Is food security enhanced by agricultural technologies in rural Ethiopia?

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Abstract

This paper investigates the interdependence of decisions on the adoption of agricultural technology and the simultaneous interaction between adoption and food security situations of smallholders, using a sample of 260 households from rural Ethiopia. Three agricultural technologies and two food security measures were estimated with simulated maximum likelihood (SML) multivariate probit models to measure the link between the adoption of agricultural technology and food security indicators and to identify their underlying determinants. The simulation results suggest that households' decisions about the adoption of agricultural technology and their food security situations were strongly and positivity interdependent, with very low likelihood of adoption and food security. The common underlying factors of technology adoption and food security situations were also identified. The results generally imply that a concerted effort is required to enhance household food security through the accelerated introduction and dissemination of appropriate agricultural technologies in rural Ethiopia.

Keywords: food security; technology adoption; multivariate probit; simulation

1. Introduction

The eradication of poverty in Ethiopia, where smallholder farming is the dominant livelihood activity and the source of vulnerability to poverty and food insecurity, is an overriding objective of the incumbent government (FDRE 1996, 2004, 2012; MoFED 2006; Brown & Teshome 2007). Achieving agricultural growth and development and thereby improving rural household welfare requires increased efforts to provide yield-enhancing resources. Agricultural technology can contribute to increased food production (food availability) and increased agricultural and rural incomes (better access to food), and entails positive spillovers to other sectors and contributes to economy-wide growth. Agricultural productivity growth is also vital for stimulating growth in other sectors of the economy (Moreno & Sunding 2003; Kidane *et al*. 2006).

Studies on the adoption of technology date back to the exploration of the economics of technological change by Griliches (1957), and the formal adoption and diffusion models applied by Mansfield (1963), Feder *et al*. (1985) and then by Green and Ng'ong'ola (1993). Since then, adoption and diffusion have been conceived as the processes governing the utilisation of innovations, and studies of adoption behaviour emphasise factors that affect the adoption of agricultural technologies. In developing countries like Ethiopia, agriculture is a strong option for spurring growth, overcoming poverty, and enhancing food security, and this has necessitated the need to increase agricultural productivity through the introduction and use of improved agricultural technologies (Moreno & Sunding 2003; World Bank 2008). A number of area- and commodity-specific studies of technology adoption conducted in Ethiopia have focussed minimally on the link between the adopted technologies and food security, their interactions, and the effect of the former on the latter. Some of the latest adoption studies in Ethiopia include the evidence provided by Chilot *et al*. (1996), Asfaw *et al*. (1997), Negatu and Parikh (1999), Mulugeta *et al*. (2001), Nega and Sanders (2006), Aklilu and Graaff (2007), Hassen *et al*. (2011) and Workneh and Puskur (2011).

Food security is assumed to exist "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO 1996). The four dimensions of food security are food availability, stability of supply, accessibility of food, and quality and safety of food. In the literature there are three categories of indicators of food security, each with limited capacity to capture the extent of food security and hunger: process, outcome, and trend indicators (Hoddinott 1999; Bickel *et al*. 2000; Swindale & Ohri-Vachaspati 2005; Smith & Subandoro 2007). The two basic outcome measures of diet quantity available to a household are daily food energy consumption per capita or per adult equivalent, and percentage of households or people that are food energy-deficient (FAO/WHO/UNU, 1985). The second diet quantity indicator is the percentage of households in a population group that do not consume sufficient dietary energy. If the estimated total energy in the food that the household acquires daily is lower than the sum of its members' daily requirements, the household is classified as food energy-deficient or food insecure.

On the other hand, the three basic indicators of diet quality of a household are diet diversity, percentage of food energy from staples, and quantities of foods consumed daily per adult equivalent (Hoddinott 1999; Smith & Subandoro 2007). Improved diet quality is associated with improved birth weight and child nutritional status, and reduced mortality (Ruel 2002, 2003). It is also recognised that inadequate diet quality rather than insufficient energy consumption is becoming the main dietary constraint facing poor populations.

Empirical evidence of food security in Ethiopia indicates the prevalence of a high level of food insecurity, with significant idiosyncratic and spatial characteristics. The specific food security studies by Samuel (2004), Berhanu (2004), Freihiwot (2007), Bogale and Shimelis (2009), Zegeye and Hussien (2011), Hadleya *et al*. (2011), Abebaw *et al*. (2011) and Hailu (2012) generally suggest that the depth and intensity of food insecurity are high, influenced by poor functioning of marketing systems and other household and socioeconomic factors. However, all the studies have focussed little on the role and measurement of adoption of agricultural technologies, and their interdependence with the food security situation of households. To account for these shortcomings, the objective of this study was to measure the multivariate interdependence of households' adoption decisions relating to agricultural technologies and their food security situation, and to identify their underlying determinants. To this end, univariate and multivariate probit estimation and simulation techniques were employed to verify the consistency and interaction of all outcome variables.

2. Research Methodology

2.1 Dataset and variables

Agricultural systems in Ethiopia are classified into four types, namely the highland mixed farming system, low plateau and valley mixed agriculture, pastoral livestock production of the arid and semi-arid zones, and commercial agriculture (Ayele 1980). This study was conducted in four districts, selected from two major sedentary sub-farming systems (Central and Eastern highlands) covering about 40% of the total sedentary farming system in Ethiopia. To account for the expected heterogeneity in the samples operating in different farming systems, a stratified two-stage random sampling procedure was employed and a total of 260 households were randomly and proportionately sampled.

The major endogamous variables considered in the analysis include the household's food security status, determined from daily calorie availability per adult equivalent compared to the predetermined daily minimum calorie requirement for Ethiopia (2 200 kilocalorie), dietary diversity status, determined from the number of food groups consumed out of seven food groups, and adoption status of three agricultural technologies (chemical fertiliser, high-yielding crop varieties, and improved livestock breeds).

The food security and adoption status of agricultural technologies in Ethiopia was generally hypothesised to be determined by family size (head count), gender of the household head (binary), literacy status (binary), farming experience (years), total cultivated land and its allocation to production of staples and cash crops (hectares), irrigation water use (binary), quantity of fertiliser (quintals) used for crop production, livestock holding in tropical livestock units (TLU), gross income earned, access to credit (binary), participation in off-farm activities (binary), distance (kilometres) to major town, nearest road and development station as a proxy for market information on food and agricultural technologies, transaction cost, and access to government extension services respectively, and a dummy variable for the two farming systems as a proxy to capture omitted location-specific characteristics (Hoddinott 1999; Bouis & Hunt 1999; Bickel *et al*. 2000; Ruel 2002, 2003; Moreno & Sunding 2003; Aklilu & Graaff 2007; Smith & Subandoro 2007; Kennedy *et al*. 2011; Hassen *et al*. 2011; Workneh & Puskur 2011).

2.2. Estimation and simulation techniques

Two food security measures and the adoption of three agricultural technologies were analysed. Chemical fertiliser, high-yielding crop varieties and improved livestock breeds were adopted by 43%, 29% and 32% of the sample households respectively, suggesting that the majority of the households were non-adopters. The interest in this regard was to measure the likelihood of households to adopt an agricultural technology, not their intensity of adoption. Accordingly, food security status and the adoption of each type of agricultural technology were estimated by a univariate probit model (Maddala 1983; Long 1997; Long & Freese 2005; Cameron & Trivedi 2009; Greene 2012):

$$y_i^* = \mathbf{x}\boldsymbol{\beta} + u_i \tag{1}$$

$$y_i = \begin{cases} 1 \ \ if \ \ y_i^* = \mathbf{x}\boldsymbol{\beta} + u_i > 0 \\ 0 \ \ if \ \ y_i^* \le 0. \end{cases} \tag{2}$$

where y_i^* is the binary latent variable for food security status, dietary diversity status, fertiliser use, adoption of high-yielding crop varieties or improved livestock breeds (observed if $y_i^* > 0$, 0 otherwise); and $\mathbf{x}$ is a vector of household-specific and other socioeconomic factors determining food security status and the adoption of an agricultural technology.

However, the above univariate probit estimation of food security measures and adoption status of each agricultural technology would be misleading for the expected problem of simultaneity. The adoption of one type of agricultural technology would be dependent on the adoption of the other, since household adoption decisions are interdependent, suggesting the need to estimate them simultaneously. To account for this problem, a seemingly unrelated multivariate probit simulation model was employed (Long 1997; Chib & Greenberg 1998; Cappellari & Jenkins 2003):

$$\begin{aligned} fert_i^* &= \mathbf{x'_1}\,\boldsymbol{\beta}_1 + \varepsilon_{1i}, \\ hyvc_i^* &= \mathbf{x'_2}\,\boldsymbol{\beta}_2 + \varepsilon_{2i} \\ hyvl_i^* &= \mathbf{x'}_3\,\boldsymbol{\beta}_3 + \varepsilon_{3i}, \end{aligned} \tag{3}$$

where

$$\begin{pmatrix} \varepsilon_{1i} \\ \varepsilon_{2i} \\ \varepsilon_{3i} \end{pmatrix} \sim N\left[\begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}\begin{pmatrix} 1 & \rho_{12} & \rho_{13} \\ \rho_{12} & 1 & \rho_{23} \\ \rho_{13} & \rho_{23} & 1 \end{pmatrix}\right], \tag{4}$$

$$\begin{aligned} E(\varepsilon|\mathbf{x}) &= 0 \\ Var(\varepsilon|\mathbf{x}) &= 1 \\ Cov(\varepsilon|\mathbf{x}) &= \rho. \end{aligned} \tag{5}$$

where $fert_i$, $hyvc_i$, and $hyvy_i$ are the households' adoption status of chemical fertiliser, high-yielding crop varieties and improved livestock breeds respectively; $\mathbf{x}_1$ to $\mathbf{x}_3$ are vectors of independent variables determining the respective adoption variables; $\boldsymbol{\beta}'s$ are vectors of simulated maximum likelihood (SML) parameters to be estimated; ε_{1i} to ε_{3i} are correlated disturbances in a seemingly unrelated multivariate probit model; and ρ's are tetrachoric correlations between endogenous variables.

In the trivariate case there are eight joint probabilities corresponding to the eight possible combinations of successes (a value of 1) and failures (a value of 0). If we focus on the probability that every outcome is a success, for instance, the probabilities that enter the likelihood function of the technology adoption simulation are explained as

$$\begin{aligned} &\Pr\left(fert_i = 1,\ hyvc_i = 1,\ hyvl_i = 1\right) \\ &= \Phi_2(\boldsymbol{\beta}_1'\mathbf{x}_1, \boldsymbol{\beta}_2'\mathbf{x}_2, \boldsymbol{\beta}'_3\,\mathbf{x}_3, \rho) \\ &= \Pr\left(\varepsilon_{1i} \le \boldsymbol{\beta}'_1\,\mathbf{x}_1,\ \varepsilon_{2i} \le \boldsymbol{\beta}'_2\,\mathbf{x}_2,\ \varepsilon_3 \le \boldsymbol{\beta}'_3\,\mathbf{x}_3\right). \end{aligned} \tag{6}$$

where Φ_2 is the bivariate standard normal distribution.

To estimate the interdependence of household decisions to adopt agricultural technology and the household's food security objectives, the above trivariate probit simulation model was extended to a multivariate probit simulation of five endogenous variables, including both groups of indicators for adoption and the food security situation:

$$\begin{aligned} fert_i^* &= \mathbf{x'_1}\,\boldsymbol{\beta}_1 + v_{1i}, \\ hyvc_i^* &= \mathbf{x'_2}\,\boldsymbol{\beta}_2 + v_{2i} \\ hyvl_i^* &= \mathbf{x'}_3\,\boldsymbol{\beta}_3 + v_{3i} \\ \sec ur_i^* &= \mathbf{x'}_4\,\boldsymbol{\beta}_4 + v_{4i} \\ hdds_i^* &= \mathbf{x'}_5\,\boldsymbol{\beta}_5 + v_{5i}, \end{aligned} \tag{7}$$

$$\begin{pmatrix} v_{1i} \\ v_{2i} \\ v_{3i} \\ v_{4i} \\ v_{5i} \end{pmatrix} \sim N\left[\begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}\begin{pmatrix} 1 & \rho_{12} & \rho_{13} & \rho_{14} & \rho_{15} \\ \rho_{21} & 1 & \rho_{23} & \rho_{23} & \rho_{25} \\ \rho_{31} & \rho_{32} & 1 & \rho_{34} & \rho_{35} \\ \rho_{41} & \rho_{42} & \rho_{43} & 1 & \rho_{45} \\ \rho_{51} & \rho_{52} & \rho_{53} & \rho_{54} & 1 \end{pmatrix}\right] \tag{8}$$

where $secur_i$ and $hdds_i$ are the households' food security and dietary diversity status respectively; $\mathbf{x}_1$ *to* $\mathbf{x}_5$ are vectors of independent variables determining the respective latent variables; v_{1i} to v_{5i} are correlated disturbances in a seemingly unrelated multivariate probit model, and the other notations and assumptions are as explained earlier.

3. Results and Discussion

3.1 Univariate estimation results

Two important dimensions of the food security situation were measured and estimated in this study. Household dietary quantity was measured by daily calorie availability per adult equivalent (kilocalorie, kcal) and percentage of households that are food energy-deficient. Accordingly, households' food security status was measured by comparing the level of the daily calorie availability per adult equivalent with the predetermined caloric requirement per adult equivalent for Ethiopia, which is 2 200 kcal per day. The distribution of the estimated daily calorie availability per adult equivalent was a bit right-skewed, suggesting that the higher number of food-insecure households fell below the mean value. Counts of food groups and food items consumed by a household were assumed to capture the level of diet quality and diversity of the household. Seven major food groups and the total counts of food items consumed by a household were analysed to measure the level of diet diversity as an indicator of diet quality. The frequency distribution of counts of food items suggested that most households consumed five kinds of food items grouped in three food categories.

The determination of the food security status of households based on their daily calorie availability showed that 42.7% of the sample households were food secure, while the majority were food insecure or calorie-deficient. The number of food items consumed in each food group was counted and a total of 26 food items were identified. The analogous binomial classification of households by their level of dietary diversity into two, as 'medium diversity' and 'low diversity' status, showed that only 40% of the households consumed more than three food groups.

Before the estimation of their interdependence, food security indicators and the adoption of the three agricultural technologies were estimated by univariate probit models (Table 1). Food security status was significantly and positively determined by female heads, cultivated land, quantity of chemical fertiliser used, annual gross income, and access to credit, but negatively influenced by family size, land allocated to staples, and irrigation water use. The results indicated that the likelihood of households to be food secure was about 42.3%. The factors determining the households' diet diversity were literacy status, livestock holding, annual income, farming system and other exogenous shocks. The probability of households having a semi-diversified diet was only 37.2%.

The adoption of chemical fertiliser was enhanced and determined by irrigation water use, agricultural income, distance to research institution and the farming system. Adoption of high-yielding crop variety, on the other hand, was improved by land allocated to cash crops and the farming system. Factors determining the adoption of improved livestock breeds were farming experience, land cultivated, irrigation water use, distance to nearest road, and the farming system. The magnitude of marginal effects of farming systems (48% to 54%) was very pronounced in enhancing the adoption of all three agricultural technologies. The second largest marginal effect was that of agricultural income (29%) on adoption of chemical fertiliser, followed by land allocated to cash crops (23%) on adoption of high-yielding crop variety. The predicted probabilities suggested that the likelihood of households to be food secure, to have a semi-diversified diet, and to adopt chemical fertiliser, high-yielding crop varieties and improved livestock breeds, were 42%, 37%, 34%, 20% and 21% respectively.

Table 1: Marginal effects of univariate probit estimates of adoption and food security status

Determinants	Food security	Dietary diversity	Fertiliser	Crop variety	Livestock breeds
Female heads	0.18*	0.05	-0.07	-0.05	-0.08
Family size	-0.06***	0.01	-0.001	0.02	0.01
Literacy status	-	0.18***	-	-	-
Farming experience	-	-	-0.002	-0.003	-0.01***
Land cultivated	0.28***	0.03	-	-	0.15***
Land allocated to staples	-0.26**	-	-	-	-
Land allocated to cash crops	-	-	0.11	0.23***	-
Livestock holding (TLU)	0.01	0.04***	-	-	-
Irrigation water use	-0.21***	-0.08	0.19**	0.08	0.14*
Quantity of fertiliser	0.12*	-0.04	-	-	-
Annual gross income (log)	0.09*	0.15***	-	-	--
Gross agricultural income (log)	-	-	0.29***	0.05	0.04
Access to credit	0.16*	-0.05	-	-	-
Off-farm activity	-0.10	-0.04	-	-	-
Distance to nearest road	-	-0.01	0.01	0.004	-0.04***
Distance to development station	-	-	0.02	0.001	0.01
Farming system	-0.06	0.54***	0.53***	0.48***	0.54***
Log likelihood	-145.06	-135.04	-123.15	-109.23	-112.94
Pseudo R^2	0.18	0.23	0.29	0.30	0.30
Predicted probability	0.42	0.37	0.34	0.20	0.21

Note: ***, ** and * signify significance levels of 1%, 5% and 10% respectively.

3.2 Interactions of adoption decisions

The expected multivariate interdependence of adoption of chemical fertiliser, high-yielding crop varieties and improved livestock breeds was accounted for by employing the multivariate probit simulation of the adoption of the three agricultural technologies (Table 2). The null that the tetrachoric correlations are jointly zero and the three adoption decisions are independent was rejected at the 1% level. The SML estimation results suggested that there was positive and significant interdependence between household decisions to adopt chemical fertiliser and high-yielding crop varieties, and high-yielding crop varieties and improved livestock breeds, but not between adoption of chemical fertiliser and improved livestock breeds.

The adoption of chemical fertiliser was enhancing the adoption of high-yielding crop varieties, since the households' decision to adopt one type of technology reinforced adoption of the other, specifically when they were adopted in the same enterprise. The adoption of chemical fertiliser was improved by irrigation water use, agricultural income and the farming system, but adversely affected by other exogenous shocks. All the covariates were similar to the results from the univariate probit estimation results. However, the probability of households adopting fertiliser was 39%, which was significantly higher than the probability predicted from the univariate probit model (34%).

Adoption of a high-yielding crop variety was improved by land allocated to cash crops, agricultural income and the farming system, but significantly and negatively affected by other exogenous shocks. The predicted probability of adopting of high-yielding crop variety was 29%, nine percentage points higher than the probability estimated in the univariate estimation (20%). Farming experience, land cultivated, irrigation water use, distance to nearest road, farming system and other exogenous shocks were significant determinants of the adoption of improved livestock breeds. The likelihood of households adopting improved livestock breeds was 31%, which was 10 percentage points higher than the probability estimated in the univariate analysis (21%).

If households were able to adopt all three agricultural technologies, their joint likelihood of adopting these technologies would be only 12%. It was unlikely for households to adopt all three agricultural technologies simultaneously. This was justified either by the fact that simultaneous adoption of all the technologies was unaffordable for the smallholders, or that all three technologies were not simultaneously accessible in the study areas. However, their joint probability of not adopting all the agricultural technologies was 44%, implying that the households were more likely to fail. This evidence suggests the need to launch a progressively developing package and scheme of agricultural technology adoption, and points to the importance of mobilising additional resources to augment households' efforts at accelerated technology adoption. It was also shown that the adoption of chemical fertiliser, high-yielding crop varieties and improved livestock breeds was determined by similar underlying factors of adoption, suggesting the feasibility of launching a synergetic programme for the adoption and dissemination of agricultural technologies in Ethiopia.

Table 2: Multivariate probit simulation results of agricultural technology adoption

Variables	**Coefficients (adoption equations)**		
	Fertiliser	**Crop variety**	**Livestock breeds**
Female heads	-0.19	-0.13	-0.29
Family size	-0.02	-	0.02
Farming experience	0.004	-0.01	-0.02***
Land cultivated	-	-	0.46***
Land allocated to cash crops	0.27	0.88***	-
Irrigation water use	0.49**	0.28	0.45**
Gross agricultural income (log)	0.81***	0.20*	0.14
Distance to major town	-	-0.003	-
Distance to nearest road	0.02	-	-0.13***
Distance to development station	0.04	-	0.04
Farming system	1.53***	1.63***	1.76***
Constant	-9.37***	-3.98***	-2.86***
Predicted probability	0.39	0.29	0.31
$\hat{\rho}_{21}$		0.41***	
$\hat{\rho}_{31}$		0.12	
$\hat{\rho}_{32}$		0.24*	
Number of simulations (draws)		100	
Log likelihood		-339.43	
Wald $\chi^2(25)$		175.88	
Wald test of rho, $\rho_{21} = \rho_{31} = \rho_{31}$ =0, $P > \chi^2(3)$		0.01	
Joint probability (success)		0.12	
Joint probability (failure)		0.44	

Note: ***, ** and * signify significance levels of 1%, 5% and 10% respectively.

3.3 Interdependence of adoption and food security

The adoption status of the three agricultural technologies was simulated with two food security indicators to identify the presence of nonlinear interdependence among them. The SML probit estimates suggest the presence of some interdependence among agricultural technology adoption decisions and the food security conditions of the households (Table 3). It was also indicated that the factors determining each equation were consistent with the results of the previous simulation of agricultural technology adoption.

Table 3: Multivariate probit simulation results of technology adoption and food security

Variables	Coefficients (equations)				
	Food security	**Dietary diversity**	**Fertilizer**	**Crop variety**	**Livestock variety**
Female heads	0.52**	0.12	-0.17	-0.06	-0.26
Family size	-0.15***	0.02	-0.02	-	0.01
Literacy status	0.30	0.53***	-	-	-
Farming experience	-	-	-.003	-0.01	-0.02***
Land cultivated	0.75***	0.13	-	-	0.47***
Land allocated to staples	-0.65**	-	-	-	-
Land allocated to cash crops	-	-	0.31	0.84***	-
Irrigation water use	-0.65***	-0.22	0.51***	0.30	0.49**
Quantity of fertiliser	0.23	-0.18	-	-	-
Livestock holding (TLU)	0.02	0.10***	-	-	-
Gross annual income (log)	-	0.45***	-	-	-
Gross agricultural income (log)	0.25	-	0.80***	0.20*	.1426348
Access to credit	0.41*	-0.13	-	-	-
Off-farm activity	-0.27	-0.12	-	-	-
Distance to major town	-	-	-	-0.003	-
Distance to nearest road	-	-	0.02	-	-0.13***
Distance to development station[a]	-	-	0.04	-	0.04**
Farming system	-0.14	1.66***	1.57***	1.59***	1.79***
Constant	-2.25	-6.02***	-9.30***	-3.94	-2.87***
Predicted probability	0.43	0.40	0.39	0.29	0.31
Joint probability (success)	0.04				
Joint probability (failure)	0.17				
Number of simulations (draws)	5				
Log pseudo likelihood	-615.52				
Wald $\chi^2(48)$	376.28				
Likelihood ratio test of rho[b] = 0, $\Pr > \chi^2(10)$		0.03			

Notes: a: Distance to development station was not a good proxy for access to government extension services.
b: For lack of space, tetrachoric correlations are not reported.
***, ** and * signify significance levels of 1%, 5% and 10% respectively.

The simulation results indicate that the probability that households are food secure and have a semi-diversified diet was 43% and 40% respectively. These probabilities were a bit higher than the probability estimated from the univariate probit models of food security status (42%) and dietary diversity status (37%). However, it was verified that households' food security conditions were not largely impacted on by the adoption of agricultural technologies, since the households' likelihood to adopt these technologies was very much limited. To enhance food security and dietary diversity status at the household level it would be necessary to facilitate the adoption of agricultural technologies. The joint probabilities of success and failure of the five variables also suggest that it would be unlikely for households to adopt all the three technologies and achieve their food security objectives simultaneously, for their likelihood to do so was only 4%.

4. Conclusion and Recommendations

The empirical evidence in this paper suggests that the food security situation of rural households in Ethiopia is very poor and that a great majority of people suffer from deficiencies in their daily calorie intake and from problems relating to dietary diversity. The adoption of agricultural technologies was very low (not more than 39%) and the majority of households were non-adopters of these simple agricultural technologies. From the likelihood of households to adopt the technologies and the unsatisfactory effects of these technologies on the food security situation, it is evident that the introduction and dissemination of yield-enhancing agricultural technologies is very limited and that the food security situation is bad. Even if the adoption of agricultural technologies was positively and significantly associated with households' food security situation, the limited success in the introduction and dissemination of the technologies at household level dilutes the opportunity to enhance food security through the use of agricultural technologies.

It is evident that the effects of government extension services and marketing infrastructural facilities are generally insignificant and sometimes irrelevant, suggesting the need to improve access to packages of agricultural technologies. In order to boost agricultural production and productivity, a concerted effort is required to generate, introduce, integrate and disseminate appropriate agricultural technology packages, which, in turn, will improve food security. Moreover, to accelerate food production and enhance the food security conditions of rural households, the functioning of input and output agricultural markets, including technological inputs and their expected net returns, need to be improved.

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