4), implying that the non-extensions give more emphasis to frequently visiting local markets than that of extensions, which requires further research if there is systematic relationship between labor scarcity in agriculture and market attendance and as to why the choice difference in attendance frequency arise.

♣ Oxen-timad-days: is the number of days of ploghing by a farmer using pair of oxen i.e. '*timad'*.

With a larger sample size of 186 maize extensions (non-matching sample), only 23(12%) of them use all primary, secondary and tertiary markets; 75(40%) use primary and secondary markets while 84(45%) use only primary markets[8]. The data shows non-extensions on average go to less number of markets (primary, secondary and tertiary) but more frequently than the extension. Among the 117 non-adopter maize farmers who responded to the question of their maize markets, 4 (3%) use all, 31% use primary and secondary while 66% use only primary maize markets, which is lower market usage than the case of adopters. Most of the non- extension maize farmers use the primary market and the average maize market attendance frequency is 1.4.

Table 3.4. Markets, average Distance and Frequency of Attendance: MAIZE

	Market	Extension	Non-extension
1	Usage[9] (P, S, T)	P=85(74%); S=22(19%); T=5(4%)	P=91(79%); S=19(17%); T=5(4%)
2	Mean Distance	4.6, 9.9 and 11.3 respectively for P, S, T	6.7, 11.7 and 9.9 respectively for P, S, T
3	Mean attending Freq. per week	1.44, 1.36 and 1.39 respectively for P, S, T	1.44, 2.10 and 1.46 respectively for P, S, T

In extension package program the role of credit is very important to integrate the input market and technology adoption. The 115 maize extension response shows that the farmers are more credit users than the non-extensions farmers nearly for all crops. Among 98 extensions that responded to the question of finance on input financing, 39(40%) farmers get access to credit to finance their maize inputs (fertilizers and/or seed), 48(49%) use their own income to purchase inputs. Here, most of the farmers tend to borrow for financing fertilizer (on average 66%) as compared to financing seed (52%), due to the possibility of using local seed instead of improved seed. A related point is the way assessment is made to access credit. The response of the farmers shows that out of the farmers receiving credit, the Development Agents assesses the majority (on average 74% of the extensions), the Peasant Association assess 14%, the input committee 2%, woreda 4% and others assess 7%. The two most important constraints for adopting technologies are the availability and access to improved seed and fertilizer inputs. The availability of improved seed is less accessible to non-extension farmers.

[8] Note that the nearest market to the residence of the farmer secondary is the second nearest and tertiary is the third nearest but can be largest central market in the district.

[9] P= primary, S= secondary, and T=tertiary

3.2.1.2. Teff

Teff is the most widely adapted crop compared to any other cereal or pulse crop in the country and can be grown under wider agro-ecologies (variable rainfall, temperature and soil conditions. The sample size of each of extension and non-extension is 112. The average land size allocated is 0.67 ha (max: 3.0 and min: 0.06ha), which is relatively higher variation compared to that of maize. Similar to the case of maize, the average land size is larger for extension compared to that of non-extension, which is 0.51 (max: 2.5 and min: 0.06 ha). The fertilizer input in teff varies from 0.25 to 225 kg, with a mean of 62.3 kg. The mean is lower than the case of maize, but there is higher standard deviation in maize (Table 3.5); maize in general responds better to fertilizer than other crops. The higher the fertilizer input utilized is the larger will be the return i.e. increasing returns to scale, whereas teff has some limit to fertilizer application; this is consistent to earlier findings (Hailemariam et al, 2006).

The numbers of extension that are using improved seed are only 7(6%); this seems very low compared to that of maize (62%) and wheat (18%). The low level of adoption of selected seed in teff is due the lack of good quality selected seed; teff varieties run out quickly due to mechanical contamination (Mulat, 1999). Teff is usually less susceptible to diseases compared to other cereals and as a result fewer chemicals are used; except the need for herbicide chemicals application to protect weed. Extensions use chemicals (27% of them) unlike all of the non-extensions (Table 3.5). The total number of oxen owned by teff extension farm households varies from 0 to 5, with average of 1.9 oxen. About 68% of them have 2 or more oxen; this figure is larger compared to the total number of extension farmers included in the national sample i.e. (22%) but close to some village level survey outputs (Holden, 2004) that is equal to 57%. Extensions with no ox are only 6.3%, which is very low compared to the case of maize (32.2%) and 16% to wheat extensions farm households. Except for teff, the range of no oxen is not significantly different from that of non-extension, which is 27% for maize, 20.5% for teff (but for teff this is 6.3%, is not significant and 28.6% for wheat. We compare the oxen Timad Days (*OTD)* and labor man-days - the mean in all crops is greater for extension than that of non-extensions (refers to Tables 3.3, 3.5 and 3.6 in estimating the two factors of production in total factor productivity and efficiency parameters.

Table 3.5: Input Usage by Sample Teff Extensions and Non- Extensions Farmers

Item		Extensions					Non-extensions				
Maize		N	Min	Max	Mean	Std	N	Min	Max	Mean	Std
Land Size		112	.06	2.75	0.64	0.4	112	0.06	2.50	0.6	0.42
Total Urea and DAP (Kg)		112	2.68	200.00	55.6	34.0	0	-	-	-	-
Selected and Local Seed	Total	112	2.00	150	31.1	27.2	112	0.16	160.0	29.0	25.7
	Only Selected seed	7	6	25	14.4	5.8	0	-	-	-	-
	Only Local seed	105	2	150	32.2	27.7	112	0.16	160.0	29.0	25.7
	Both SS+LS users	0	-	-	-	-	0	-	-	-	-
Natural Fertilizer (Kg)		4	10	100	46	39	0	-	-	-	-
Chemical Expenditure (birr)		30	3.00	120.00	37.4	25.7	0	-	-	-	-
Receive Advice Offered?		Y=59,no=11		-	-	-	47	-	-	-	-
Total No. of OXEN		112	.00	5.00	1.9	0.71	112	0.00	5.00	1.60	0.67
Total *OTD*s		112	1.75	161.6	24.6	22.5	112	2.0	60.00	19.5	15.0
Labor in man-days		112	6.55	192.0	62.3	42.7	112	5.1	193.0	56.1	43.2

Source: CSA 2001, Extension Data

3.2.1.3. Wheat

As the sample size for wheat is relatively lower compared to other crops in the sample this needs careful analysis. We need, therefore, to use more supporting descriptive statistics for most of the statistical computations. The average land size for wheat extension and non-extensions stand close to 0.5 and 0.35 ha respectively, which is less than the comparable land size for maize and teff. When we compute this figure using the national data the average wheat land-size is 0.43 and 0.57 for extensions and non-extension farmers respectively; it has higher difference for non-extension farmers due to the fall in the sample proportion of SNNPR that has the highest average land size in national sample[10]. Regarding fertilizer use, the average fertilizer use is 53 kg, (Table 3.6); the average here is below that of both maize and teff. However, this average figure coincides with that of the national average for wheat sample. In terms of the improved seed use, low percentage of extension farmers are using selected seed compared to that of maize. This shows maize technology is the most widely adopted and intensive improved seed applied in the extension system, obviously for its yield advantages and easy management practices.

Table 3.6: Input use by Sample Wheat Extension and Non-Extension Farmers

Item	Extension					Non-extension farmers				
Wheat	N	Min	Max	Mean	Std	N	Min	Max	Mean	Std
Land Size	56	0.08	3.0	0.5	0.44	56	0.08	1.00	0.35	0.18
Total Urea and DAP (Kg)	56	2.00	400	68.5	67.0	56	-	-	-	-
Selected Total	56	300	100	46.9	22.9	56	1.50	150	44.5	33.83
Plus Only improved	9	18	100	45.3	23.5	-	-	-	-	-
Local Only Local Seed	48	3	100	46.3	22.9	56	1.50	150	44.5	33.83
Seed Both imp and LS	1	-	-	-	-	0	-	-	-	-
Natural Fertilizer (Kg)	5	1.00	200	200	200	6	20.00	900	261.67	323.14
Chemical Expenditure (birr)	4	8.0	63	38.6	22.7	0	-	-	-	-
Receive Advice Offered? Yes	35	-	-	-	-	9	-	-	-	-
Total No. of OXEN	56	0.00	4	**1.7**	0.72	56	0.00	4	**1.4**	0.54
Total *OTD*s	56	1.00	40	**11.7**	8.05	56	1.00	53.00	**9.97**	9.75
Labor in man-days	56	3.35	160	**31.3**	23.6	56	6.75	125.45	**29.46**	21.62

Source: Extension Survey Data, 2002

The table shows that about 87% of the wheat growers in the extension are using local seed as compared to 100% in wheat non-extension. This figure is almost comparable to the case of maize non-extension but high localization of improved seed in wheat. Most of the extension (62%) use advice from development agents. The mean oxen ownership in maize extension is higher compared to that of non-extensions (1.7 for extensions vs 1.4 non-extension). This tendency is similar for average OTDs spent on wheat production i.e. 11.7 for extensions (min 3.35 and max 40) and 9.97 OTDs for non-extensions farmers [min one OTD (0.13 ha land size) and max of 53 OTD]. The fact that of extensions is higher than that of non-extensions is clearly seen in the case of maize and wheat. The table also depicts the labor allocation in adult equivalent; the mean labor spent in man-days is 31.3 for extensions and 29.5 man-days for non-extensions, which is also consistent in labor allocation in case of maize and teff.

3.2.2. Estimations

3.2.2.1. Total Factor Productivity

Our estimate for TFP is based on a single output, as the individual extension and non-extension farm households are different for the three crops. This makes the share of output in total output equal to one (or 100%), while the share of quantity of inputs in total value of inputs is calculated for all the three crops. Values of inputs in this case are value of fertilizer, OTD and labor calculated as a share of the value of

[10] During random selection, only one farm-household is included from SNNPR.

each input in the total value of inputs. The *Tornqvist TFP Index, by* its nature described as the output index divided by the input index; the natural logarithm the TFP is, therefore, the difference between the natural logarithm of output index and the natural logarithm of the input index. Both the output and input indices consider quantity of output and quantity of input, except that input for both extension and non-extensions is weighted by the share of the value of each input in the sum of value of all inputs (Colelli, et al 1998).

As the empirical estimated index indicates, in the analysis we took the difference between extension and non-extension output and input usage. When the index value for two households (where one is extension and the other is non-extension) is below 1.0, it implies the TFP falls from extension to non- extension farmer by a percentage equal to the difference multiplied by 100. Similarly, if the estimated TFP is greater than 1.0, the TFP increases from extension to non-extension farmers by some percent (Collie et al 1998). We summarized the estimate of the TFP for maize, teff and wheat in Table 3.7.

Table 3.7: Estimated Total Factor Productivity Difference for Maize, Teff and Wheat [*Tornqvist TFP Index*]

Category	Maize		Teff		Wheat	
Number of ∆TFP < 1.000	74	65%	73	65%	53	96%
Number of ∆TFP > 1.000	34	30%	30	27%	2	4%
Number of ∆TFP = 1.000 (0.95-1.05)	7	6%	9	8%	0	0%
Minimum	*0.101*	-	*0.152*	-	*0.122*	-
Maximum	*1.954*	-	1.914	-	1.602	-
MEAN ∆TFP	*0.801*	-	*0.853*	-	*0.364*	-
Standard Deviation	0.414	-	0.435	-	0.290	-
Sample size	115	99%	112	100%	55	100%

Source: Summarized Estimation

Table 3.7 reveals that on average in 65% of the cases, TFP increases when we move from non-extension to extension maize producers; the opposite happens in 30% of the cases, while there is no difference in TFP between extensions and non-extensions in only 6% of the cases. For maize producers, compared to the other two crops, there is large difference in TFP level between matching cases (farmers from different PAs), perhaps implying there is high technological diffusion in case of maize;

and second, agro-ecological difference largely influences TFP in maize, and this is less visible in the case of teff. However, for wheat, as we can see from the table there is large difference in TFP for the same case (matching and non-matching). This shows either there is less diffusion in wheat or more importantly, fertilizer makes difference in TFP. The later is sound as there is high diffusion in wheat-improved seed with high possible variation in fertilizer application and soil texture.

The estimated result reveals that on average TFP falls from extension to non-extension by 20%, 15% and 60% in matching cases for maize, teff and wheat respectively. This shows in majority of the cases there is a rise in productivity from non-extensions to extensions. Basically, the level and type of input usage and the level of diffusion of technologies between extensions and non-extensions determines the level of difference. Moreover, the output and productivity of maize and wheat, is affected by the difference in an on-farm application of improved seed, while for teff this may not be important as improved seed can have less impact due to high physical contamination of seeds. Fertilizer input, agro-ecology, soil fertility, and other socioeconomic factors can cause the differences. In case of wheat, fertilizer application as major input brings the difference between extensions and non-extensions rather than improved seed (see the descriptive statistics). There are suggestions that a specific level of improved seeds of wheat is required in a specific proportion to fertilizer, which the non-extensions don't have the information to apply in that proportion. We use multiple regressions to identify the TFP determinants of TFP difference.

$$\begin{aligned} TFP_i = {} & \alpha_0 + \alpha_1 LABOR_i + \alpha_2 OXTIMDAYS_i + \alpha_3 QFERT_i + + \alpha_4 QSEED_i + \\ & \alpha_5 LANDSIZE_i + \alpha_6 HHSIZE_i + \alpha_7 NOFEMALE_i + \alpha_8 NOMALE_i + \\ & \alpha_9 DISTPRMKT_i + \alpha_{10} PRICE_i + \alpha_{11} EXTADVS_i + \alpha_{12} NLS_i + \alpha_{13} SEX_i + \\ & \alpha_{14} AGE_i + \alpha_{15} EDUDMY_i + \alpha_{16} RELIGDUMY_i + \alpha_{17} REGIONDMY_i + \\ & \alpha_{18} WOREDDUMY_i + \varepsilon_i \end{aligned}$$

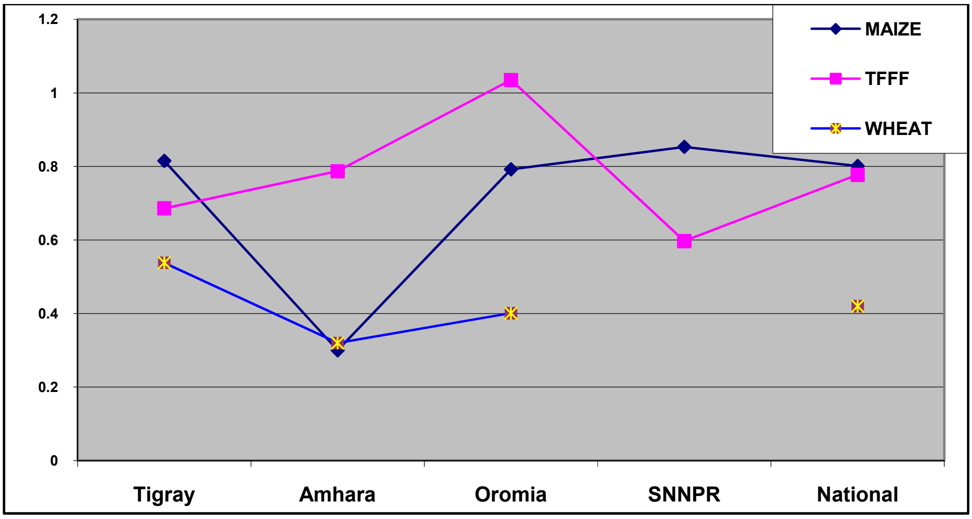
Where, LANDSIZE:Land size; HHSIZE: Household Size; LABOR: Labor in adult equivalent; NULIVSTOK: livestock size; SEX: Sex; DISPRIMKT: Distance from primary market; NUMALE: Number of male; NUFEMALE: Number of female; QSEED: Quantity of seed; QFERT: Quantity of fertilizer; PRICE: output Price; AGE: Age; EXTADVIC: Access to Extension advise; EDUCDUMY: Education Dummy; RELIGDUMY: Religion Dummy; REGDUMY: Region dummy; WORDUMY: Woreda dummy; ε_i: error term, $\varepsilon i \sim N(0,\delta^2)$. Note that the variable assumes its natural logarithm when '*L*' is added to its original name.

We can see the variation of TFP differences among regions (see Table 3.7 and 3.8). Despite the sample size, the high difference between extension and non-extension farmers in mean TFP is observed in wheat production, with an average discrepancy of about 58%. The least variation is in maize production (18% excluding Amhara region) followed by teff (23%). In all crops, most of the TFP of extension farmers exceed that of the non-extension farmers (67%, 79% and 96% of the cases in maize, teff and wheat respectively). Graph 3.1 depicts the level difference among regions.

Table 3.8: Mean TFP Differences between Extension and Non-extension among Regions

CROP	Region:		Mean	%>(Mean=1.0)	N	Std. Dev
	Tigray		0.815		18	0.07
	Amhara		0.300		1	-
MAIZE	Oromia		0.792		68	0.373
	SNNPR		0.853		28	0.379
		Av. Total	0.801	67%	115	0.405
	Tigray		0.686		37	0.397
	Amhara		0.787		16	0.468
TEFF	Oromia		1.035		51	0.397
	SNNPR		0.597		8	0.390
		Av. Total	0.777	79%	112	0.185
	Tigray		0.538		6	0.321
	Amhara		0.320		35	0.236
WHEAT	Oromia		0.401		14	0.376
	SNNPR		-		-	
		Av. Total	0.420	96%	55	0.110

Figure 3.1: Mean Regional TFP: Maize, Teff and Wheat



One problem in comparing the regional difference in TFP is the different sample size among regions. For instance in case of maize, the sample included from Amhara is only one matching household, which fails to be representative for Amhara region. If we ignore such small sample size cases, the comparison of the rest of the regions show that particularly in case of teff the TFP difference between extension and non-extensions tend to be lower in Oromia and Amhara, which is possibly emerging from the suitability of land for teff and beter soil fertility than the case of South and Tigray. In case of maize, there is a s such no big regional difference in TFP differences between extensions and non-extensions, which doesn't necessarily imply the productivity is equal among regions. From the summary table (Table 3.9) we can infer that distance from primary market, per hectare OTDs, age, land size, labor in adult equivalent and the agro-ecology variable region dummy variables are important determinants of TFP differences between extension and non-extension farmers. The other variables are less important.

A study (Howard et al, 1999) revealed that technology (fertilizer and improved seed), environmental factors (soil) and farm management practices (planting time, spacing, frequency of plowing) determine maize yield. The same study found that fertilizer application rate, farmer assessment of soil fertility and soil color, frequency of plowing (negative relationship with teff yield contrary to maize), and farmer's decision on technology choice are determining teff yield.). Household size is influencing wheat and teff, which is consistent with the finding in the descriptive statistics. The number of livestock has mixed role and this is consistent to both the descriptive statistics and the theory. Our descriptive statistics shows that there is discernable relationship between education and technology adoption; however, in the regression analysis it has no significant coefficient. This can possibly be related to the level of threshold in education attainment, which tends to have an impact on productivity.

Table 3.9: Determinants of Total Factor Productivity: Maize, Teff, Wheat (Summary)

Variable	Adopters			Non-extension farmers		
	Maize	Teff	Wheat	Maize	Teff	Wheat
Age	√(-)		√(-)			√(-)
Distance from primary market			√**(+)**	√**(+)**	√**(+)**	
Number of male		√(+)				
Number of female						√(+)
Access to Extension advise	√(-)					
Quantity of seed			√(-)			
Quantity of fertilizer	√(-)		√(-)			
Price of Output		√(-)				
Per hectare *OTD*	√**(-)**	√**(-)**	√**(-)**	√**(+)**	√**(+)**	√**(+)**
Number of livestock	√(-)					√(+)
Land size	√**(+)**	√**(+)**	√**(+)**	√**(-)**	√**(-)**	√**(+)**
Household Size		√(-)	√(+)			
Labor in adult equivalent	√**(-)**	√**(-)**	√**(-)**	√**(+)**	√**+)**	√**(+)**
Total Oxen-timad-days		√**(-)**		√**(+)**	√**(+)**	
Education Dummy				√		
Religion Dummy						√
Region dummy	√			√	√	
Woreda dummy	√	√			√	√

3.2.2.2. Technical Efficiency

For estimation of the technical efficiency, we used the model:

$LnQ= F (LANDSIZE_i , OXTIMDAYS_i, LABOR_i, QFETILIZi, QSEED_i) + U_i -V_i$

Where: LANDSIZE is the plot size; OXTIMDAYS is the number of OTDs spent; LABOR is quantity of labor; QFETILIZ is quantity of fertilizer applied; and QSEED is quantity of seed used; and

$|U_i| = \delta_o + \delta_1 LLANDSIZE_i + \delta_2 LOXTIMDAYSi + \delta_3 LLABOR_i + \delta_4 LQFETILIZ_i + \delta_5 LQSEED_i$, and $V_i \sim N (0, \sigma^2)$

The estimation result of the stochastic frontier model is depicts that the WALD test and the log-likelihood statistics both rejected ***translog*** in favor of ***Cobb-Douglas*** stochastic frontier at 1% level of statistical significance for all estimations (Table 3.10).

Table 3.10: Estimated Technical Efficiency (Normal/truncated-Normal distributions)

Variables (Dependent LQOUTPUT)	Stochastic Frontier Estimation results Truncated											
	Maize				Teff				Wheat			
	Extension		**Non-extension**		**Extension**		Non-extension		**Extension**		Non-extension	
	Coef.	**Z-stat**	Coef.	**Z- stat**	Coef.	**Z- stat**	Coef.	**Z-stat**	Coef.	**Z- stat**	Coef.	**Z**
CONSTANT	2.864	∞	3.178	∞	2.53	∞	2.101	19.61	3.210	∞	2.591	∞
LLABOR	0.179	∞	+0.000	0.01	0.05	2026	0.09	3.55	0.013	113.4	0.322	∞
LOXTIMDAY	0.035	∞	+0.000	0.00	0.14	1432	0.04	1.86	0.002	43.69	0.040	∞
QFERT	0.067	∞	-	-	-0.008	-993	-	-	-0.007	-81.04	-	-
QSEED	-0.085	∞	-0.000	-0.01	-0.02	-∞	-0.012	-1.11	-0.004	-22.11	-0.204	∞
LANDSIZE	0.955	∞	1.000	∞	0.995	∞	0.944	46.05	0.998	∞	0.816	∞
# Observations	186		186		241		241		56		56	
Log-likelihood	-136.58		91.2		103.6		54.4		38.6		-16.7	

Next, the most important test is weather γ=0 or γ=1, the technical efficiency effects are not simply random errors. In other words, we need to test the null hypothesis that there is no inefficiency component. The test result of this estimation, which is based on the z-statistics, shows that except for maize and wheat extension farmers for the rest of the truncated-normal estimations the null is rejected at 1% level of statistical significance while it fails to reject the null in the case of maize and wheat extension farmers (Table 3.11). For maize and wheat extension farmers therefore we resort to estimating the half-normal distribution and in this case the z-test again rejects the null that there is no inefficiency component at 1% level of statistical significance. Based on these two sets of tests outcomes on the distribution of the inefficiency components, we predicted the technical efficiency for extension and non-extension farmers of the three crops and summarized as in Table 3.11.

Table- 3.11: Technical Efficiency Estimated for Maize, Teff and Wheat Extension and Non-Extension Farmers

TECHNICAL EFFICIENCY	MAIZE		TEFF		WHEAT	
	Extension	Non-extension	Extension	Non-extension	Extension	Non-extension
Maximum	1.00	1.00	1.00	0.96	1.00	1.00
Minimum	0.15	0.35	0.47	0.48	0.44	0.18
Mean TE	**0.52**	**0.84**	**0.80**	**0.83**	**0.76**	**0.63**
Standard Deviation	0.28	0.21	0.16	0.12	0.22	0.22
Number of FHH >mean	92	142	158	148	25	24
Number of FHH <mean	94	44	83	91	30	31
Sample size	**186**	**186**	**241**	**239**	**55**	**55**

In this estimation we use a sample size of 186 participating extensions and 186- maize non-extension for maize, 241 each for teff and 56- extension and non-extension each for wheat; totally six different frontiers. We infer from Table 3.11 that in case of maize and wheat the mean technical efficiency of extension farmers is greater than that of non-extension, while this is not true for the technical efficiency in teff. When we compare the technical efficiency in crops, we see that maize has the highest mean (0.80), with 66% of the sample extension farmers producing above the average. The mean technical efficiency of the non-extension farmers for maize is 0.83 and about 148 (61%) non-extension farmers are operating above the mean. Despite the smaller sample size, the mean technical efficiency of extension farmers is higher than that of non-extension farmers. About 62% of the extension farmers have technical efficiency higher than the mean technical efficiency of non-extensions for wheat with only 43% for non-extensions. Therefore, most of the extension farmers are technically more efficient than the non-extension farmers.

We can see the level of inefficiency by region (Table 3.12). The table depicts that in most of the six cases inefficiency declines from South to Northern Ethiopia. This shows the natural environment mostly characterized by agro-ecologies influences efficiency in agriculture.

Table 3.12: Mean Inefficiency of Extension and Non-extension Farmers by Region and crop

Region	Maize				Teff				Wheat				Mean
	Extension		Non-Ext		Extension		Non-Ext		Extension		Non-Ext		
	Mean Ineffi	N	Mean Ineffi	N	Mean Ineffi	N	Mean Ineffi	N	Mean Ineffi	N	Mean Ineffi	N	
Tigray	0.41	11	0.26	47	0.35	47	0.22	63	0.37	11	0.48	5	0.35
Amhara	0.78	80	0.38	5	0.24	67	0.25	70	0.45	19	0.43	34	0.29
Oromia	0.20	68	0.012	94	0.09	57	0.10	94	0.02	19	0.22	14	0.10
SNNPR	0.35	27	0.37	40	0.13	70	0.08	12	-		0.043	2	0.19

As Table 3.12 depicts, in case of maize, both extensions and non-extension inefficiency is highest for Amhara, which shows there is a potential to increase efficiency; moreover there is a rising efficiency from South to North Ethiopia. The falling tendency in case of teff is similar for both extensions and non-extensions, and the falling tendency again is true for teff despite the smallest sample size. The rising inefficiency trend from North to South Ethiopia is possibly due to the falling soil fertility from South to North Ethiopia, or any other reason possibly related to productivity trap (Todaro, et al 2003) and this requires in-depth analysis.

What determines the technical efficiency of extension and non-extension farmers for the three crops? The behavior of the farm household is influenced by environmental and socio-economic variables.

The multiple regression model based on the technical inefficiency effect term is distributed N (μ_i, σ_v^2) where μ_i can be specified and defined as $\mu_i = \delta o + \sum_{j=1}^{m} \delta_o \beta_{ij}$; where β_j are socioeconomic and infrastructure variables which are theoretically or possibly empirically identified variables.

The model:

$INEF_i = \beta_0 + \beta_1 AGE_i + \beta_2 SEX_i + \beta_3\ EDUDMY_i + \beta_4\ RELIGN_i + \beta_5 HHSIZE_i + \beta_6 REGIONDMY_i + \beta_7 TFP_i + \beta_8 DISTPRMKT_i + \beta_9 CREDITAV + \beta_{10} GROCEXP_i + \beta_{11} NOFEMALE_i + \beta_{12}\ EXTADVS_i + \beta_{13} NLS_i + \beta_{14} LANDSIZE + \varepsilon_i$

We run maximum likelihood estimation for extension and non-extension of the three crops summarized in Tables 3.13. The dependent variable in all cases is technical inefficiency. The estimation of inefficiency determinants using two stages is indeed controversial; a problem with the two-stage procedure is a lack of consistency in assumptions about the distribution of the inefficiencies. In the first stage, inefficiencies are assumed to be independently and identically distributed (identically independently distributed) in order to estimate their values. However, in the second stage, estimated inefficiencies are assumed to be a function of a number of firm-specific factors, and hence are not identically distributed (Colelli et al 1998). Kumbhakar et al (1991), Reifschneider et al (1991) estimated all of the parameters in one step to overcome this inconsistency. The inefficiency effects were defined as a function of the firm-specific factors (as in the two-stage approach), but were incorporated directly into the Maximum Likelihood Estimation (MLE). In this study we use the two-stage estimation by using the MLE as in Arega et al, 2003.

The summary (Table 3.13) depicts that among other variables, agro-ecology/ regional dummy, average selling price, land size, total factor productivity, number of livestock and number of female in most of the cases determine the level of inefficiency. We expect there is a negative relationship between selling price and inefficiency. But it has positive relationship with inefficiency implying farmers producing at a level closer to the frontier sell at lower price than farmers producing at lower production frontier, which sell their output at higher price. This selling price here shows an effect relationship rather than cause. Second the income-leisure argument is also important to consider. Improved technology is profitable for both maize and teff, even if output prices decline by 25% or 50% (Howard et al, 1999), which shows the selling price depends on the productivity of farmers assuming that more efficient farmers are more productive. The direction of influence of plot size on efficiency is mixed in general, as in cases of many findings; Kumbahakar et al (1991) and Alvarez and Arias (2004) show that large farms are relatively more efficient while Ahmed and Ureta (1995) found negative relationship for Spain diary farms. Huang and Kalirajan (1997) found that the size of household arable land is positively related to technical efficiency in maize, rice and wheat production in China. Parikh et al. (1995) find that cost inefficiency increases in farm size. Hazarika et al. (2003) show that cost inefficiency in tobacco production is negatively related to tobacco plot size but unrelated to total farm size in Malawi. For Kenya, the estimation result for maize shows that larger maize plot sizes are more deficient (Liu, 2005), which is contrary to the finding in this study for Ethiopia.

Table 3.13: Summary to the Determinants of Inefficiency in Maize, Teff, and Wheat

Variable	Adopters			Non-extension farmers		
	Maize	Teff	Wheat	Maize	Teff	Wheat
Education Dummy	√(-)					
Religion Dummy		√(+)				
Region dummy	√(-)	√(-)	√(-)	√(-)	√(-)	√(-)
Age	√(-)	√(+)				
SEX						
Distance from primary market				√(-)		
Number of female	√(-)		√(-)	√(+)	√*(-)	
Grocery Expenditure	√(-)					
Number of livestock		√(-)				√(-)
Current selling Price		√(+)	√(+)	√(-)	√(+)	
Land size	√(+)	√(+)		√(+)		√ (-)
Household Size			√ (+)			
Total Factor Productivity	√(-)	√(-)		√(+)	√(+)	
Constant	√(+)				√(-)	

* Household size and number of female are substitutes in this case.

In the case of the regional dummy, the coefficient is statistically significant at 1% level in all cases; this may imply that as we move from north to south Ethiopia, inefficiency tends to decrease. If we ignore the sampling, on average this is found to be true for all cases, which is consistent with the descriptive statistics. The education dummy in most of the cases has the expected negative sign even though in some cases it is insignificant. The significance is consistent to the earlier findings in Ethiopia (Mulat et al 2003; Arega et al 2003; Beyene, 2004). Primary education indeed is the source of efficiency it is also a source of economic growth (Paulos and Mekonnen, 2004). We should not underestimate the contribution of female in the household; generally they can have a role of facilitating agricultural activities and also engage in different farm activities themselves, so that they tend to increase farm efficiency. The finding in this study shows that in both extension and non-extension farmers the number of female is increasing leading to improvement in efficiency though past studies didn't sufficiently support the role of female in efficiency analysis.

Rational people normally expect that too much expenditure on recreation is a sign of inefficiency in livelihood. The finding in this study shows that grocery expenditure, as a measure of recreation is not as such influence farmer's inefficiency in Ethiopia. The variable is significant only in the case of extension maize farmers out of six cases. The case of maize is contrary to our expectation in that the rise in grocery expenditure is decreasing inefficiency. This is possibly due to the positive role of the expenditure on recreation in facilitating information and experience exchange among farmers, particularly when the expenditure lies within the economic and social norm of the society.

The total factor productivity indicating as one of the positive factors determining the level of efficiency of extension and non-extension farmers, as the finding depicts for all the two cereals (except wheat). This is consistent with the theory that factor productivity influences the level of efficiency of producers (Colelli and Batisse, 1998. This finding is new of its kind and requires in-depth analysis to determine the coefficients. In this connection what the study revealed is that the agro-ecologic factors such as soil and climate influences TFP and the level of TFP influences the efficient utilization of factors of production.

There is vast potential in Ethiopia to increase output by increasing total factor productivity through application of modern technology (as in extension farmers) and use of farm resources. This is evidenced by the mean efficiency in maize, teff and wheat is 52%, 80% and 76% extension farmers respectively, there is an efficiency gap ranging from 48% in maize to 24% in wheat, implying that farmers can increase output by increasing efficient utilization of their inputs. In non-extension farmers, the mean efficiency is 84%, 83% and 63% for maize, teff, and wheat implying that they can increase output by increasing their efficiency on average by 16%, 17% and 37% respectively.

4. Concluding Remarks and Policy Recommendations

After the commencement of the extension program in 1995/96, the number of farmers using modern technology inputs has increased considerably. This study was conducted with and objectives of assessing the TFP and technical efficiency and the differences between farmers engaged in the extension package program and the non-extension farmers. It presents the results based on sample farmers producing maize, teff and wheat from four regions. For the TFP comparison, we employed the *Tornquvist index*, which is found to be appropriate measurement for this kind of study. Under this index, the TFP estimation is based on the utilization of labor, fertilizer and draught power (oxen-timad-days) inputs. The estimated result shows that 65%, 65% and 96% of the sample extension farmers in maize, teff and wheat respectively have TFP greater than that of the non extension farmers, implying that on average TFP declines from extensions to non-extensions for the majority of sample households for all the three crops; and this is true for both matching and non-matching cases. It has an overall implication that the technologies in extension package have brought about substantial difference between extensions and non- extensions participating farmers. Based on the finding we detect that high TFP difference is observed in wheat, followed by maize and teff. The estimation from multiple regression analysis clearly indicated that, TFP differences other than the inputs show that age, distance from market, frequency of cultivation per hectare of land, plot size, labor and agro-ecological differences are significantly influencing the level of TFP. Fertilizer use is important determinant in case of extensions farmers. Number of male or female in the farm household, access to extension advises, price of output, quantity of seed, education and religion dummies do not seem to have consistent influences on the level of TFP. This kind of study is hardly conducted in Ethiopia and makes it difficult to compare with other finding. However, based on this finding, we can safely conclude that technology packages of extension service on average have made some remarkable difference in productivity between extension and non-extension farmers.

Similarly, based on the data set, technical efficiency was estimated for maize, teff and wheat extension and non-extension farmers. Econometric tests significantly rejected the trans-log production function in favor of Cobb-Douglas; and second, regarding the tests for using selecting half-normal against truncated-normal, the later is rejected. The estimated result shows that in terms of technical efficiency for the given samples, the maximum mean technical efficiency is observed in maize non-adopters while the minimum is observed in maize adopters households. The implication for maize producing households is that compared to the most technically efficient farmers, there are many technically inefficient farmers in the extension rather than in the case of non-extension maize farmers. Moreover, on average maize extension farmers can increase technically efficient utilization of inputs by about 48% as compared to only 16% in non-extension. The technical efficiency in teff is higher for extensions i.e. 80% and almost equal to the case of non-adopters in maize that is 83%. On average, teff extension farmers can increase efficiency by about 20% while the non-extensions can increase by about 17%. At the other end the, technical efficiency of wheat extension and non-extension farmers is about 76% and 63% respectively, implying that they can increase efficiency on average by about 24% and 37%. We observed that teff and wheat extension farmers are more efficient than the non-extension farmers while this is contrary to the case of maize, where most of the extensions are less efficient. Behind these findings is that in stochastic frontier, all farmers are compared against the most efficient farmer. The estimated technical efficiency shows there is vast potential in Ethiopia to increase output by increasing total factor productivity through application of modern technology and by allocating and managing resources- labor, draught power, and fertilizer/inputs. This demands efficient farm management practices at farm level.

It may be safely concluded from this study that the agro-ecologies play a significant role in influencing TFP and Technical efficiency and hence due consideration should be given in agricultural technology transfer to target agro-ecology based technology. There is ample potential yet to be tapped for both extension & non-extension farmers not only by improving efficiency in resource utilization, but also by increasing total factor productivity through application of modern technologies on various agro-ecologies. Finally, conducting similar studies further dealing with TFP and efficiency with wider sample size coverage might be justifiable to bring about more dependable result, informing on the coefficients of the determinants

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