Measuring the Impact of Ethiopia's New Extension Program on the Productive Efficiency of Farmers

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1. Introduction

The growing gap between food demand and supply in Ethiopia is mainly attributed to the very low productivity of the agricultural sector. Heavy reliance on obsolete farming techniques, poor complementary services such as extension, credit, marketing, and infrastructure, and inappropriate agricultural policies are among the major factors that have greatly retarded the development of Ethiopia's agriculture. Despite its dominant share in the country's total agricultural output, and hence in the GDP, smallholder agricultural production lacked the necessary attention in the country's agricultural development efforts in the past. One of the major policy shifts since the change of government in 1992 has been the substantial emphasis placed on improving the productivity of peasant agriculture through increased use of a package of improved agricultural technologies.

As part of the agricultural development-led industrialization development strategy, the Ethiopian government introduced the new extension program (NEP) based on the experiences of SG 2000 (SG) project which embarked upon the popularization of large-scale (usually half-hectare) on-farm demonstration plots for already available improved agricultural production technologies. In formulating NEP, attempts had been made to screen out and preclude the shortcomings of past extension systems. First, the extension service was erroneously organized by commodity rather than by function. Second, the extension service was rather prescriptive in the sense that it only transmitted information with little or no supply of inputs. Third, the extension service was limited only to high potential areas of the country, neglecting other agro-ecological zones. Fourth, demonstration sites were not widely distributed and they were rather undertaken in fences. Fifth, extension information was not effectively communicated through different methods. Sixth, budgets, manpower, means of transport, etc., were not adequately allocated for the extension service and there was inefficiency in administration and management (TGE, 1994).

NEP was thus developed against the above backgrounds aiming to improve the productivity of smallholder farmers through better access to improved production technologies such as fertilizer, improved seeds, pesticides and better cultural practices mainly for cereal crops, including maize, wheat, and teff. The program provided credit, inputs and extension assistance to participants willing to establish half-hectare demonstration plots on their own land and to settle 25-50% down payments for improved inputs. It promotes integrated technology packages developed for different agro-ecological zones, including the highland mixed farming zone, highland degraded and low moisture zone, lowland agro-pastoralist zone, and lowland pastoralist zone. Its implementation was launched in 1995/96 cropping season as an expansion of SG package approach, primarily through dissemination of crop technologies. In 1995/96, about 36,000 half-hectare on-farm demonstration plots were established and average yields for the major crops including, maize, wheat, teff and sorghum have increased by 98% and the increment was more than double for maize and wheat (Takele, 1996). In 1996/97 and 1997/98, the number of government sponsored demonstration plots was 650, 000 and 2.9 million, respectively (Befekadu and Berhanu, 1999).

The rapid expansion of NEP has taken place at a time of major changes in markets, policies, and institutions affecting the agricultural sector: a new credit system launched in 1994, gradual liberalization of the fertilizer market from 1991 to 1997, and government decentralization. Despite considerable yield increments obtained from the demonstration plots of the SG project in the high-potential agricultural areas, knowledge about the impact of NEP on the production efficiency of farmers is very scanty. The success of NEP is believed to depend upon how well the three functions of extension, credit and input delivery meet the particular needs of smallholders, a situation very different from that of SG project, which was limited to specific high-potential zones with relatively better functioning credit and input delivery services. For example, NEP credit system is more complex: there are multiple actors (banks provide credit, regional governments guarantee credit, and extension agents approve participants and collect payments); interest is charged; and local administration follows strict enforcement rules. Further, NEP needs to deal with a fertilizer sector characterized by increasing retail prices due to subsidy removal and supply inefficiencies.

There are growing concerns about NEP that would seriously harm its effectiveness in enhancing new technology utilization and in bringing about the desired improvements in productivity. First, extension agents, apart from their own little technical knowledge about new technologies, are involved in too many non-extension tasks: processing credit applications, dealing with input distributors, mobilizing farmers for public works, and collecting loans and taxes. Second, rapid expansion of NEP to less favorable and marginal areas required more supervision and credit, than less, due to the low literacy rates and poor asset endowments of the farmers in these areas, against the background of a rather limited number of extension agents and dwindling credit portfolios to regions. The overall impact of increased plots per extension agent and the extra tasks is a lower quality extension message. This opens up possibilities for farmers to experience greater production inefficiency and hence loss of potentially obtainable output from new technology due to lack of familiarity with the new technology, market information and credit. There is, however, lack of adequate empirical evidence regarding the impact of NEP on production efficiency in different agro-ecological zones, given a package of improved technologies.

The objective of this paper is, therefore, to assess the impact of NEP on the technical and allocative efficiency of farmers and to identify the underlying factors influencing their level of efficiency in eastern Ethiopia. It specifically measures and compares the technical, allocative, and overall productive efficiencies of participant and non-participant farmers in NEP, relative to their respective technologies. The paper is organized as follows. The next section presents the analytical framework and the data and empirical procedures are presented in the third section. In the fourth section, the results are presented and discussed and the last section draws conclusion and policy implication.

2. Analytical framework

Production efficiency has two components: technical and allocative efficiency. Technical efficiency is the extent to which the maximum possible output is achieved from a given combination of inputs. On the other hand, a producer is said to be allocatively efficient if production occurs in a subset of economic region of the production possibilities set that satisfies the producer's behavioral objective (Ellis, 1988). Farrell (1957) distinguishes between technical and allocative efficiency in production through the use of a 'frontier' production function. Technical Efficiency is the ability to produce a given level of output with a minimum quantity of inputs under certain technology. Allocative efficiency refers to the ability of choosing optimal input levels for given factor prices. Overall productive efficiency is the product of technical and allocative efficiency. Thus, if a firm has achieved both technically efficient and allocatively efficient levels of production, then the firm is economically efficient and new investment streams may be critical for any new development.

Since Farrell's (1957) seminal paper, there has been a growing interest in methodologies and their applications to efficiency measurement. While early methodologies were based on deterministic models that attribute all deviations from maximum production to inefficiency, recent advances have made it possible to separately account for factors beyond and within the control of firms such that only the latter will cause inefficiency. Aigner et al. (1977) and Meeusen and Van den Broeck (1977) independently proposed the stochastic frontier production function to account for the presence of measurement errors and other noise in the data, which are beyond the control of firms. Stochastic frontiers have two error terms. The first accounts for the presence of technical inefficiencies in production and the second accounts for measurement errors in output, weather, etc and the combined effects of unobserved inputs in production.

The production technology of a firm is represented by a stochastic frontier production function (SFPF) as

$$Y = f\left(X;\beta\right) + v - u \qquad (1)$$

where Y measures the quantity of agricultural output; X is a vector of the input quantities; β is a vector of parameters; $f\left(X;\beta\right)$ is the production function; v is assumed to be independently and identically distributed $\mathrm{N}(0,\sigma^2{}_v)$ random error, independent of the u; and u is a non-negative random variable, associated with technical inefficiency in production, and is assumed to be independently and identically distributed as half-normal, $u \sim \left|N(0,\sigma^2 u)\right|$. The maximum likelihood estimation of equation (1) yields estimators for β and λ where $\lambda = \dfrac{\sigma_u}{\sigma_v}$ and $\sigma^2 = \sigma^2 u + \sigma^2 v$. Jondrow et al. (1982) have shown that the assumptions made on the statistical distributions of v and u, mentioned above, make it possible to calculate the conditional mean of u_i, given $\varepsilon_i = v_i - u_i$ as

$$\mathrm{E}(u_i / \varepsilon_i) = \frac{\sigma_u \sigma_v}{\sigma} \left[\frac{\phi(\varepsilon_i \lambda / \sigma)}{1 - \Phi(\varepsilon_i \lambda / \sigma)} - \frac{\varepsilon_i \lambda}{\sigma} \right] \quad (1)$$

where Φ and ϕ are, respectively, the standard distribution and the standard normal density functions, evaluated at $\varepsilon_i \lambda / \sigma$.

The conventional stochastic efficiency decomposition methodology uses the level of output of each firm adjusted for statistical noise (i.e., $Y_i - v_i$), observed input ratios, and the estimated parameters of the SFPF to decompose overall efficiency into technical and allocative efficiency (e.g., Bravo-Ureta and Rieger, 1991; Bravo-Ureta and Evenson, 1994). However, while the parameters of the SFPF are estimated using an output-orientated approach, technical efficiency is derived by imposing an input-orientated approach implied by the simultaneous solution of adjusted outputs and the observed input ratios to yield the technically efficient input vectors. Inconsistency arises when efficiency estimates that could be obtained directly from the SFPF differ from those actually derived through the decomposition, due to possible scale effects. Therefore, adopting an input orientation for efficiency decomposition when original SFPF specifications have an output orientation requires that observed output be adjusted for statistical noise as well as scale effects. This is accomplished by first defining a scale factor as the deviation from constant returns to scale as

$$\pi_i = \theta - 1, \quad (2)$$

where π_i is the scale factor for the i^{th} firm and θ is the quasi function coefficient of the production technology. Imposing an input orientation on the original output-orientated SFPF will produce overall inefficiency effect, u_i^*, that is composed of pure technical inefficiency effect equivalent to the output-orientated technical inefficiency, u_i, and a scale effect, φ_i, so that we have

$$u_i^* = u_i + \varphi_i. \quad (3)$$

Consistency requires that input- and output-orientated technical inefficiency effects be equal (i.e., $u_i^* = u_i$). To the extent that there is a non-zero scale effect, the conventional decomposition methodology gives inconsistent efficiency estimates. In the output-orientated approach, the scale effect is embodied, and hence already accounted for, in the deterministic structure of the production frontier. From this it follows that the observed output must be adjusted not only for statistical noise but also for scale effects.

The scale effect is a proportion of the output-orientated technical inefficiency effect so that the scale effect of the i^{th} firm can be given by

$$\varphi_i = \pi_i u_i \,. \tag{4}$$

From equations (2) and (4), the input-orientated adjusted output of the i^{th} firm can be derived using the following relation

$$Y_i^* \equiv f(X_i;\beta) - u_i^* = Y_i - v_i - \pi_i u_i \,, \tag{5}$$

where Y_i^* is the observed (or actual) output adjusted for statistical noise captured by v_i and scale effects captured by φ_i. $f(\cdot)$ is the deterministic frontier output, and u and v are, respectively, the inefficiency and random components of overall deviations from the frontier. Adjusted output, Y_i^*, is used to derive the technically efficient input vector, X^t. The technically efficient input vector for the i^{th} firm, X_i^t, is derived by simultaneously solving equation (5) and the observed input ratios $\frac{x_1}{x_i} = k_i \,(i > 1)$ where k_i is equal to the observed ratio of the two inputs in the production of Y_i^*.

Assuming that the production function in equation (1) is self-dual (e.g. Cobb-Douglas), the dual cost frontier can be derived algebraically and written in a general form as follows

$$C_i = h(W_i, Y_i^*;\delta) \,, \tag{6}$$

where C_i is the minimum cost of the k^{th} firm associated with output Y_i^*, W_i is a vector of input prices for the i^{th} firm, and δ is a vector of parameters to be estimated. The economically efficient input vector for the i^{th} firm, X_i^e, is derived by applying Shephard's Lemma and substituting the firm's input prices and adjusted output level into the resulting system of input demand equations

$$\frac{\partial C_i}{\partial W_n} = X_{ni}^e (W_i, Y_i^*; \theta), \tag{7}$$

where θ is a vector of parameters, $n = 1, 2, ..., N$ inputs. The observed, technically efficient, and economically efficient costs of production of the i^{th} firm are equal to $W_i^/ X_i$, $W_i^/ X_i^t$, $W_i^/ X_i^e$, respectively. These cost measures are used to compute technical (TE) and overall productive or economic efficiency (EE) indices for the i^{th} firm as follows

$$\text{TE}_i = \frac{W_i^/ X_i^t}{W_i^/ X_i}, \tag{8}$$

$$\text{EE}_i = \frac{W_i^/ X_i^e}{W_i^/ X_i}. \tag{9}$$

Following Farrell (1957), the allocative efficiency (AE) index can be derived from equations (8) and (9) as follows

$$\text{AE}_i = \frac{W_i^/ X_i^e}{W_i^/ X_i^t}. \tag{10}$$

Identification of factors influencing efficiency has also been an important exercise but debate as to whether the single or two-stage method is appropriate is not settled. Battese and Coelli (1995) and Kumbhakar (1994) challenge the two stage approach by arguing that the farm-specific factors should instead be incorporated directly in the first stage estimation of the stochastic frontier because such factors can have a direct impact on efficiency and they proposed a model incorporating these variables. Nevertheless, the two-stage method is mostly preferred due to a round-about effect of variables on efficiency (Assefa, 1995; Kalirajan, 1991; Bravo-Ureta and Rieger, 1991; Bravo-Ureta and Evenson, 1994; Sharma et al., 1999). The linear regression model has thus been a common approach to the analysis of the effects of farm-specific factors on productive efficiency. After transforming the efficiency scores using the Box-Cox procedure and taking logs (Judge et al., 1985) we get

$$\ln\left(\frac{\mathrm{E}_i}{1-\mathrm{E}_i}\right) = X_i^{/}\beta + \varepsilon_i \, , \qquad (11)$$

where E_i is the i^{th} firm's level of efficiency, X is a vector of explanatory variables, β is a vector of parameters to be estimated, and ε is a vector of identically and independently distributed random errors N(0, σ^2).

Despite its well known limitations, we use a Cobb-Douglas functional form for the SFPF because the methodology employed in this study requires that the production function be self-dual. In fact, Taylor et al. (1986) argued that as long as interest rests on efficiency measurement and not on the analysis of the general structure of the production technology, the Cobb-Douglas production function provides an adequate representation of the production technology. Moreover, in one of the very few studies examining the impact of functional form on efficiency, Kopp and Smith (1980) concluded "…that functional specification has a discernible but rather small impact on estimated efficiency" (pp. 1058). That is why the Cobb-Douglas functional form has been widely used in farm efficiency analyses both for developing and developed countries (see Battese, 1992).

3. Data and empirical procedures

3.1. Data

The data for this study come from two samples of farmers, one sample composed of farm households participating in the extension program and another composed of non-participant farm households, in two selected districts, Meta and Babile, each representing distinct agro-climatic zones in eastern Ethiopia. Meta district was selected to represent a typical wet highland zone where there is very high population pressure on land and receives relatively better rainfall amount and distribution ranging between 900 and 1200 millimeters per annum. Meta is a high potential cereal production zone where NEP is widely implemented to enhance the production of food grains. The most widely grown cereals in Meta are maize, barley and wheat. On the other hand, Babile district was selected to represent a dry land zone receiving an annual rainfall between 500 and 700 millimeters. Babile is an important target of NEP and NGO's activities in view of widespread food insecurity. Dry land technologies generated by Alemaya University and other research centers are mainly tested and promoted in Babile. Technologies include short-cycle, drought tolerant, and better yielding varieties of maize and sorghum along with the appropriate fertilizer recommendations and agronomic practices. Sorghum, maize and groundnuts are widely grown in Babile.

The surveyed farmers were randomly selected after an initial stratification of farm households in three Peasant Associations into participants and non-participants in NEP. The participant and non-participant sample farm households surveyed in Meta were, respectively, 53 and 47, whereas 50 farm households from each group were surveyed in Babile. Data were collected through frequent visits to the sample farm households' crop fields to carry out interviews and to take plot-level measurements and observations throughout the 2001/2002 agricultural year. Input data were collected on a fortnight basis by asking the farmer to recall his/her activities during the past two weeks. Data included labor time disaggregated by source, gender, age, and field operation. The quantities of oxen-traction, seed, organic/inorganic fertilizer, pesticides, and herbicides, and the prices of all purchased inputs were also collected during this time. Output data on all the quantities of cereals, pulses, and oil crops harvested were collected. A separate survey was conducted to collect output price information from Muti, Chelenko and Babile markets during planting and harvesting times of the major crops.

A summary of the values of the variables used in the analysis is presented in Table 1. Participants in NEP in both districts obtained higher average crop output value per hectare of cultivated land in view of higher average yields of the major crops, including maize, sorghum, groundnuts, wheat and barley. Moreover, the participants have higher cultivated

Table 1

Summary statistics of the variables used in the analysis

Variable	Meta		Babile	
	Participants	Non-participants	Participants	Non-participants
	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)
Value of crop output (Birr/ha)	3350 (1306)	1490 (769)	3660 (1508)	1471 (714)
Hybrid maize yield (kilogram/ha)	5100 (2460)	---	---	---
Local maize yield (kilogram/ha)	2040 (670)	2030 (1300)	1070 (740)	930 (550)
Sorghum yield (kilogram/ha)	---	1460 (1000)	1100 (510)	980 (470)
Groundnuts yield (kilogram/ha)	---	---	740 (390)	670 (300)
Wheat yield (kilogram/ha)	2000 (920)	1700 (1070)	---	---
Barley yield (kilogram/ha)	1380 (970)	1420 (2150)	---	---
Cultivated Land (ha)	0.73 (0.60)	0.65 (0.16)	1.70 (0.66)	1.45 (0.60)
Labor (Man-days/ha)	65 (32)	68 (16)	57 (29)	53 (80)
Fertilizer (kilogram/ha)	69 (36)	22 (24)	42 (12)	17 (10)
Age	39 (12)	41 (12)	37 (10)	38 (10)
Education (literacy) dummy	0.77 (0.35)	0.66 (0.31)	0.66 (0.42)	0.40 (0.26)
Off-farm income (Birr)	209 (62)	91 (143)	327 (91)	287 (28)
Extension visit	6 (3)	0.8 (1)	8 (7)	4 (3)
Man equivalent	1.58 (0.8)	1.39 (0.53)	1.57 (0.57)	1.45 (0.57)
Cash Credit (Birr)	71 (96)	32 (78)	337 (421)	50 (21)
Livestock unit	2.47 (1.69)	2.04 (1.24)	5.67 (0.59)	3.90 (0.45)
Maize-potato share (percent)	54 (12)	63 (33)	---	---
Cereal-Pulse share (percent)	8 (2)	11 (5)	45 (10)	39 (13)

Note: S.D. = Standard deviation.

land, livestock units, off-farm income, cash credit, household labor and extension visits than the non-participants. Both groups of farmers in Meta have comparably high average percentage of cultivated area allocated to the maize-potato cropping system, which provides greater opportunities for efficient use of land in the face of increasing land shortages in the wet highland zone.

In view of the increasing pressure on land in the wet highland zone, both participant and non-participant farmers in Meta have less average cultivated land and livestock than farmers in the dry land zone, Babile. Both groups of farmers in Babile have comparably high average percentage of cultivated area allocated to the cereal-pulse cropping system, which offers opportunities for crop diversification to cope with the risk of crop failure due to drought as well as for improving yield through soil fertility improvement and better control of pests and diseases (Bezabih, 2000).

3.2. Empirical models

For the investigation of the technical, allocative and economic efficiencies of participant and non-participant farmers, separate stochastic frontier production functions, of the following form, are estimated for participant and non-participant farmers

$$\begin{aligned} \ln Y_i = \beta_0 + \beta_1 \ln \mathit{land} + \beta_2 \ln \mathit{labor} \\ + \beta_3 \ln \mathit{fertilizer} + \beta_4 \ln \mathit{materials} + (v_i - u_i), \end{aligned} \quad (12)$$

where $\ln$ denotes the natural logarithm (base, e); Y_i denotes the gross value of crop output of the i^{th} farmer, the weights being the shares in total revenue; *land* denotes the total land cultivated in hectares; *labor* denotes the total of family labor, exchange labor, and hired labor used in man-days; *materials* denotes the implicit quantity index of seeds and chemicals (pesticides, insecticides, herbicides, and fungicides) estimated as the value of all seeds and chemicals deflated by a weighted price index of the inputs, the weights being the share of each input in total cost.

The solution to the cost minimization problem in equation (13) is the basis for deriving the dual cost frontier, given the input prices (w_n), parameter estimates of the stochastic frontier production function ($\hat{\beta}$) in equation (12), and the input-orientated adjusted output level Y_i^* in equation (5)

$$\underset{x}{\text{Min}}\, C = \sum_n w_n X_n \quad (13)$$

$$\text{Subject to } Y_i^* = \hat{A}\prod_n X_n^{\hat{\beta}_n} .$$

Substitution of the cost minimizing input quantities into equation (13) yields the following dual cost function

$$C(Y_i^*, w) = \mathrm{K} Y_i^{*\psi} \prod_n w_n^{\alpha_n} , \tag{14}$$

where $\alpha_n = \psi\hat{\beta}_n$, $\psi = \left(\sum_n \hat{\beta}_n\right)^{-1}$, $\mathrm{K} = \frac{1}{\psi}\left(\hat{A}\prod_n \hat{\beta}_n^{\hat{\beta}_n}\right)^{-\psi}$, $\hat{A} = \exp(\hat{\beta}_0)$.

The investigation of factors influencing technical and allocative efficiencies of participant and non-participant farmers is carried out by estimating the following model

$$\ln\left(\frac{\mathrm{E_i}}{1\text{-}\mathrm{E_i}}\right) = \beta_0 + \sum_i \beta_i X_i , \tag{15}$$

where E is efficiency (i.e., technical or allocative), β is a vector of unknown coefficients of the inefficiency variables, X_i, to be estimated. The variables that are hypothesized to influence farm level production efficiency in the Ethiopian context (Assefa, 1995; Getachew, 1995) are: AGE (the age of the household head); RWEDUC (dummy for literacy of the household head in terms of reading and writing); PREDUC (dummy for attendance of primary education); CASHCR (amount of cash credit obtained); EXTNSN (the number of visits to a farmer by an extension agent during the cropping season); PARTCPN (the number of years the farmer participated in extension programs); LSTKUNT (livestock unit); OFINCM (amount of off-farm income obtained by the household); CERPULS (percentage of cultivated area allocated to the cereal-pulse cropping system) for Babile; MZPOT (percentage of cultivated area allocated to the maize-potato cropping system) for Meta; and MKTDIST (distance to the district market in walking minutes).

4. Empirical results

The maximum-likelihood (ML) estimates of the parameters of the stochastic frontier production function are presented in Table 2. The ordinary least squares (OLS) estimates of the average production functions are also presented for comparison. A common stochastic frontier model for all farmers in each of the districts, irrespective of whether they participated in NEP, was estimated to see if the two samples of farmers actually used different technologies. Using the generalized likelihood ratio (LR) test (Coelli and Battese, 1996), the aggregate model for Babile could not be rejected while the corresponding model for Meta was strongly rejected[1]. This indicates that while the participant and non-participant farmers actually used different production technologies in the wet highland zone, those in the dry land zone used homogenous technologies. This confirms the serious shortage of improved technologies for Babile, as is the case with other moisture-stressed agro-climatic zones (Bezabih, 2000). Therefore, the aggregate model for Babile was chosen as the preferred model to predict the efficiency indices for both groups of farmers.

As expected, the output elasticities of all variables are positive in all SFPF specifications. For participants in Meta, all input variables are positive and highly significant in determining crop production. For non-participants in Meta, who have no access to input credit and can neither afford to buy adequate amounts fertilizer and chemicals, these variables are not statistically significant. The estimate of the variance parameter, λ, is significant in the SFPF of both participant and non-participant farmers in both districts, implying that the inefficiency effects are significant in determining the level and variability of crop production in the study areas.

The dual frontier cost function for participants in Meta, derived analytically from the stochastic production frontier shown in Table 2, is given as

[1] The LR test-statistic for the null hypothesis of aggregate function is equal to 8 for Babile and 12 for Meta compared to 9.5, the 95 percent χ^2 critical value with 4 degrees of freedom.

$$\ln C_i = -7.107 + 0.464 \ln w_A + 0.240 \ln w_L + 0.166 \ln w_F + 0.129 \ln w_M + 1.406 \ln Y_i^*. \quad (16)$$

Table 2

OLS and ML estimates of the average and stochastic frontier production functions [a, b]

Variable	Meta				Babile	
	Participants		Non-participants		Aggregate	
	OLS estimates	ML estimates	OLS estimates	ML estimates	OLS estimates	ML estimates
Intercept	6.174*** (19.414)	6.632*** (19.785)	5.624*** (10.968)	6.013*** (12.146)	6.069*** (19.053)	6.615*** (24.374)
ln (Land)	0.262*** (3.372)	0.330*** (3.774)	0.884** (2.500)	0.747** (2.095)	0.415*** (3.477)	0.433*** (3.631)
ln (Labor)	0.179*** (2.669)	0.171** (2.011)	0.309** (2.183)	0.256* (1.787)	0.145*** (2.990)	0.183*** (3.812)
ln (Fertilizer)	0.140** (2.152)	0.118** (2.105)	0.069 (1.168)	0.063 (0.971)	0.141*** (3.991)	0.098** (1.936)
ln (Materials)	0.111*** (3.028)	0.092** (2.454)	0.044 (0.738)	0.075 (1.208)	0.089 (1.031)	0.058 (0.796)
R^2	0.82		0.60		0.70	
λ		4.146* (1.715)		2.332* (1.624)		2.729*** (2.513)
σ_u^2		0.978		0.195		0.283
σ_v^2		0.006		0.036		0.038
Log-likelihood		12.64		-12.919		-39.57

[a] ***, significant at 0.01 level; **, significant at 0.05 level; *, significant at 0.1 level.
[b] Figures in parentheses represent asymptotic *t*-ratios.

The dual cost frontier for non-participants in Meta is given as

$$\ln C_i = -4.132 + 0.655 \ln w_A + 0.225 \ln w_L + 0.055 \ln w_F + 0.065 \ln w_M + 0.876 \ln Y_i^*. \quad (17)$$

The dual cost frontier for all sample farmers in Babile is given as

$$\ln C_i = -7.445 + 0.561 \ln w_A + 0.236 \ln w_L + 0.127 \ln w_F + 0.075 \ln w_M + 1.295 \ln Y_i^*. \quad (18)$$

where C_i is the minimum cost of production of the i^{th} farmer; Y_i^* is the index of output adjusted for any statistical noise and scale effects as specified in equation (5); w_A is the seasonal rent of a hectare of land in Birr, w_L is the daily wages in Birr; w_F is the price of fertilizer in Birr per kilogram; and w_M is the price index of seeds and chemicals.

4.1. Efficiency estimates

Using the cost frontiers, average input prices and equations (8), (9), and (10), the technical, allocative, and economic efficiency indices are computed for each producer. The frequency distributions and summary statistics of these indices for participant and non-participant farmers in NEP are presented in Tables 3 and 4. For participant farmers in Meta, the estimated mean technical, allocative, and economic efficiency indices are 79%, 80%, and 65%, respectively, whereas the corresponding results for non-participants are 72%, 85%, and 63%.

Table 3

Frequency distribution and summary statistics of efficiency estimates for participant and non-participant farmers in Meta district, eastern Ethiopia

Level (percent)	TE Number (percent farms)		AE Number (percent farms)		EE Number (percent farms)	
	Participants	Non-participants	Participants	Non-participants	Participants	Non-participants
<50	-	5(11)	-	4(9)	6(11)	13(28)
51-60	7(13)	5(11)	-	2(4)	11(21)	8(17)
61-70	8(15)	7(15)	5(10)	1(2)	19(36)	11(23)
71-80	9(17)	12(25)	16(30)	4(9)	12(22)	10(21)
81-90	16(30)	16(34)	23(44)	12(25)	5 (10)	5(11)
91-100	13(25)	2(4)	9(17)	24(51)	-	-
Mean	79 [a]	72 [a]	80 [b]	85 [b]	65	63
Minimum	50	37	65	26	40	24
Maximum	97	93	99	99	84	85

[a, b] Significant mean difference at 0.05 level.

The results for Meta indicate that both participant and non-participant farmers in NEP exhibit equally high overall (or productive) inefficiencies due to their low technical and allocative efficiencies of production. Relative to their respective technologies, the participants have significantly higher technical but lower allocative efficiencies than the non-participant farmers with the result that both groups exhibit similar overall (productive) efficiencies. The participants and non-participants can gain, respectively, an average crop output growth of 35% and 37% through full improvements in technical and allocative efficiencies. The results suggest that although NEP improved the technical efficiency of participant farmers in Meta, given their improved technology, it again induced greater allocative inefficiencies and hence didn't impact on overall productive efficiencies.

For participant farmers in Babile, the results in Table 4 show that the mean technical, allocative, and productive efficiency indices are 68%, 81%, and 54%, respectively, whereas the corresponding results for non-participants are 66%, 84%, and 57%, indicating substantial productive inefficiencies among both groups of farmers. The participants and non-participants can gain, respectively, an average crop output growth of 46% and 43% through full improvements in technical and allocative efficiency. Apart from using homogenous technologies, the two groups do not have significantly different technical, allocative, and overall productive efficiencies.

The results in both agro-climatic zones confirm the failure of NEP in enhancing the productive efficiencies of farmers. NEP has had no positive impact on the productive efficiencies of farmers. The empirical evidence regarding the influence of new technological interventions on technical efficiency is mixed. The positive impact of NEP on technical efficiency especially in the wet highland zone is in agreement with Seyoum et al. (1998) who found considerably higher technical efficiency of maize production among participants in the SG project compared with the non-participants in eastern Ethiopia. Taylor et al. (1986) also obtained a positive influence, though insignificant, of an agricultural credit program on technical efficiency of farmers in Brazil. On the contrary, Xu and Jeffrey (1998) obtained significantly lower technical efficiency for hybrid rice production in China as compared with conventional rice production while Singh et al. (2000) obtained lower technical efficiency for newly established Indian dairy processing plants after liberalization of the dairy industry compared to the old plants.

Table 4
Frequency distribution and summary statistics of efficiency estimates for participant and non-participant farmers in Babile district, eastern Ethiopia

Level	TE		AE		EE	
	Number (percent farms)		Number (percent farms)		Number (percent farms)	
(percent)	Participants	Non-participants	Participants	Non-participants	Participants	Non-participants
<50	5(10)	8(16)	7(14)	1(2)	14(28)	16(32)
51-60	4(8)	7(14)	1(2)	-	24(48)	15(31)
61-70	16(32)	12(25)	3(6)	3(6)	12(24)	3(6)
71-80	16(32)	9(18)	9(18)	6(12)	-	14(29)
81-90	9(18)	12(25)	23(46)	30(61)	-	1(2)
91-100	-	1(2)	7(14)	9(19)	-	-
Mean	68	66	81	84	54	57
Minimum	23	25	16	32	13	16
Maximum	88	92	99	98	68	88

The negative influence of NEP on allocative efficiency in both areas is actually consistent with all the above studies. For example, Taylor et al. (1986) obtained a significant negative impact of an agricultural credit program in Brazil on allocative efficiency of participant farmers. Xu and Jeffrey (1998) also obtained significantly lower allocative efficiency for hybrid rice production in China as compared with conventional rice production across all the three regions studied. Singh et al. (2000) also obtained lower allocative efficiency for newly established Indian dairy processing plants after liberalization of the dairy industry compared to the old plants as they needed time to reach full operation, the right choice of products and other managerial skills required for higher performance.

4.2. Factors influencing efficiency

The parameter estimates of the OLS regressions employed to identify the factors influencing participant and non-participant farmers' levels of technical and allocative efficiencies in the respective districts are presented in Tables 5 and 6. For participant farmers in Meta, the results show that technical efficiency of participants is positively and significantly influenced by education, credit, previous participation in extension programs, and the share of the maize-potato cropping system while their allocative efficiency is positively influenced by education, credit, and previous participation in extension programs.

Table 5

Factors influencing the efficiency of participant and non-participant farmers in Meta district, eastern Ethiopia [a, b]

Variable	Participants		Non-participants	
	TE	AE	TE	AE
Constant	1.211** (1.982)	0.231* (1.611)	0.523 (1.125)	0.125 (0.658)
AGE	-0.025 (-0.369)	-0.129 (-1.478)	0.036 (1.150)	0.063* (1.854)
EXTNSN	0.032 (1.021)	0.012 (0.055)	0.001 (0.667)	0.003 (0.656)
RWEDUC	0.183** (1.986)	0.088* (1.705)	0.058* (1.670)	0.063* (1.667)
PREDUC	0.021 (1.063)	0.101 (1.535)	0.011 (1.023)	0.028 (1.002)
FARMSZ	-0.321 (-1.012)	0.001 (0.002)	-0.014 (-0.101)	0.014 (1.023)
CREDIT	0.117** (2.116)	0.205** (2.189)	0.082* (1.635)	0.102* (1.852)
PARTCPN	0.201** (2.354)	0.091* (1.820)	0.087 (1.221)	0.033 (1.153)
LSTKUNT	0.01(0.985)	0.066 (1.033)	0.005 (0.036)	0.009 (0.786)
OFINCM	0.012 (1.01)	0.188 (0.963)	0.160 (1.185)	0.005 (1.001)
HHLABR	0.001 (0.687)	0.023 (0.990)	0.001 (0.855)	0.022 (0.881)
MZPOT	0.228 ** (2.132)	0.022 (1.021)	0.174 * (1.812)	0.029 (1.020)
MKTDIST	0.021 (1.212)	-0.034 (-1.425)	0.014 (1.127)	-0.071(-1.188)
R^2	0.72	0.54	0.53	0.51
F	5***	4***	6***	3***

[a]*** significant at 0.01 level; ** significant at 0.05 level; * significant at 0.10 level.
[b] Figures in parentheses are *t*-ratios.

The role of credit and education cannot be overemphasized in the effective functioning of NEP. The serious shortage of cash facing the farmers due to deteriorating product prices and the demands of new inputs for adequate knowledge of proper utilization have undesirable impact on timely farming operations and optimal input applications, thereby influencing farmers' levels of technical and allocative efficiencies (Ali and Byerlee, 1991; Assefa, 1995). Further, the positive and significant impact of previous participation in extension programs on technical and allocative efficiency confirms the important role of greater experience with new techniques of production in promoting farmers' technical and allocative efficiency under improved technology. This also implies that NEP is likely to enhance the technical and allocative efficiency of farmers in the long run as farmers fully respond to the new demands of the technologies and the program also begins to have better credit and input supply systems.

For non-participant farmers in Meta, the results show that technical efficiency is positively and significantly influenced by education, credit, and the share of the maize-potato system while their allocative efficiency is positively and significantly influenced by age, education, and credit, indicating that traditional farmers make better technical and allocative decisions if they acquire basic education, have greater experience with traditional technology, and have better access to credit. However, unlike in the case of the participants, previous participation in extension programs doesn't significantly influence the technical efficiency of non-participant farmers. This is perhaps because these farmers have rarely benefited from extension programs in view of their poor access to sufficient amount of land to allocate for the application of new technology, poor awareness of the benefits of new technology, serious cash constraints to settle down payments for input credit, and their highly risk averse behavior (Assefa, 1995).

Furthermore, even when farmers happen to participate in previous programs, they do not seem to apply new methods and cultural practices they acquired through programs and projects to their own traditional crops in the subsequent years after 'graduation'. For instance, farmers destroyed soil conservation structures following the phasing out of projects and also continued planting traditional maize by broadcasting instead of planting in rows, which they practiced while growing improved maize. They are generally little prepared to take advantage of new techniques learnt to improve their efficiency in traditional crops production, and neither could they continue using improved technology to improve their efficiency in food production, due to the serious supply constraints especially of improved seeds which are only rationed through NEP (Mulat, 1999).

Table 6

Factors influencing the efficiency of participant and non-participant farmers in Babile district, eastern Ethiopia [a, b]

Variable	Participants		Non-participants	
	TE	AE	TE	AE
Constant	2.195***(3.698)	2.103*** (5.223)	3.101*** (3.589)	1.523** (2.325)
AGE	0.029 (1.135)	0.071* (1.655)	0.044 (1.201)	0.102* (1.944)
EXTNSN	0.071 (1.178)	0.023 (1.02)	0.087 (1.457)	0.149 (1.052)
RWEDUC	0.095* (1.825)	0.108** (2.078)	0.067* (1.626)	0.121** (2.005)
PREDUC	0.132 (1.452)	0.021 (1.077)	0.021 (1.142)	0.022 (1.014)
FARMSZ	-0.028 (1.014)	0.033 (1.025)	-0.014 (-0.101)	0.027 (1.110)
CREDIT	0.017 (0.116)	0.022 (1.350)	0.002 (0.833)	0.103 (1.425)
PARTCPN	0.037 (1.256)	0.049 (1.057)	0.087 (1.921)	0.009 (0.981)
LSTKUNT	-0.021 (-1.211)	0.038 (1.422)	-0.005 (-0.036)	0.004 (0.861)
OFINCM	0.128* (1.950)	0.092* (1.735)	0.260** (2.268)	0.092* (1.967)
HHLABR	0.092 (1.015)	0.025 (1.273)	0.113 (1.481)	0.002 (0.699)
CERPULS	0.119**(2.070)	0.002 (0.989)	0.233*** (3.568)	0.011 (1.089)
MKTDIST	-0.011 (-1.058)	-0.102 (-1.512)	-0.027 (-1.201)	-0.020 (-1.114)
R^2	0.61	0.57	0.56	0.49
F	10***	4.5**	7***	3.6**

[a] *** significant at 0.01 level; ** significant at 0.05 level; * significant at 0.10 level.
[b] Figures in parentheses are t-ratios.

For both participant and non-participant farmers in Babile, the results in Table 6 show that their technical efficiency is positively and significantly influenced by education, the share of the cereal-pulse system, and off-farm income, whereas their allocative efficiency is positively and significantly influenced by age, education and off-farm income. Although not significant, while previous participation in extension programs, credit, extension visits, and household labor have a positive influence, market distance has a negative influence on the technical and allocative efficiency of farmers in Babile. Although insignificant, livestock ownership negatively influences technical efficiency but has a positive impact on allocative efficiency. The negative influence on technical efficiency may be due to the competitive nature of crop and livestock production under conditions of serious feed shortages where farmers have to feed livestock through heavy thinning and defoliation (Storck et al., 1997), or have to travel long distances in search of feed thereby delaying critical farming operations.

5. Conclusions and policy implications

This paper employed a robust stochastic efficiency decomposition technique that accounts for scale effects to derive the technical, allocative, and overall productive efficiency of two samples of farmers, participants and non-participants in Ethiopia's New Extension Program, in two agro-climatic zones in eastern Ethiopia. The results indicate that both groups of farmers have considerable overall productive inefficiencies suggesting the existence of immense potentials for enhancing production through improvements in efficiency with available technology and resources.

In the wet highland zone, the participants in the program used a superior technology and have higher technical but lower allocative efficiencies than the non-participant farmers, relative to their respective technologies, with the result that both groups experienced greater and comparable overall productive inefficiencies. Therefore, the results show no evidence of impact of NEP on production efficiency in the wet highland zone. In the dry land zone, on the other hand, apart from using homogeneous technologies, the two groups do not have significantly different technical and allocative efficiencies and, therefore, NEP has had no positive impact on overall productive efficiency of farmers in the dry land zone. An investigation of the influence of several socio-economic and institutional factors on efficiency revealed that education, credit, previous participation in extension programs, and the share of the maize-potatoes cropping system positively influence production efficiency in the wet highland zone. In the dry land zone, on the other hand, education, off-farm income, and the share of the cereal-pulse cropping system have a positive impact on efficiency.

The results suggest the need for providing farmers with greater access to education and credit for improved inputs to raise their productive efficiency. Strengthening existing off-farm employment opportunities will also greatly help relieve farmers' liquidity constraints at times of critical farming operations. Promoting local innovative cropping systems through research and extension within the complex farming systems that have evolved in response to a wide range of constraints and opportunities will have greater impact on crop productivity.

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