TECHNOLOGICAL CHANGE AND FARM HOUSEHOLD FOOD SECURITY IN MORETNA JIRU DISTRICT OF THE CENTRAL HIGHLANDS OF ETHIOPIA

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Abstract: *Food security is a relative concept defined as the access to food by all people at all times to enough food for an active, productive and healthy life. Food security can be achieved when households produce enough staple crops for their own consumption or when they have enough disposable income to meet their food needs from the market. Like many developing countries, Ethiopian farmers in the highlands predominantly practice subsistence farming, and are often subject to food insecurity. At the current rapidly growing population and the declining arable land, the elimination of chronic food insecurity is highly linked with the use of productivity increasing technological innovations. This study has been conducted with the major objective of assessing the impact of technological change on farm household food security in one of the districts of the Central Highlands of Ethiopia. With the help of simultaneous equation Tobit model, the relationship between household food security and technological change has been analyzed. Based on the recommended calorie consumption per adult equivalent requirement (243 kg of grains per annum), 67.5 percent and 32.5 percent of the sample farm households are classified as food secure and insecure respectively. Similarly, for the technological change, 75.8 percent of the sample farmers are found as adopters of improved crop varieties while the remaining 24.2 percent of farmers as non-adopters. The result indicates that there is a significant and positive simultaneous interaction between technological change and household food security. On the one hand, a unit percentage change in the intensity of technology*

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adoption (share of improved crop, varieties) positively changes the probability of the household being secured by 31 percent, revealing that the response of household food security to technology adoption is much higher than other factors. On the other hand, a 1 percent increase in the level of food security increases the probability of adopting improved technologies by 10 percent. Hence efforts to improve food security could enhance the probability and intensity of technology adoption. In general, it is clearly confirmed that technology adoption and household food security have been highly correlated.

INTRODUCTION

Food security is defined as access by all people at all times to enough food for an active, productive, and healthy life (World Bank, 1986). Currently some 800 million people in developing countries are estimated to be food insecure (IFPRI, 2002). Several studies have well documented that there exists severe food insecurity in Ethiopia, affecting a large number of people (IFAD, 1989; Maxwell 1992; Debebe and Maxwell 1992). About 62 percent of the population is estimated to be food insecure (Von Braun, 1990). The poor agricultural performance along with the rapidly growing population has led to a worsening food insecurity problem. The agricultural sector has failed to meet the growing demand for food. The per capita food production has dropped by 1.3 percent per annum against a 3 percent population growth rate during 1979-90 (World Bank, 1994).

In addition, the apparent high level of poverty has been exacerbating the food insecurity problem since chronic food insecurity is caused by the inability of the household to produce, purchase or to have access to food (Sen, 1981). It is estimated that about 52 percent of the population live below the poverty line (World Bank, 1996). Especially, rural poverty remains unabated and about 65 percent of the rural population live in absolute poverty (World Bank, 1992)

Food security is achieved when households produce enough staple crops for their own consumption or when they have enough disposable income to meet their food needs from the market. The production of cash crops by rural households can enhance food security by providing households with additional income for purchasing food. Well functioning competitive markets are also important for food security because they facilitate marketing and transportation of foods between surplus and deficit regions, assuring rural and urban households of adequate supplies of staple foods at reasonable prices.

Under Ethiopian conditions in general and that of the Central Highlands in particular, where smallholders are dominantly subsistent, the production of food plays a significant role in household food security. In a correlated condition where smallholders dispose only about 20 percent of their crop production (Desalegne, 1984), the role of markets and distribution aspect of food security is limited.

Since the 1990s, high priority has been given to agriculture to stimulate agricultural growth and ensure household food security. Agricultural growth can contribute to food security in two ways: (1) through growth in food production which enhances better food availability and a decline in food prices, and (2) through higher cash income (alleviated poverty) which enables greater command over food and increases investment capacity (Sen, 1990; Eicher, 1990). But, the growth of agriculture depends mainly on the use of improved agricultural technologies. The potential contribution of technological innovations towards tackling food insecurity is reducing the root cause - unstable and low food crop production and yield. Alauddin and Tisdel (1991) showed that the 'Green Revolution' in Bangladesh had reduced the relative variability of food grain production and yield.

In smallholder mixed farming systems in the Central Highlands of Ethiopia where tef and wheat are the major crops covering about 70 percent of the annually cultivated land, food security is largely dependent on these crops and pulses grown in rotation with these cereals (Workneh, 1999). Livestock products also supplement the major food sources directly or indirectly through cash revenue. Food availability in Ethiopia is to a large extent determined by the country's domestic production of cereals: the correlation between annual per capita availability and production is 0.76 (Webb *et. al.*, 1992). It is also estimated that about 71 percent of the calorie supply in

Ethiopia is derived from cereals (FAO, 1996). In terms of area coverage, cereals rank first which account for 79.6 percent of the total cultivated land covered with annual crops, while among cereals Teff ranks first after which come maize, wheat, sorghum, and barley (CSA, 2002).

At the current rapidly growing population and the declining arable land, the elimination of chronic food insecurity is highly linked with the use of productivity increasing technological innovations, which have to be supportive to and compatible with a sustainable intensification of agriculture.

The agricultural research system in Ethiopia has been generating a number of production technologies for the major food crops (teff, maize, wheat, barley, sorghum, chickpea, faba bean and lentil) for more than three decades. The superior performance of the production technologies compared to the local packages has been verified through several on-farm demonstration trials. Concerted efforts have been made in the area of technology transfer to the smallholder agriculture since 1993 to ensure food security at the household level. In this case the Sasakaw Global 2000 (SG2000) extension project and its prototype adopted by the Ministry of Agriculture have been successful in transferring mainly improved crop production technologies through participation of farmers using demonstration plots (0.50 ha).

The aim of this study is, therefore, to demonstrate the impact of technological changes on farm household food security while looking into the effect of food security status on technological change.

The specific objectives of the study are:

1. To examine technological changes, i.e., use of improved crop varieties, fertilizer and herbicides in the production of major food crops (wheat, teff, lentil, faba bean, chickpea and sorghum); and

2. To assess the effect of technological change and other socio-economic factors in securing better food status.

METHODOLOGY

Model

Many empirical studies have employed the Tobit model to investigate the influence of technological change on adoption and food crop production (e.g Adesina and Zinnah, 1993, Brham et al, 1995; Deaton, 1997 and more detail www.cabi-publishing.org).

The Tobit model has an advantage in that its coefficients can be further disaggregated to determine both changes in the probability of being above the limit value, usually zero, and changes in the value of the dependent variable if it is already above the limit (McDonald & Moffitt, 1980). Important economic and policy implications can be derived from these disaggregated coefficients.

The stochastic model underlying Tobit could be defined by the following relationship:

$$y_i = \beta' X_i + \varepsilon_I \qquad \text{if } \beta' X_i + \varepsilon_I > 0 \qquad (1)$$

$$= 0 \qquad \text{if } \beta' X_i + \varepsilon_I \leq 0$$

Where y is the dependent variable; **X** is a vector of independent variables; β is a vector of parameters to be estimated; and ε is an independently distributed error term assumed to be normal with zero mean and constant variance σ^2.

The Tobit model assumes that there is a stochastic index equal to $(\beta' X_i + \varepsilon_I)$ whose value is observed only when it is positive, and hence qualifies as an unobserved, latent variable.

Following Tobin J. (1958), the expected value of y in the model is

$$E(y) = \Phi(z)\beta' X + \sigma\phi(z) \qquad (2)$$

Where **$z = \beta'X/\sigma$, $\phi(z)$** is the unit normal density, **$\Phi(z)$** is the cumulative normal distribution function and σ the standard error of the error term.

Further, McDonald and Moffitt (1980) show that:

$$E(y) = \Phi(z)\, E(y^*) \qquad (3)$$

Where **$E(y^*)$** is the expected value of y for observations above the limit.

Based on such basic relationship, McDonald and Moffit (1980) show that the marginal effect of an independent variable on the expected value of the dependent variable is:

$$\partial E(y)/\partial X_I = \Phi(z)\beta \qquad (4)$$

The change in the probability of being above the limit as independent variable **X_I** changes is:

$$\partial \Phi(z)/\partial X_I = \phi(z)\beta/\sigma \qquad (5)$$

The marginal effect of an explanatory variable on the expected value of y of those above the limit is:

$$\partial E(y^*)/\partial X_I = \beta[1 - z\phi(z)/\Phi(z) - \phi(z)^2/\Phi(z)^2\,] \qquad (6)$$

The empirical models are discussed below. In this study, it is hypothesized that technological change along with other socio-economic factors status affects farm household food security while technological change itself is an endogenous variable which could be affected by the food security status of farm households. Therefore, a simultaneous equation Tobit model is used to determine the factors affecting household food security and technological change.

Technological change is, here, defined as the share of total cultivated land covered with improved varieties of crops while food security is calculated as a ratio of per capita food grain availability to the recommended per capita food grain requirement, i.e., 243 kg grain per adult equivalent. The annual requirement per adult equivalent, 243 kg of grain, is computed from the recommended calorie consumption and the average calorie contents of cereals, pulses and oilseeds (Latham, 1979).

The simultaneous equation Tobit model involves a two-stage estimation procedure: The first stage involves the estimation of the Tobit models for food security and intensity of technology adoption (technological change) by regresing the respective endogenous variables on selected independent variables. In the second stage, the predicated values of the respective endogenous variables obtained in the first step are used to compute the maximum likelihood estimates of the explanatory variables (Amemiya, T. (1979); Nelson and Olson, 1978).

The simultaneous estimation of food security (**FOODSEC**) and technological change (**TECH**) is expressed algebraically as a system of simultaneous equations as shown below:

$$\mathbf{FOODSEC} = \omega\mathbf{TECH} + \beta\mathbf{X} + \varepsilon_1 \qquad \mathbf{(7)}$$

$$\mathbf{TECH} = \omega\mathbf{FOODSEC} + \beta\mathbf{X} + \varepsilon_2$$

Where **X** is a vector of independent variables, $\omega$and β is vectors of parameters for the respective variables, and ε_1 and ε_2 are the error terms.

In the first stage, the predicted values of the endogenous variables are estimated using the following instrumental variables:

FOODSEC = f(SEX, AGE, EDUCATIO, FAMLYSIZ, CULTLAND, VERTPROP, FERTCOST, TLU, OFFARMWO)

(8)

TECH = g(SEX, AGE, EDUCATIO, PROPACTV, CULTLAND, CERLPROP, VERTPROP, HIRELABR, OFFARMWO, EXTCONTA, GETCREDI)

The description of variables is given in Table 1.

The second stage involved estimation of the following equations:

$$\textbf{FOODSEC} = \beta_{01} + \beta_{11}\textbf{PV}_{\textbf{TECH}} + \beta_{21}\text{SEX} + \beta_{31}\text{AGE} + \beta_{41}\text{EDUCATIO} + \beta_{51}\text{FAMLYSIZ} + \beta_{61}\text{CULTLAND} + \beta_{71}\text{VERTPROP} + \beta_{81}\text{FERTCOST} + \beta_{91}\text{TLU} + \beta_{101}\text{OFFARMWO} + \varepsilon_1$$

$$\textbf{TECH} = \beta_{02} + \beta_{12}\textbf{PV}_{\textbf{FOODSEC}} + \beta_{22}\text{SEX} + \beta_{32}\text{AGE} + \beta_{42}\text{EDUCATIO} + \beta_{52}\text{PROPACTV} + \beta_{62}\text{CULTLAND} + \beta_{72}\text{CERLPROP} + \beta_{82}\text{VERTPROP} + \beta_{92}\text{HIRELABR} + \beta_{102}\text{OFFARMWO} + \beta_{112}\text{EXTCONTA} + \beta_{122}\text{GETCREDI} + \varepsilon_2 \quad \textbf{(9)}$$

Where $\textbf{PV}_{\textbf{FOODSEC}}$ and $\textbf{PV}_{\textbf{TECH}}$ are the predicted values of **FOODSEC** and **TECH** obtained from the first stage, respectively. ε_i the error term assumed to be normal with zero mean and constant variance σ^2.

Variables specification

The household food security model is specified based on the hypotheses that technological change is positively related to household food security status; improved agricultural technologies increase the productivity of the farm and thereby improve food availability in the household.

Sex (SEX) and age (AGE) of the household head are hypothesized to influence farm household food security negatively. In Ethiopia, women often have limited access to resources and are vulnerable to food insecurity problem. Older farmers are expected to have limited access to resources, information, and technology, which result ultimately in vulnerability to food insecurity problem.

Education level of the farm household head (EDUCATIO) is expected to influence household food security positively since educated farmers have more access to information and technology, which enhances farm productivity and improve food security status.

It is hypothesized that family size (FAMLYSIZ) is negatively related to household food security. A household with large family size is more likely to be food insecure as compared to a household with small family size. The size of cultivated land (CULTLAND) and livestock (TLU) are hypothesized to influence the status of household food security positively since farmers with larger cultivated land and livestock are often wealthier and more likely to be more food secure. In addition, farmers with off-farm work (OFFARMWO) are expected to be more food secure than those without off-farm income.

It is further hypothesized that the quality of land is positively related to food security by affecting food production. In this case farmers with more proportion of Vertisols land (VERTPROP) are more likely to be food secure. Land areas with Vertisols were reported as fertile and the most preferred soil type in the study area.

Fertilizer expenditure (FERTCOST) is expected to influence the food security status negatively. The increasing fertilizer price accounts for the largest share of production cost for the cash-constrained subsistence farmers. Farmers are normally expected to settle their input loan immediately after harvest when food grain prices are often very low. This causes the farmers to sell more food grain, which ultimately depletes the availability of food in the household.

The technology adoption model is specified based on the following hypotheses: It is hypothesized that the food security status of farm households positively affects the technology adoption decisions. It is expected that food secured households have access to resources and information so that they are more likely to adopt new technologies. It is further hypothesized that technology adoption decisions are affected by the socio-economic characteristics of the farm households, i.e., sex (SEX), age (AGE), and education level (EDUCATIO) of the farmer. It is expected that male-headed households are more likely to adopt new technologies since they have more access to resources than the female-headed households. Age could affect technology adoption positively or negatively depending on the situation. It is expected that younger farmers are more likely to adopt new technologies, as they are often more educated and risk takers than older farmers. The education level of the farmer is expected to influence technology adoption positively.

It is further hypothesized that the proportion of active labor (PROPACTV) in the household is positively related to adoption decisions. A larger household labor may enhance the adoption of improved varieties since it solves the labor constraint created by the new technology.

The size of cultivated land (CULTLAND) is expected to affect technology adoption decision positively since it reflects wealth and capacity to bear risks by the farmers. It is also hypothesized that the proportion of cultivated land allocated to cereals (CERLPROP) is positively related to the technology adoption decisions. This is of course related to the availability of a good number of dependable improved varieties released for cereals. In this case, farmers do have a number of options to make a choice that is compatible to their environment.

The proportion of Vertisols land (VERTPROP) is expected to affect the adoption decision positively. Improved varieties have good productivity with minimum risk on fertile soils. The use of hired labor (HIRELABR) for farm operations often indicates the capacity of the farmer having a relatively enough working capital. Hence, it is hypothesized that farmers who practice use of hired labor are more likely to adopt improved technologies. Farmers with off-farm activities (OFFARMWO) are also expected to adopt new technologies since the off-farm income increases the capacity of the farmers to bear risks associated with new practices.

Institutional services such as access to credit (GETCREDI) and the numbers of extension visits (EXTCONTA) are hypothesized to affect the adoption of improved varieties positively.

DATA

This study is based on data, which was collected from randomly selected farm households in Moretna-Jiru district in 2000/01 cropping season. A two stage random sampling technique was employed where the first stage involved a random selection of peasant associations (villages), while in the second stage farmers were randomly selected from these villages proportional to the population size of the respective villages. A total of 140 sample farmers were surveyed in nine villages of the district. However, because of missing values, some cases were lost and data from only 120 sample farmers were used in the analysis.

Moretna-Jiru district is located in Northern Shewa with elevations ranging from 1500 to 2650 meters above sea level and with an average annual rainfall of 800 mm. The district comprises two agro-ecologically contrasting areas: with the upper land area of Vertisols dominated agro-ecology and the gorge area with non-Vertisols dominated agro-ecology and rugged topography. The former is characterized by high production potential while the latter is somehow a marginal area. For this study, among the nine randomly selected sample villages three were from the gorge area.

The district is characterized by cereal based farming system where wheat and tef (*Eragrostis abyssinica*) are the major crops followed by chickpea, lentil, grasspea and fababean. According to the data from the district agriculture bureau, some 30,213 ha of land was cultivated with different field crops in the 2000/01 cropping season.

Farm households in the district obtain their staple food almost entirely from production of food crops. Hence, for this study, the annual production of cereals, pulses and oil crops, i.e., all field crops produced by the sample farmers were used to measure the food status of the households. The sample farmers were classified into two groups, food secure and food insecure, based on the recommended calorie consumption per adult equivalent[1], the average calorie content and annual production of cereals, pulses, and oilseeds. Based on this approach, 81 (67.5%) farmers were found food secure while 39 (32.5%) farmers were food insecure. For the technological change, 91 (75.8%) farmers were found adopters of improved crop varieties while 29 (24.2%) farmers were non-adopters.

[1] The recommended calorie consumption per adult equivalent is estimated to be 243 kg of grains per annum (Lathum, 1979).

Farm household characteristics

A list and description of variables characterizing farm households are given in Tables 1 and 2.

The sample result indicated that the average farm household had food availability, which is 35 percent above the minimum requirement while the food secured households had a twofold of its family food requirement.

The sample farmers on average planted 43 percent of their cultivated land with improved varieties. The average age of the sample farmers was 44.75 years with an average family size of 5.38. The average family size of the food secure households (5.11) is significantly ($p<0.066$) lower than that of the food insecure households (5.92). Food insecure households tended to have larger family size than the food secure household.

The sample farmers had on average 5.89 Gemede or 1.5 hectares of land. The landholding of food secured households (6.31 Gemed) is greater than that of the food insecure households (5.01Gemed) which is statistically significant ($p<0.01$). In terms of soil type, on average, 52 percent of the total cultivated land of the sample farmers was Vertisols. It was also found that there was a significant difference ($p<0.018$) between food secure and food insecure househlods in terms of Vertisols proportion. Food secure households tended to have more Vertisols land (57 percent), which is more productive soil type in the area. Indeed, it has an important productivity implication.

The average farmer had a livestock size of 4.81 TLU. It was found that food secured households had more livestock than food insecure households ($p<0.024$). Livestock size is an important indicator of wealth in the rural households.

On average, 63 percent of the sample farmers used hired labor for some farm operations. Only 8 percent of the farmers had off-farm work activities. With regard to institutional services, on average, farmers were visited about 8 times by the extension agents while 76 percent of the farmers had access to credit service.

In terms of technology adoption, the average farmer planted 43 percent of his cultivated land with improved varieties while adopters, on average, planted 56 percent of their cultivated land with improved varieties. Farmers in the study area, on average, planted 67 percent of their total cultivated with cereals. This clearly reveals the cropping system of the area, i.e. cereal-based cropping system. Moreover, technology adopters covered 71 percent of their cultivated land with cereals while the non-adopters planted only 52 percent of their land with cereals.

The average family size of non-adopters is significantly ($p<0.01$) greater than that of adopters. But, 80 percent of adopters of improved technology used hired labor for their farm operations while only 7 percent of the non-adopters used hired labor. In addition, it was found that the fertilizer expenditure of technology adopters (Birr 479) was much higher than that of the non-adopters, which was only about Birr 85. This is indeed in line with the fact that improved varieties need to have more fertilizer application to express their yield potential. About 86 percent of the adopters obtained credit facilities while only 45 percent of the non-adopters had access to this service. The average number of extension visits was found beyond expectation, i.e., non-adopters were visited more frequently than that of adopters. This is perhaps related to the degree of resistance to adoption of new innovations from the farmers' side or the method of extension service delivery.

Table 1: Mean Values of Factors Affecting Household Food Security

Variables	Description	Total Sample		Food insecure		Food secured		T & χ2 Test♣ P-Value
		Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	
FOODSEC	Food security = per capita food grain availability divided by the minimum per capita food requirements, i.e., 243 kg grain	1.35	1.26	0	0	2.0	1.0	0.000
TECH	Proportion of improved variety (proportion of cultivated land planted with improved varieties)	0.43	0.43	0.40	0.28	0.44	0.49	0.614
SEX	Sex of the head (Dummy; 1= if male, 0= otherwise)	89.2%	-	92.3%		87.7%	-	0.442
AGE	Age of the head (years)	44.75	12.79	43.03	12.26	45.58	13.0	0.308
EDUCATIO	Education of the head (Dummy; 1= if read & write, 0= otherwise)	65%	-	66.7%	-	64.2%	-	0.791
FAMLYSIZ	Total family size (persons)	5.38	2.27	5.92	2.44	5.11	2.15	0.066
PROPACTV	Proportion of active labor force	0.56	0.24	0.56	0.22	0.55	0.25	0.812
CULTLAND	Cultivated land (Gemed*)	5.89	2.42	5.01	1.92	6.31	2.53	0.006
CERLPROP	Proportion of cereal crops	0.67	0.19	0.68	0.19	0.66	0.19	0.508
VERTPROP	Proportion of Vertisols area	0.52	0.35	0.41	0.37	0.57	0.32	0.018
FERTCOST	Total fertilizer cost (Birr)	383.50	250.83	414.33	240.38	368.6	255.84	0.352
TLU	Livestock (TLU)	4.81	2.81	3.97	2.45	5.21	2.89	0.024
HIRELABR	Hired labor (Dummy; 1= if yes, 0= otherwise)	62.5%	-	56.4%	-	65.4%	-	0.339
OFFARMWO	off-farm work (Dummy; 1= if yes, 0=otherwise)	8.3%	-	2.6%	-	11%	-	0.113
EXTCONTA	Extensions contact (no. of visits)	7.59	10.3009	5.92	6.80	8.40	11.57	0.220
GETCREDI	Access to credit (Dummy; 1= if yes, 0=otherwise)	67.9%		75.6%		74%		0.516
	Observations		**120**		**39**		**81**	

*1 Gemed = 0.25 ha

♣T-Test of equivalence of means of Food secured versus insecure households

Note: Food availability is calculated as the difference between total food grain production and total fertilizer expenditure in grain equivalent. The fertilizer expenditure was converted into grain equivalent using the average grain price in 2000/01 cropping season. The rationale for deducting the fertilizer expenditure is that farmers are normally expected to settle their input loan immediately after harvest.

Table 2: Mean values of Factors Affecting Technology Adoption

Variables	Description	Non-adopters		Adopters		T & χ2 Test♣ P-Value
		Mean	Std. Dev.	Mean	Std. Dev.	
FOODSEC	Food security = per capita food grain availability divided by the minimum per capita food requirements, i.e., 243 kg grain	1.45	1.15	1.32	1.29	0.645
TECH	Proportion of improved variety (proportion of cultivated land planted with improved varieties)	0	0	0.56	0.41	0.000
SEX	Sex of the head (Dummy; 1= if male, 0= otherwise)	100%	-	86%	-	0.031
AGE	Age of the head (years)	44.38	9.51	44.87	13.72	0.859
EDUCATIO	Education of the head (Dummy; 1= if read & write, 0= otherwise)	66%	-	65%	-	0.947
FAMLYSIZ	Total family size (persons)	6.28	2.39	5.10	2.17	0.014
PROPACTV	Proportion of active labor force	0.55	0.22	0.56	0.25	0.808
CULTLAND	Cultivated land (Gemed*)	5.48	2.20	6.01	2.48	0.306
CERLPROP	Proportion of cereal crops	0.52	0.20	0.71	0.16	0.000
VERTPROP	Proportion of Vertisols area	0.47	0.38	0.53	0.34	0.420
FERTCOST	Total fertilizer cost (Birr)	84.70	54.80	478.68	210.54	0.000
TLU	Livestock (TLU)	4.77	2.50	4.82	2.91	0.928
HIRELABR	Hired labor (Dummy; 1= if yes, 0= otherwise)	7%	-	8%	-	0.000
OFFARMWO	off-farm work (Dummy; 1= if yes, 0=otherwise)	14%	-	7	-	0.222
EXTCONTA	Extensions contact (no. of visits)	12.40	10.2	6.10	9.92	0.003
GETCREDI	Access to credit (Dummy; 1= if yes, 0=otherwise)	45%	-	86%	-	0.000
	Observations		**29**		**91**	

* 1 Gemed = 0.25 ha.

♣T-Test of equivalence of means of adopters versus non-adopters

MODEL RESULTS AND DISCUSSION

The maximum likelihood estimates of the simultaneous Tobit models are given in Tables 3 and 4. Table 3 provides the Tobit estimates and marginal changes of household food security status. Table 4 provides the Tobit estimates and marginal changes of the intensity of adoption of improved varieties. The changes in probabilities with respect to the change in the exogenous variables are also presented.

Factors Affecting Farm Household Food Security

The model result indicated that family size had a significant ($p<0.01$) and negative effect on household food security. Under the contexts of the smallholder agriculture where productivity is low, households with large family size are normally vulnerable to food insecurity problem. They are often unable to meet the household demand for food throughout the year. As indicated from the regression result, for a household whose family size increased by an additional person, the probability of household food security decreased by 11 percent. In addition, for each additional person added to the household, the level of food security decreases by 32 percent for the entire sample and by 23 percent for food secured households.

The size of cultivated land has positively and significantly ($p<0.01$) influenced household food security. This is perhaps attributed to the fact that those farm households, which have a relatively larger cultivated land, produce enough food as compared to those who operate small-cultivated land. For each additional land (Gemede) cultivated by the household, the probability of being food secured increased by 11 percent. Moreover, each additional unit of land cultivated increases food security by 32 percent on average for the entire sample and by 24 percent for food secured households.

The proportion of Vertisols areas had a positive and significant ($p<0.05$) effect on the level of household food security. As indicated from the regression results, for a 1 percent increase in the proportion of Vertisols area, the probability of food security increased by 18 percent while the level of food security raised on average by 52 percent for the entire sample and

38 percent for food secured households. The surveyed farmers noted that Vertisols farms are more productive than any other soil types in the study areas. They are often planted with high yielding varieties, particularly wheat.

Fertilizer expenditure was negatively and significantly ($p<0.01$) related to household food security. For every expense of additional Birr 10 spent on fertilizer purchase, the probability of food security decreased by 1 percent. Similarly, the level of food security decreased on average by 3 percent for the entire sample and by 2 percent for the food secured households. The negative relation occurred due to mainly the largest share of fertilizer cost in crop production. The cash constrained farmers often get fertilizer on credit basis; farmers have to settle their fertilizer credit immediately after crop harvest. This is indeed the time when crop prices get low. As a result, farmers are prompted to sell a significant proportion of their grain production to repay the input loan. This has ultimately a negative effect on household food security.

Livestock ownership positively and significantly ($p< 0.05$) influenced household food security. For each additional livestock, the probability of food security increased by 4% while the level of food security increased on average by 10% for the entire sample and by 7.3% for the food secured households. In Ethiopia, livestock is often used as indicator for the wealth status of farm households. Households with relatively good number of livestock are better off as compared to those with small number of livestock.

As expected, adoption of improved technologies had a positive effect on household food security. Improved agricultural technologies normally raise food grain production and productivity. The regression results revealed that a 10% change in the intensity of technology adoption increases the probability of being food secured by 3.14%. Moreover, for a 10% increase in the share of improved varieties, the level of food security increased on average by 8.9% of the minimum requirement for the entire sample and by 6.4% of the minimum per capita food requirement for the food secured households. This result clearly indicated that the response of household food security to technology adoption is much higher than that of other factors.

Table 3: Simultaneous Equation Tobit Model Estimates for Household Food Security

Variable	Maximum likelihood Estimate	t-ratio	change in probability $\partial\Phi(z)/\partial X$	Total change $\partial E(y)/\partial X$	Intensity change among food secured households $\partial E(y^*)/\partial X$
ONE	0.429	0.553			
SEX	-0.091	-0.217	-0.025	-0.070	-0.051
AGE	0.005	0.413	0.001	0.004	0.003
EDUCATIO	0.181	0.614	0.049	0.139	0.101
FAMLYSIZ	-0.417	-6.645***	-0.114	-0.321	-0.233
CULTLAND	0.419	6.273***	0.114	0.323	0.235
VERTPROP	0.675	1.980**	0.184	0.520	0.378
FERTCOST	-0.004	-4.649***	-0.001	-0.003	-0.002
TLU	0.130	2.345**	0.035	0.100	0.073
OFFARMWO	0.722	1.514	0.197	0.556	0.404
TECH	1.150	1.826*	0.314	0.886	0.644

Censored observations = 39, Uncensored observations = 81

$\sigma = 1.10$, $z = 0.74$, $\Phi(z) = 0.77$, $\phi(z) = 0.30$

Note: * = significant at P<0.10; ** = significant at P<0.05; *** = significant at p< 0.01.

Other socio-economic factors were not found to be significant in influencing the status of household food security.

Technological Change: Intensity of Technology Adoption

The proportion of cultivated land planted with cereals had a positive and significant (p< 0.01) effect on technology adoption. In fact, a number of improved agricultural technologies have bèen generated for cereals more than any other crops. In addition, cereals are often high yielding and staple food crops for the majority of the population. As the regression result indicated, a 1 percent change in the share of cereals increases the probability of technology adoption by 87 percent. Moreover, the intensity of technology adoption (the percentage of total cultivated land covered with improved varieties) increased on average by 93 percent for the entire sample and by 60 percent for adopters.

Access to credit facilities positively ($p<0.10$) influenced intensity of technology adoption. Access to credit increases the probability of technology adoption by 15 percent, while it increases the intensity of technology adoption on average by 16 percent for the entire sample and by 10 percent for adopters. In Ethiopia, most technologies, i.e. improved seeds, fertilizer, herbicides, etc. are often disseminated to farmers on input credit basis. This provides a good opportunity to farmers for adopting improved agricultural technologies.

Table 4: Simultaneous Equation Tobit Model Estimates for Technology Adoption

Variable	Maximum likelihood Estimate	t-ratio	change in probability $\partial\Phi(z)/\partial X$	Total change $\partial E(y)/\partial X$	Intensity change among adopters $\partial E(y^*)/\partial X$
Intercept	-0.458	-1.188			
SEX	-0.064	-0.388	-0.050	-0.054	-0.040
AGE	0.002	0.455	0.002	0.002	0.001
EDUCATIO	-0.065	-0.655	-0.051	-0.055	-0.035
PROPACTV	-0.253	-1.290	-0.198	-0.213	-0.137
CULTLAND	-0.008	-0.371	-0.006	-0.007	-0.004
CERLPROP	1.112	4.290***	0.869	0.934	0.601
VERTPROP	-0.020	-0.164	-0.016	-0.017	-0.011
HIRELABR	0.135	1.295	0.105	0.113	0.073
OFFARMWO	-0.143	-0.774	-0.112	-0.120	-0.077
EXTCONTA	-0.003	-0.465	-0.002	-0.003	-0.002
GETCREDI	0.191	1.681*	0.150	0.160	0.103
FOOD	0.126	2.396**	0.098	0.106	0.068

Censored observations = 29, Uncensored observations = 91

$\sigma = 0.32$, $z = 0.98$, $\Phi(z) = 0.84$, $\phi(z) = 0.25$

Note: * = significant at P<0.10; ** = significant at P<0.05; *** = significant at p< 0.01

The status of household food security was significantly ($p<0.05$) and positively related to technology adoption. Food secured households are often well-off so that they are likely to take risks and adopt new technologies. The regression result indicated that a food secured household had a probability of 10 percent for adopting improved technologies. A 1 perceent increase in the level of food security increases the intensity of technology adoption on average by 11 percent for the entire sample and 7 percent for adopters.

CONCLUSION AND IMPLICATION

In this paper, the relation of household food security with technological change and other socio-economic parameters has been analyzed using a Tobit model. Model results revealed that family size is negatively related to household food security. This implies that farm households with large family size are highly vulnerable to recurrent food insecurity problem. Therefore, efforts should be made in improving the access of farm households to family planning services so that there will be reasonable family size compatible to the current limited resources.

It was also found that farm size and land quality positively affects farm household food security. Farmers with relatively large and fertile cultivated land tend to be more food secured. In addition, livestock ownership was related to better food security status. These are indeed related to the resource endowments of the farmers. Hence, more emphasis should be given to resource-poor farmers to improve their food security status.

Though its magnitude appears to be small, fertilizer expenditure negatively affects food security. The negative effect emanates from the settlement of input loan immediately after harvest when grain prices get low. In this case, farmers are forced to sell a great proportion of their grain production to repay their input loan and unable to feed their family throughout the season. On the other hand, results confirm that access to credit service is positively related to technology adoption decision. The current input credit facility is found to be effective in promoting the adoption of improved agricultural technologies. Therefore, a strategy should be designed in such a way that farmers settle their input loan when grain markets are reasonably compensated with fair prices. In addition, farmers should be trained on efficient application of fertilizer based on verified recommendation to minimize the fertilizer expenditure and loss of efficiency.

Model results show that the magnitude of household food security response to intensity of technology adoption is significantly higher than that of other factors. Therefore, more efforts should be made to promote the adoption of improved agricultural technologies in order to ensure food security at the household level.

The share of cultivated land covered with cereals is positively related to technology adoption. This implies that the current crop technology transfer activities are limited to cereal technologies, which are often high yielding. The cereal-dominated technology has an important soil fertility implication in that it results in heavy nutrient mining. In this case, some further analysis may be needed to address the effect of cereal dominated farming on soil fertility and food security in the study area.

Finally, it was found that household food security is positively related to technology adoption. Hence, efforts to improve household food security could enhance the probability and intensity of technology adoption. In general, the results confirm that technology adoption and household food security show a synergetic effect.

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