Crop Production Risk Implication on Intensity of Technology Adoption in Ethiopia: Multivariate Probit Model Analysis

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Abstract

The main objective of the study is investigating the impact of production risks on adoption of improved production technologies (such as improved seed, inorganic fertilizer and chemical inputs) and the level of adoption of multiple improved production technologies in Ethiopia particularly in Amhara region. The study used two years cross sectional data collected in 2011 and 2013. The study applied two stage regression analysis, first, I regressed the production function in order to drive expected output and risk factors (variance and skewness). In the second stage, I have regressed multivariate probit and order probit models of adoption including expected output, variances and skewness of output as risk measure. The result revealed that expected output, variance and skewness of output are major determinant for adoption decisions of improved seed, inorganic fertilizer, chemical inputs and the level of adoption of multiple improved production technologies. Moreover, credit access, membership of farm cooperatives, ownership of livestock, land size and percentage of irrigated land size positively and significantly determine the adoption decisions of improved seed, inorganic fertilizer and chemical inputs and the level of adoption of multiple improved production technologies. To increase adoption of modern production technology consequently increase production and reduce production risk. Policy makers should put emphasis on overcoming credit market failures, to create strong and sustainable farm cooperatives and production risk and risk aversion farmers should be considered when designing economic policies.

Key words: production risk, modern farm technology adoption, multivariate probit model and Ethiopia.
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1. Introduction

In Africa, agriculture is a highly effective means of achieving growth, eradicating poverty and improving food security. Agriculture is currently contributing for 30-40% of nations' gross domestic product, and a leading source of jobs for over two-thirds of the population [1]. However, African agriculture faces many hindrances and challenges such as lack of physical infrastructure, lack of information on the best agricultural practices, lack of adequate inputs, soil and land degradation, Poor market linkage, climate shock and rainfall variability. All these problems are the major causes of low productivity and in many places declining agricultural productivity and become a pro for continuing food insecurity and rural poverty in many African countries including Ethiopia. In Ethiopia, agriculture suffered frequently with unaffordable weather conditions. Droughts periodically reverse agricultural sector performance gains with devastating effects on household food security and poverty levels [2]. Consequently, the majority of small holder farmers live in food insecurity and Ethiopia experiences widespread structural food deficits. The study by Bewket [3] evokes that in 2004-2005, 38.7% of population in Ethiopia lived in extreme poverty, which is reduced to 29.6% in 2010 that lead to chronic dependence on food aid.

Therefore, reducing severity of poverty and feeding growing population basically dependent upon the progress of agricultural output growth [4] (Datt and Ravallion, 1996). Accordingly, agriculture sector may be improved either via area expansion and irrigation or via yield-increasing technological change. The first two way (area expansion and irrigation) are minimal at world level and expanding land size leads to forest degradation and drought consequently may leads to crop production risk [4] and [5]. Therefore, agricultural technology development, and adoption of the available technology and new agricultural practice are essential strategy for increasing agricultural productivity, achieving food self-sufficiency and alleviating poverty and food insecurity among smallholder farmers. Kennedy & Bouis [6] argue that increased technology development and adoption can raise agricultural output and farm level resilience to agricultural production shocks, hence improve household food intake.

However, to affect productivity, the available technology must be adopted in the Production processes. Unlike the invention of a new technology, which often appears to occur as a single event or jump, the adoption of that technology usually appears as a continuous and rather slow process [7]. Yet, it is diffusion rather than invention or innovation that ultimately determines the pace of economic growth and the rate of change of productivity. Until many users adopt a new technology, it may contribute little to our well-being.

By recognizing the importance the agriculture sector in the economy, Ethiopia had made various action in providing and distributing inputs like chemical fertilizer, chemical inputs and improved seed. However, the productivity of the sector still very low and use of improved technology such as improved seed, chemical fertilizer and pesticide and herbicide is limited as compare to other African countries. For instance the use of fertilizer in Ethiopia was 23.67 kg per hectare while the corresponding figures for Kenya, and Malawi, were 44.31kg/he and 39.89kg/hec in 2012, respectively [8]. An understanding of adoption decisions about new technology in agriculture is therefore crucial for formulating effective policies.

To grasp the factors that decelerate the productivity and new technology adoption need to consider the impact of risk behavior of the farm households on agricultural technology adoption decisions in addition to socio-economic and institutional factors. The adoption of a new agricultural technology is highly condition with its profitability, degree of risk associated with it, capital requirements, policy variables, and socioeconomic characteristics of farmers. Many of the literatures (see [9], [10] and [11]) have been argued that farm households were not fully benefited from improved inputs (fertilizer, improved seed, pesticide and herbicide) because of mixture factors such as liquidity constraint, risk averse behavior of the farm, lack of information, lack of extension contact and etc.

Over the years growing body of literature has emerged, quantifying the effect of risk aversion on input use, particularly, in fertilizer and improved seeds. The evidence is conflicting and the controversy continues. The study Yesuf and Bluffstone [9] and Ogada et.al [10] found production risk or year-to-year variability in yields discourages farmers from adopting inputs and applying profit-maximizing input levels. On contrary, Binswanger [12] argued that the low observed levels of input use cannot be attributed to risk and he found that farmers who are risk-averse will seek risk reducing strategies and technologies to adopt in their farming systems. Vulnerability factors deal with the impact of technologies on the level of exposure of farmers to economic, biophysical and social risks. Those technologies that have a lower risk have a greater appeal to smallholders who are naturally risk-averse [11].

A few studies were done in Ethiopia on determinants on input use, have been indicated availability and affordability to quality seeds, risk aversion, inadequate supply of input, lack of credit access, knowledge gab, cost of technology, and adoption static nature of farmers were the most critical factors for low adoption of fertilizer and improved seeds (see, [13] [14] [15] and [16]). However, all these studies were focused on identification of determinants of single technology adoption using cross sectional data neglecting dynamic relationships among economic variables. In fact, most of the time farmers adopt more than one technology simultaneously (for example, fertilizer and improved seed). If there is simultaneity in adoption decision-makings, picking single technology yields biased, inefficient and inconsistent estimates [17]. Because of the fact that technology adoption is a dynamic process, stick to a cross section data may leads to inconsistent and unreliable results. Farmers do not simply decide whether or not to permanently adopt an improved variety, but instead they make a series of decisions: whether or not to try planting an improved variety, how much land to allocate to the improved variety, whether or not to continue to grow it, and whether to try a different improved variety [18].

Thus, all these and related aspects of economic variables necessitates to conduct this study. The study tries via employing two year cross sectional data sets from the EPIICA survey and multivariate probit model which capture the correlation between agricultural technology adoption decisions. In addition to the model novelty, this study shows the effect of production risks on agricultural technology adoption unlike the previous studies which ignored it. The study provides important information for researchers and policy makers focused on the agriculture productivity, production risk and technology adoption.

The paper is organized in five sections. The first part of the paper deals with general induction about the study focal points. While, in the second section and third, reviews literature and conceptual farm work are briefly presented, respectively. Data sources, methodology, result and discussion are organized in section four. Finally, section five summarizes the main findings, and present conclusion and policy recommendation.

2. Critical Review of Technology Adoption Determinants in Ethiopia

Agricultural technology development has been giving an essential strategy for increasing agricultural productivity, achieving food self-sufficiency and alleviating poverty and food insecurity in developing countries followed 1950s bad agricultural crisis and food insecurity in Asia. The Green Revolution experience of the 1960s-1970s in Asia and Latin America was a response to widespread poverty and food insecurity in developing countries at a time when close to one third of the population in the world (one billion people) were vulnerable to hunger and malnutrition [19] [20]. Technological improvements from the "Green Revolution" such as high-yield crops and chemical fertilizer has dramatically increased global agricultural productivity. The study by Meinzen-Dick et.al [11] on innovation of natural resources management in developing countries reveals that the use of agricultural technologies affects the rate of increase in agricultural output and determines how the increase in agricultural output impacts on poverty levels and environmental degradation. The development of agricultural technology for both food and non-food crops, rural financial markets, the dissemination of assets and information, developing agricultural research and extension facilities targeted towards the smallholder farmer all work together to prevent long-term famine through increased agricultural productivity [19]. New technology is needed for areas with shortages of land or water, or with particular problems of soil or climate. These are frequently areas with a high concentration of poor people, where such technology could play a key role in improving food security.

In Ethiopia, the uses and adoption improved agricultural technology particularly improved seed, inorganic fertilizer, herbicide and pesticide have been remaining low. The previous literatures identify some of the main factors:

The availability of modern agricultural production technologies to end users, and the capacities of end users to adopt and utilize these technologies are also critical. A host of demand and supply side factors have been invoked to explain the limited adoption of fertilizer in Ethiopia including limited knowledge and education [21] [22]. Information and local availability of inputs and farmers' ability to access those inputs are critical in facilitating the process of technology adoption [23].

Dercon et.al [24] a study on consumption, risk, technology adoption and poverty in Ethiopia, found that fertilizer use associated with is high returns of cereal yield but, high risky technology. The riskiness of fertilizer derived from the sharp increase in fertilizer price and returns to using fertilizer were lower in the last few years of our sample, and turning negative more rapidly when moving away from the median.

Farmer's level of education has critical influence on the adoption decisions. The adoption studies of chemical fertilizer in north Ethiopia [25] and improved maize variety in central highland Ethiopia [26], level of education (EDU) of the head of the household has a positive and significant influence on the adoption and intensity of adoption. Knight et.al [27] used Ethiopian farmer's choices between a hypothetical certain prospect and a risky prospect with a higher average return (contextualized in terms of livestock and crop production) to estimate risk attitudes. The authors then relate these risk attitudes to education and technology adoption where technology adoption was defined in terms of a farmer's use of at least one innovative input and one innovative crop. They found that risk aversion was negatively related to the farmer's level of education. Technology adoption was positively related to a farmer's education and negatively related to increased risk aversion, which led the authors to conclude that risk does have a negative influence on technology adoption, but increased education can foster technology adoption both directly and indirectly through a decrease in risk aversion.

Furthermore the previous studies have done in Ethiopia suggested that information about new technology, local availability of inputs, farmers' ability to access those inputs and its cost have influences the adoption decision of farmers. For instance; improved seed, chemical fertilizers and herbicides [15] [16] [28] [29] found that farmers' decisions to adopt agricultural practices, among other things remains to constant, depend on 'household endowments and access to information.

Access to extension services: The uptake of new technologies is often influenced by the farmer's contact with extension services, since extension agents provide improved inputs and technical advice According to Yu et.al [23] access extension services is imperative that agricultural training and extension programmes be intensive enough to promote adoption not only of improved yield-raising technologies, such as improved seeds, but also of fertility-restoring and conservation technologies.

Access to credit: Farmers without cash and no access to credit will find it very difficult to attain and adopt new technologies. Credit constraint is one main source of low adoption of agriculture technology in Ethiopia [23] [25] [30] [31].

3. Conceptual framework of econometrics model: household resource allocation under risk and uncertainty model

As noted extensively in the introduction and review of related literature, risk behavior farm households can give rise to heterogeneous resource allocation across households with varying endowments of productive assets. The main purpose of the study to investigate the effects of production risks on adoption and utilization of improved inputs with special attention on fertilizer improved seed, chemical inputs (pesticide and herbicide) in Ethiopia. First the researcher, used flexible moment based approach pioneered by Antle's [32] [33] to estimate the variability of crop (variance) and the third moment (skewness) of crop production which is proxy of production risks. Theoretical framework of flexible moment based approach is provided as follows.

The production and consumption decisions are inseparable with farm households [34]. Farm households are considered to be the central decision makers regarding agricultural production. Individual farmers have to decide which commodities to produce in which quantities, by which method, in which seasonal time periods. It is the objective of the farmers to maximize their utility, which deviates from pure profit maximizing behavior in many cases. In such case the technology adoption decision of the farmers is based on the risk behavior of the farm households and cost and benefit of new technology as compared to standard technology. To give effective policy recommendation in this study included linkages between production and consumption decisions, characteristic for farm households operating under uncertainties in farm household model.

Let assume the decision of farmers to adopt new technology is based on the objective of maximizing utility function. Assume farm households are price taker (both in input and output market) and any climate risk or technology risk affects the crop production yield. In such case risk averse farm households choose the input vector "X" which maximized their expected utility based on the given output and input prices and a priori knowledge of the structure of the risky production technology. Let "Ui0" is utility of farmers non- adopting of modern agricultural technology and "Ui1" is utility of farmers adopting modern agricultural technology. Farmers adopt the modern agricultural technology if and only if "Ui1" is greater than "Ui0". Which implies that very low level of utility or incentive of the new technology the farmer will not adopt the new technology, but at a sufficient high level of utility of the new technology, the farmer will mostly adopt new technology.

The production function is given by

$$Q = F\,(X^{mt}, X^{ot}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (1)$$

Where Q is output, X^{mt} is present use of modern inputs such as fertilizer, improved seed and chemical input (pesticide and herbicide) used at time "t" X^{Ot} is other inputs used at time "t" such as farm size, labor, capital, manure, irrigation and other production shifter factors. The production functions F (.) is assumed a continuous and twice differentiable [35]. The expected utility maximization problem for risk averse farmers as function of profit is presented by

$$MaxE[U(\pi)] = max \int_0^Q [U(pf(X^{mt},\ X^{Ot}, \varepsilon^t) - w^m X^{mt} - -w^o X^{ot})] d\, G(\varepsilon) \ldots\ldots\ldots\ldots\ldots (2)$$

Where U (.) is the Von Neumann-Morgenstern utility function, P is output price, w is input price, E is the expectation operator, "ε" while captures all the unobserved household heterogeneity such as unreported farm management ability, land fertility, risk management measures, and rate of discount which could affect input use and farm productivity.

The first order condition (FOC) for fertilizer input specified as follow

$$E[w^m U^{'}] = \mathrm{E}\ [\mathrm{p}\frac{\partial f\,(X^{mt}, X^{Ot}, \varepsilon^t)}{\partial X^{mt}} * U^{'}] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$w^m E(U^{'}] = \mathrm{PE}\ [\frac{\partial f\,(X^{mt},\ X^{Ot}, \varepsilon^t)}{\partial X^{mt}}] * EU^{'} + cov[\mathrm{U}^{'}, \partial\, f(X^{mt}, X^{Ot}, \varepsilon^t)/\partial X^{mt}] \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

$$\frac{W^m}{P} = \mathrm{E}\ [\frac{\partial f\,(X^{mt},\ X^{Ot}, \varepsilon^t)}{\partial X^{mt}}] + \frac{cov\,[\mathrm{U}^{'}, \partial f(X^{mt},\ X^{Ot}, \varepsilon^t)/\partial X^{mt}]}{E(U^{'})} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where U'= $\frac{\partial U(\pi)}{\partial \pi}$ for risk neutral framers the ratio of input price to output price is equal to the expected marginal product of the fertilizer inputs which means the second term of the equation (5) will disappeared. However, in case of risk averse the second term of equation (5) is different from zero and it measures the deviation risk neutrality situations. The term would be proportional and opposite in sign to the marginal risk premium with respect to the input under consideration [10].

The case of risk neutrality the optimal input decision can be find using standard approach of equating ratio of input price to output price to expected marginal product ($\frac{W^m}{P} = \frac{\partial f}{\partial X^m}$). However, presences risk averse and market imperfection the optimal input decisions depend on the shape of utility function U (.), production function F (.) and risk function G (.) [36]. Solving equation (5) mathematically is very difficult. In addition to this, to estimate risk function parametric and risk preference the distribution "ε" is required. For the same reason Antle [32] [33] proposed the flexible moment based approach. The approach provides a general econometric methodology for estimating higher moments of output as functions of inputs. Thus, given input and output data for a production period, there exist means of modeling and estimating the effects of alternative production practices and input combinations on production risk [33]. According to the Antle model maximizing the expected utility of profit with respect to any input is equivalent to maximizing a function of moments of the distribution of "ε", those moments having themselves "X "as argument. This is given by:

$$\mathrm{MaxE[U(\pi)]} = \mathrm{F}\big[\mu_1\big(\mathrm{X}^{\mathrm{ft}}, \mathrm{X}^{\mathrm{st}}, \mathrm{X}^{\mathrm{ht}}, \mathrm{X}^{\mathrm{ot}}\big), \mu_2\big(\mathrm{X}^{\mathrm{ft}}, \mathrm{X}^{\mathrm{st}}, \mathrm{X}^{\mathrm{ht}}, \mathrm{X}^{\mathrm{ot}}\big), \ldots\, \mu_{\mathrm{m}}\big(\mathrm{X}^{\mathrm{ft}}, \mathrm{X}^{\mathrm{st}}, \mathrm{X}^{\mathrm{ht}}, \mathrm{X}^{\mathrm{ot}}\big)\big] \ldots\ldots\ldots (6)$$

Where μ_i= (i= 1, 2…m) is the m^th moment of farm profit, and F (.) is a cumulative distribution function and completely unspecified. Using the FOC of this problem, the marginal impact of modern farm inputs for example fertilizer input on the first moment is given by:

$$\frac{\partial \mu_1(\mathrm{X}^{\mathrm{mt}}, \mathrm{X}^{\mathrm{ot}})}{\partial \mathrm{X}^{\mathrm{mt}}} = \alpha_1 \mathrm{F} + \alpha_2 \mathrm{F} \frac{\partial \mu_2(\mathrm{X}^{\mathrm{mt}}, \mathrm{X}^{\mathrm{ot}})}{\partial \mathrm{X}^{\mathrm{mt}}} + \alpha_3 \mathrm{F} \frac{\partial \mu_3(\mathrm{X}^{\mathrm{mt}},\ \mathrm{X}^{\mathrm{ot}})}{\partial \mathrm{X}^{\mathrm{mt}}} + \cdots + \alpha_{\mathrm{m}} \mathrm{F} \frac{\partial \mu_{\mathrm{m}}(\mathrm{X}^{\mathrm{mt}},\ \mathrm{X}^{\mathrm{ot}})}{\partial \mathrm{X}^{\mathrm{mt}}} + \mathrm{v}^{\mathrm{mt}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

4. Specification of Empirical model for improved farm inputs adoption decisions

4.1 Multivariate probit model

Most previous studies in particularly were done in Ethiopia, only single technology adoption considered and the possibility of simultaneous over the complementary technology is ignored (see [13] [14] [37]. However, the link exists between adoption decisions of more than one modern farm technology [10] [38]. This study used multivariate probit model to estimate factors affecting adoption decisions of households to modern agriculture technology. The multivariate probit model represents the probability of a limit observation for each modern farm inputs, which is parameterized as

Fertilizer: $Y_{it}{}^{F} = \beta X_{it} + \varepsilon_F \ and \ \ Y_{it} = 1\, if y_{it}{}^{*} > 0 \ldots\ldots\ldots\ldots$ (1)

Improved seed: $Y_{it}{}^{S} = \beta X_{it} + \varepsilon_s and \ \ Y_{it} = 1\, if y_{it}{}^{*} > 0 \ldots\ldots\ldots\ldots\ldots$ (2)

Chemical inputs: $Y_{it}{}^{P} = \beta X_{it} + \varepsilon_c and \ \ Y_{it} = 1\, if y_{it}{}^{*} > 0 \ldots.\ldots\ldots\ldots.$ (3)

Where Y_{it} is the latent variable with value $Y_{it}=1$ if farmer adopt new technology ($y_{it}{}^{*}$>0) or $Y_{it}=0$ if farmer do not adopt new technology ($y_{it}{}^{*} \leq$0), X_{it} is explanatory variables which affect the adoption decision of farmers, and ε_{F}, $\varepsilon_{s}$and ε_{c} are error terms. In multivariate probit model the distributions of stochastic disturbances term jointly follow a multivariate normal distribution (MVN) with zero conditional mean and variance (δ^2)and covariance is non-zero (ρ).

$$\rho = \begin{bmatrix} \delta^2 & \rho_{12} & \rho_{13} \\ \rho_{21} & \delta^2 & \rho_{23} \\ \rho_{3} & \rho_{32} & \delta^2 \end{bmatrix}$$

4.2 Order probit model

In order to investigate factors influencing the intensity of use of modern farm technology (such as fertilizer, improved seed, and pesticide and herbicide) the researcher need to make threshold between adopters and non-adopters. In the case where multiple technology adoption consider, defining the boundary point (threshold) between adopter and non- adopter is the main problem to examine the determinants of technology adoption intensity [39] [40]. To overcome this problem, following Teklewold H. et.al [39] and Nkegbe et.al [40] I used the number of modern farm technologies adopted by farming households as our dependent variable measuring extent of adoption. Information on the number of modern farm technologies adopted could have been treated as a count variable. Count data mostly analyzed by binomial and Poisson regression model [41] [42]. As sited by Teklewold H. et.al [39] count data analyzed by Poisson regression model, but underlying the assumption is that all event have the same probability. Furthermore, Poisson regression model assuming equality between the variance of the count-dependent variable and its conditional mean, known as the equidispersion condition [41] [42] however, most review literature by Nkegbe et.al [40] the count-dependent variable has been observed to exhibit over dispersion, implying the variance is greater than the conditional mean, due largely to the preponderance of zero observations of the dependent variable in such data sets. These two assumption are not hold in our application the probability of modern farm technology adoption. Given the experience and knowledge of farm households about the new farm technology the probability of the adopting the chemical fertilizer could differ from the probability of adopting the improved seed and chemical inputs.

In this paper, the order probit model had been applied to analyze the level of multiple modern production technologies adopted by farmers. In literature, this approach has been used by [39]. Order probit model parameterized as follows

$Y^{*}{}_{it} = \beta X_{it} + \varepsilon$ --- (1)

Where $Y^{*}{}_{it}$ is number of modern farm technology adopted by smallholder farmers. In this study I considered only three modern production technologies (MPT) such as fertilizer, improved seed and chemical input (pesticide and herbicide) therefor $Y^{*}{}_{it}$ is will be 0= non-MAT adopt, 1=one of MPT adopt, 2=two of MPT adopt and 3=all MPT adopt by farmers.

Let $\alpha_1, \alpha_2 and \ \ \alpha_3$ be unknown cut points (or threshold parameters), and define

$$Y=0 \text{ if } Y^{*}{}_{it} \leq \alpha_1$$

$$Y=1 \text{ if } \alpha_1 < Y^{*}{}_{it} \leq \alpha_2$$

$$Y=2 \text{ if } \alpha_2 < Y^{*}{}_{it} \leq \alpha_2$$

$$Y=3 \text{ if } \alpha_2 < Y^{*}{}_{it} \leq \alpha_3$$

Assume the stochastic disturbs term has normal distribution with mean zero and the variance δ^2. The response probability (number of MPT adopting probability) we simply compute

$$P(y=0|x) = P(Y^*_{it} \le \alpha_1|x) = P(\beta X_{it} + \varepsilon \le \alpha_1) = \Phi(\alpha_1 - X\beta) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

$$P(y=1|x) = p(\alpha_1 < Y^*_{it} \le \alpha_2|x) = \Phi(\alpha_2 - X\beta) - \Phi(\alpha_1 - X\beta) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3)}$$

$$P(y=2|x) = p(\alpha_2 < Y^*_{it} \le \alpha_3|x = \Phi(\alpha_3 - X\beta) - \Phi(\alpha_2 - X\beta) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(4)}$$

$$P(y=3|x) = p(Y^*_{it} > \alpha_3|x) = 1 - \Phi(\alpha_2 - X\beta) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ldots\ldots\ldots\ldots \text{(5)}$$

4.3 Study Area, Data Type and Sources

Data for this paper obtained from a household survey project entitled “The Ethiopian Project on Interlinking Insurance with Credit in Agriculture (EPIICA)". The survey jointly conducted by university of California, San-Diego, university of Athens, university of Greece and FAO ,EEA, Dashen Bank and Nyala Insurance company during 2011 to 2013 in Amhara region. The primary intention of the survey is to promote the use of fertilizers by smallholder farmers and hence boosting productivity [43]. In early 2011, EPIICA conducted its baseline survey [44] (McIntosh et.al, 2013). Four administrative zone west Gojjam, south wello, north wello and north Shewa were selected as sample zone. The survey covers 120 kebelles and households within the selected kebelles were randomly sampled to participate in the study; in each village 18 cooperative member households and 2 households that are not a member of the primary cooperative were selected [44].

5. Result and Discussion

5.1 Adoption of Improved Farm inputs in Selected Zones of Amhara

The adoption rate of farm inputs such as improved seed, inorganic fertilizer and chemical inputs increased between the two survey periods (see table 1). For instance, 58 percent and 75 percent of the households adopted inorganic fertilizer in 2011 and in 2013, respectively. However, adoption rate of technologies is unevenly distributed among the target zones. Hence, West Gojjam, followed by North Shewa, possess higher adoption rate. On the other hand, the lowest adoption rate of improved seed, inorganic fertilizer and chemical inputs are registered in south Wollo and North Wollo.

The adoption rate variation may be due to the fact that West Gojjam and North Shewa are characterized by a relatively suitable agro-ecological zones where households mainly rely on farm income. Therefore, other things remain constant; households demand improved seed, inorganic fertilizer and chemical inputs to boost their farm earnings. On the other hand, low adoption rate in North and South Wello may be due to the relatively lower return of agricultural land. In addition, many of households are engaged in off farm activities. Both of the arguments above hold in line with the fundamental economic theory where households act rationally.

Table 1: Inorganic fertilizer, improved seed and chemical input adoption level by zone

technology	2011					2013				
	North Shewa	West Gojjam	South Wello	North Wello	total	North Shewa	West Gojjam	South Wello	North wello	total
Frequecey of adopter										
inorganic fertilizer	206	360	44	61	671	226	346	210	79	861
improved seed	81	320	18	15	434	99	272	56	44	471
chemical inputs	140	152	12	10	314	192	238	55	10	495
Percentage of adopter										
inorganic fertilizer	31	54	7	9	58	26	40	24	9	75
improved seed	19	74	4	3	38	21	58	12	9	41
chemical inputs	45	48	4	3	27	39	48	11	2	43

Source: Author calculations from EPIICA 2011&2013 survey

5.2 The joint and marginal probability of technologies adoption

The joint and the marginal probability of improved seed, inorganic fertilizer and chemical inputs adoption is presented in table 2. Of the total sampled households 61 percent applied one or more modern inputs (improved seed, inorganic fertilizer, and chemical inputs) during the 2011 survey. Although, simultaneous adoption of all three technologies was 17%, the percentage of households who applied one or more of these technologies reached 89 percent. However, 11 percent of the households did not apply any of the three technologies in 2013. The probability of applying all three inputs jointly was 18 percent in 2013.

Among the three technologies, inorganic fertilizer was the most common technology used by the sampled households. It was used as a single technology by 14 percent of the households, 19 percent in combination with improved seed and 6 percent with chemical inputs in 2011. The usage of inorganic fertilizer was increased in 2013.

The percentage of households adopting improved seed did not show significant increment in 2013. While 4 percent of the households used it as a single technology, 12 percent used it in combination with inorganic fertilizer and 7 percent with chemical inputs. This provides a useful insight: those who adopt improved seed are more likely to adopt inorganic fertilizer and chemical inputs or vice versa. The probability of chemical input adoption was very low, only 7% of the households adopted it in the 2011 survey. Its adoption rate dramatically increased in the 2013 survey in which 41 percent of the sample households used it in their crop production.

Table 2: Joint and marginal probability of technologies adoption

	2011				2013			
	Joint probability	Marginal probability			Joint probability	Marginal probability		
		Inorganic fertilizer	Improved seed	Chemical inputs		Inorganic fertilizer	Improved seed	Chemical inputs
Inorganic fertilizer	0.14	0.14	-	-	0.32	0.32	-	-
Improved seed	0.01	-	0.01	-	0.04	-	0.04	-
Chemical inputs	0.04	-	0.04	-	0.05	-	-	0.05
Inorganic fertilizer & improved seed	0.19	0.19	0.19	-	0.12	0.12	0.12	-
Inorganic fertilizer &Chemical inputs	0.06	0.06	-	0.06	0.13	0.13	-	0.13
Chemical inputs& improved seed	0.01	-	0.01	0.01	0.07	-	0.07	0.07
all	0.17	0.17	0.17	0.17	0.18	0.18	0.18	0.18
none	0.39	-	0.00	-	0.11	-	-	0-
total	1.00	0.56	0.41	0.07	1.00	0.74	0.40	0.42

Source: Author calculations from EPIICA 2011&2013 survey

5.3 Conditional and unconditional probability of technology adoptions

Although the empirical joint and marginal probability of technologies adoption provides interesting results, the conditional and unconditional probabilities presented in table 3 provide an interesting indication of the existence of possible dependence among the three technologies (improved seed, organic fertilizer and chemical inputs). The unconditional probability of inorganic fertilizer adoption was 91 percent; however, this increased to 95 percent conditional on one technology (improved seed) and to 97 percent conditional on the two technologies i.e. improved seed and chemical inputs in the 2011 survey. In the 2013 survey, unconditional probability of inorganic fertilizer was 82; it was 73 percent, 72 percent, and 72 percent on conditional use of only one technology improved seed, one technology chemical inputs and two technologies (improved seed and chemical inputs). This means that the probability of inorganic fertilizer adoption could be substantially increased if the adoption of improved seed and chemical inputs were increased.

The unconditional probability of improved seed adoption is 61 percent. However it increased to 63 %, 64% and 73% conditional on the use of fertilizer, chemical inputs and two technologies (fertilizer and improved seed) in the 2011 survey. The unconditional and conditional probability of improved seed declined in the 2013. The unconditional probability declined to 45 percent, the conditional probability of using improved seed were 45%, 59% and 58 % given the use of inorganic fertilizer, chemical inputs and combination of inorganic fertilizer and chemical inputs during the 2013 survey. The unconditional probability of chemical inputs was 44% and it increased to 47% and 47% conditional on using one improved seed and one inorganic fertilizer in the 2011 survey.

In general, the descriptive statistics, both conditional probabilities, joint and marginal probabilities revealed that there is interdependence among the adoption of the three technologies. This implies that households adopting one technology could have high probability to adopt other technologies than non- adopters.

Table 3: Sample Conditional and unconditional probability of technology adoption

Probability	2011			2013		
	Fertilizer	Improved seed	Chemical inputs	Fertilizer	Improved seed	Chemical inputs
Pr (.)	0.91	0.61	0.44	0.82	0.45	0.47
pr(./fer=1)	1.00	0.63	0.41	1.00	0.40	0.41
pr(./im=1)	0.95	1.00	0.47	0.73	1.00	0.62
pr(.chi=1)	0.84	0.64	1.00	0.72	0.59	1.00
pr(./im=1, fer=1)	1.00	1.00	0.47	1.00	1.00	0.61
pr(./fer=1, chi=1	1.00	0.74	1.00	1.00	0.58	1.00
pr(./im=1, chi=1)	0.97	1.00	1.00	0.72	1.00	1.00

Note: fer=inorganic fertilize, im= improved seed, chi=chemical inputs
Source: Author calculations from EPIICA 2011&2013 survey

5.4 Econometrics Estimation Result: Determinants of Agricultural Technology Adoption

I. Multivariate Probit Estimation

The primary objective of this section is to investigate the determinant factors of agricultural technology adoption decisions. Descriptive analysis allows assessing the relative importance of unobserved heterogeneity and genuine state dependence in explaining persistence in the decision to improved seed, fertilizer and chemical input adoption. The multivariate model allows the joint estimation of the three technologies adoption decisions allowing for correlation among error terms in the improved seed, inorganic fertilizer and chemical input equations.

Table 4 reports the results of the multivariate probit model that consists of the improved seed, inorganic fertilizer and chemical input adoption decision equations. The significant Wald chi square value implies that the explanatory variables jointly determine the farmers' decision to adopt improved seed, fertilizer and chemical inputs. The significance of LR test (p =0.000) implies that adoption decisions about improved seed, inorganic fertilizers and chemical inputs are dependent. All decisions are affected by the same unobservable heterogeneities. Thus, the decisions are jointly determined. This is plausible because improved seed, inorganic fertilizer and chemical inputs are complementary agricultural production technologies. The estimated correlation coefficients, ρ_{ij}, between each of the three technologies adoption decisions are statistically significant. The correlation coefficient between three technologies are positive. This suggests that the unobservable factors which increase the probability of adoption decision with respect to improved seed also increase the probability of adoption of fertilizer and chemical inputs.

Estimation result from table 4 revealed that the adoption of fertilizer increase the probability of improved seed and chemical inputs. This implies adoption of one technology encourage households to adopt others. The estimated correlation coefficient among three technologies were positive and significant at 1 percent. This implies that unobservable factors that make a farmers participate in one activity tend to lead it to participate in all simultaneously. Furthermore, the finding revealed that three agricultural technologies are complementary. This finding consistent with conditional and unconditional probability of three farm inputs. The correlation coefficient between improved seed and fertilizer is much large 33.9 percent and found it significant at 1 percent. The correlation coefficient between improved seed and chemical input is 26.33 percent. The correlation coefficient between fertilizer and chemical input was 0.2456 and it found significant at one percent.

Different specific factors of farm like household demographic characteristics, location dummies and risk measurement variables have been among factors that determine the adoption decisions. The finding shows that education level of the farm household's head has positive effect and it significantly promote the adoption decisions of improved seed. This evidently demonstrate that education emerges as an important factor in enhancing agricultural technology adoption and is in line with [26] education enhances farmers` ability to obtain, analyze and interpret information. However, education of the farm household's head has positive effect but weakly promote the adoption decision of individual technologies such as fertilizer and chemical inputs. It is against the researcher expectation that as farmers acquire more of agricultural technologies, their ability to obtain, process, and use new information improves and they are likely to adopt. However, due to experience sharing among the farmers there may not be a significant knowledge difference among illiterate and literate households about the use and advantage of fertilizer and chemical inputs and these two technologies used by farmers for many years. Therefore, there may not be a significant difference among illiterate and literate farm households in adopting inorganic fertilizer and chemical inputs.

The results in table 4 show that inclusion of the site variables in the model such as West Gojjam, South Wello and North Wello variables had significant effect on adoption of technologies. All site variables had positive and significant effect on adoption of improved seed implying that compared to North Shewa which was dropped for reference, respondents at West Gojjam, South Wello and North Wello were more likely to adopt improved seed. The result can be explained by productivity variation among zones; for instance West Gojjam zone is one of the highest productive areas in the country and the sampled households reside around Bahir Dar town with better access to information, access to credit and even access to require of inputs have better decisions on using new technologies. All these factors create the favorable conditions for farmers to adopt new technologies. The site variables, South Wello and North Wello had significant and negative effect on decision of adoption of chemical fertilizer and chemical inputs, respectively. It may not be surprising to have negative and significant coefficient for the South Wello dummy in the chemical fertilizer and chemical inputs adoption model. It is due to the fact that relatively lower returns of agricultural land many of households engage in off farm activities in South and North Wello. Therefore, it may discourage household's adoption decisions of modern agricultural technology. Moreover, it can argued that regional-specific factors, such as, agro-ecological and other location characteristics play a significant role in affecting adoption decisions made by farmers.

Percentage of irrigated land had found significantly improves the adoption of all three agricultural technology. This implies that households with more percentage of irrigated land have more chance to adopt all technologies listed in this research. The finding is similar to the result of Berihun et.al [14] which concluded that farmers' reluctance in adopting agricultural technologies mainly steams from erratic nature of rain fall and lack of irrigation water where the technology is in question for increasing yield rather there appear a believe that it may damage the productive potential of crops sown. Due largely to this reason, if farmers get irrigable water, their probability of adopting the intended technology is found to be high.

The land size of household was positively correlated with adoption of the fertilizer and chemical inputs. It was found to be significant at 1 percent. As the land size owned by the households increases, the probability of adoption of inorganic fertilizer and chemical inputs significantly increases. The finding is consistent with previous studies which say that large scale farmers are less risk averse and more inclined to adopting new technologies than small scale farmers [45][46]. Moreover, the positive correlation between farm size and the probability of technology adoption may arise from the economies of scale in acquiring information and getting input credit.

The ownership of livestock is also important in influencing the adoption of improved seed and chemical inputs. It is measured by tropical livestock unit (TLU). As tropical livestock unit increases, the probability of improved seeds and chemical inputs adoption significantly increases. The result can be explained by the fact that households who have more livestock may finance input cost by selling their livestock. However, the ownership of livestock was positively and insignificantly correlated with the adoption decision of inorganic fertilizer. Households with more livestock may have chance of increased availability of organic fertilizer (manures and compost). In fact inorganic fertilizer and manure are substitute inputs. Thus, farm households that have and apply sufficient quantities of manure would not apply inorganic fertilizer. As expected, membership of local cooperatives is important in promoting adoption of inorganic fertilizer and improved seed inputs.

Household's memberships in local cooperative happen to determine the probability of adopting improved seed and inorganic fertilizer positively and significantly. In fact a rural local cooperative in Ethiopia provides agricultural inputs especially improved seed varieties and inorganic fertilizer to the farmers. Therefore, local cooperative member households may have chance of getting input credit, information and acquire knowledge about the new technology and thus could increase the probability of adoption decisions.

The finding revealed that access to credit positively and significantly affect the farmers' adoption decisions of agricultural technologies. This implies that credit is an important factor to facilitate adoption of modern technologies. Households having access to credit had better chance to adopt all three technologies than their counterparts. The finding is consistent with previous studies in Ethiopia, which states that households with access to credit are more likely to adopt agricultural technologies [23] [25]. Access to credit minimizes the liquidity constraints and thereby enhances the adoption of improved seed, fertilizer and chemical inputs. Since poor households may not be able to purchase key inputs, farm credit is believed to help them to fulfill their financial requirement to purchase inputs. Moreover, male dummy, off-farm income, average slope index and use of manure had significant effect on adoption of agricultural technologies.

The risk measure factors such as expected output, variance and skewness of output are also important determinant factors for modern agricultural technology adoption decisions. The expected output, derived from adopting a given technology, is found to be significantly and positively related to the probability of adoption of inorganic fertilizer, improved seed and chemical inputs. In other words, farmers need to assure higher output before adopting inorganic fertilizer, improved seed and chemical inputs. Yield variability as measured by variance of output had negative and significant impact on adoption decisions of the individual modern farm technology. This implies that crop output variability discourages new technologies adoptions among farmers. Year to year variability of crop output would reduce the likelihood of inorganic fertilizer, improved seed and chemical inputs adoption.

In addition to variance and expected output I have included skewers of output as measure of higher possibility of crop failure (downside risk) and it was found to be positive and significant for improved seed adoption. The significance of skewness of output distribution for the adoption of improved seed is evidence that farmers are using improved seed to hedge against crop failure. The result is consistent with the study of [11] which states that technologies which minimize crop failure have a greater appeal to smallholders to adopt these technologies. The positive correlation between skewness of output and improved seed adoption decisions may be explained by the fact that improved seed is pest and drought resistant and it is compatible with the use of other inputs like fertilizer and chemical inputs. While skewness of output significantly and negatively promotes individual inorganic fertilizer and chemical inputs adoption.

Table 4. Determinants of agricultural technology adoption decisions

Explanatory variables	Improved seed		Chemical fertilizer		Pesticide and herbicides	
	coefficient	Std.error	coefficient	Std.error	coefficient	Std.error
Male headed dummy	-0.24481*	0.11921	-0.13349	0.121416	-0.36963**	0.12501
Education status of head of households	0.074207*	0.032427	0.020317	0.033381	-0.055	0.032457
Dummy for households in Gojjam	1.461819***	0.094503	1.628437***	0.11605	-0.46516***	0.096384
Dummy for households in south Wollo	-0.41197***	0.128487	0.406136***	0.113906	-0.10158	0.136315
Dummy for households in north Wollo	0.280183**	0.114822	-0.10916	0.115381	-1.39913***	0.154792
Percentage of irrigated land	0.005934**	0.001913	0.011215***	0.001866	0.003827**	0.001343
Average slope index (1 all parcel steeply sloped, 3 all flat)	-0.08201	0.131945	-0.19156	0.127863	-0.10415	0.133528
Average altitude index(1=all parcel much above 5=all much below	0.077763	0.104207	0.326481	0.09522	0.340889***	0.107031
Use of manure in kg	-5.3E-05	0.000052	4.54E-05	7.32E-05	0.000269**	8.67E-05
Primary cooperative membership dummy	0.233456**	0.097946	0.424076***	0.090775	-0.11102	0.097551
Livestock ownership in TLU	0.083344*	0.017755	0.045331	0.020539	0.060042**	0.019329
Credit dummy(1=credit access, 0 otherwise)	0.286085*	0.086076	1.160107***	0.136112	0.221367**	0.083385
Log of value of production asset	0.035801	0.054718	0.30199***	0.062996	0.34545***	0.059585
Log of age of the household head	-0.73051	0.500241	-0.54723	0.579824	-1.30018	0.783288
Log Age square of the household head	0.222193	0.249954	0.161572	0.290024	0.531317	0.392636
Log of family labor(age > 14)	0.063943	0.092143	-0.02978	0.090717	-0.4384***	0.092418
Log of off-farm income	-0.02057**	0.009418	-0.01461	0.009191	-0.00074	0.009195
Log of land size in hectare	0.073856	0.071524	0.406812***	0.077272	0.92103***	0.084676
Risk factors measurement						
Log of Expected output	0.646915***	0.135126	1.627236***	0.160534	2.667209***	0.223369
Variance of output	-0.00664	0.042886	-0.10729**	0.044614	-0.11073*	0.054953
Skewness of output	0.206669**	0.015772	-0.14249**	0.016173	-0.03028**	0.020878
cons	-6.38077***	1.072149	-12.8225***	1.208997	-21.0464***	1.825602
rho21	0.338838***	0.044842	7.56	0.0000		
rho31	0.263267***	0.04239	6.21	0.0000		
rho32	0.221505***	0.04548	4.87	0.0000		

Log likelihood ratio test of rho21 = rho31 = rho32 = 0 chi2(3) = 100.624 Prob chi2 = 0.0000

The joint significant test of Location dummy chi2 (9) = 534.01 Prob > chi2 = .0000

II. Number of Modern Production Technology Adoption: Ordered Probit Regression

The adoption of technology requires the fixed investment in land, capital and human capital. Thus all farmers will not be in the same position to adopt all the available technologies. For example, small scale farmers may face the liquidity constraint to purchase inputs. Due to different reasons some farmers may adopt single farm input even if the other complementary inputs are required. Others may adopt more than one technology simultaneously, but it may not be at optimal level. Therefore, studying the intensity of adoption of modern production technologies in addition to the adoption decisions is believed to be critical for policy makers. In this study the multiple of technologies adopted by households were used as proxy for intensity of technology adoption. Table 5 presents coefficient estimates and marginal effects of the ordered probit model, for the various explanatory variables influencing farmers' preferences for the multiple of improved agricultural technology (IAT) adoption. The thresholds, or cut points, reflect the predicted cumulative probabilities at covariate values of zero. The results show that factors that tend to significantly determine the multiple of technologies that households are willing to adopt are gender, site variable, percentage of irrigated land, average land altitude index, Primary cooperative membership, Livestock ownership (TLU), credit, value of production asset, family labor(age > 14), parcel size, Expected output and risk measurement factors (variance and skewness of output). Note that the ordered probit coefficient measures the direction of relationship between the dependent variable (adoption) and the explanatory variables and the coefficient can either be positive or negative. Marginal effects show the magnitude of change.

The inclusion of site variable /agro-ecological variables examined are significant and affect the probability level of adoption of multiple of improved production technologies in different direction. The households in North Wello zone were significantly less likely to adopt different improved production technologies. Whereas households in West Gojjam were significantly more likely to adopt the multiple of IATs, but the site variable South Wello was not significant. The result can be explained by farmers who depend on rains for crop production in Amhara region as it is also true for the majority of Ethiopian farmers might be reluctant to adopt IATs. Famers in North and South Wello frequently faces drought and this may lead farmers to be reluctant to adopt numbers of IATs than framers in North Shewa and West Gojjam. Household's membership in at least one primary cooperative significantly increases the likelihood that the farmer would adopt more than one agricultural technology. Households who are member of primary agricultural cooperative are 6.9 percent more likely to adopt more than one IATs. As it can be seen the above discussion, households who is member of primary agriculture cooperative may have information advantage over non-member households and this may encouraged them to adopt the number of IATs.

The result confirmed that households who have more irrigated land were more likely to adopt more than one technology. The estimation result suggested that one more increase in the percentage of irrigated land leads to an increase the probability of adopting number of IPTs by 0.18 percent. Land size was found to have a positive relationship with the probability of adoption of the number of modern production technologies. An increase in land size by 1 hectare would decrease probability of using more than one modern production technology by 16.11 percent. The probability of number of agricultural technologies adoption decisions were influenced positively and significantly by access to credit. It was found significant at 1 percent. This implies that increase in this variable will lead to increased adoption of more than one IPTs. Making credit available to farmers is an important way of increasing the level of demand for different inputs and hence increasing the level of production. .Especially poor households may not be able to purchase key inputs, however farm credit helps poor farmers' fulfill the financial requirement to purchase inputs.

Ownership of livestock have significant and positive effect on the number of IPTs adopted. This indicates that households with more livestock are more likely to adopt more than one IPTs. One more unit increasing TLU leads to increase the probability of more than one IPTs adoption by 1.72 percent. The result may be due to the fact that households with more livestock may finance input cost by selling their livestock. Off farm income has been found significant but negative effect on the number of IPTs adoption. The result may explained by both pull and push factors which are believed to be causes for farmers to adopt off-farm activities than farm activities. Accordingly, a farm household can be pulled into the off-farm sector due to higher returns to labor and capital assets and the less risky nature of investment in the off-farm sector. The push factors that may drive to be engaged in off-farm income sources includes the need to increase family income when farm income alone cannot provide sufficient livelihood and, the desire to manage agricultural production and market risks in the face of a missing insurance market. The risky nature of crop production and repeated bad weather conditions may encourage households to participate more in non-farm activities rather than on crop production. The value of the production assets influences positively the adoption of more than one IPTs by households. In fact production asset (capital) are complementary input with fertilizer, improved seed and chemical inputs so that more value of production assets may require more of another complementary inputs. A unit increasing of value production asset would increase the adoption more than one technology by 5.33 percent.

As in the case of adoption decision, risk measure factors such as expected output, variance and skewness of output have been found again to be an important determinant of number of IPTs adoption. The estimation result shows that, high level of expected output from adopting available technology induces farmers to adopt more than one IPTs. A unit increasing of expected output would result increase in probability of adoption of more than IPTs 46.97 percent. Consistently, with MV probit model estimation, ordered probit estimation confirmed that Variances and skewness of output are significant determinant for decision of adoption a multiple of IPTs. As one unit increase in variance of output would result decrease in the probability of adoption of more than one IPTs by 1.52 percent. Skewness was found to have a negative relationship with the probability of decision of adoption a multiple of IPTs. The implication of this result is that risk aversion increases farmers' reluctance to adopt a multiple of farm inputs.

Table 5. The determinants of the number of production technology: order probit estimation

			Marginal effect			
Explanatory variables	Coef.	Std/err	MAT=0	MAT=1	MAT=2	Mat=3
Male headed dummy	-.2660**	0.0920	0.0590	0.0049	-0.019	-0.0448
Education status of head of households	0.0054	0.0243	-0.001	-0.000	0.0004	0.0009
Dummy for households in Gojjam	.9814***	0.0771	-0.2178	-0.0182	0.0709	0.1652
Dummy for households in south Wollo	-0.0287	0.0962	0.0064	0.0005	-0.0021	-0.0048
Dummy for households in north Wollo	-.5287***	0.0905	0.1173	0.0098	-0.0382	-0.0890
Percentage of irrigated land	.00758***	0.0018	-0.0017	-0.0001	0.0005	0.0013
Average slope index (1 all parcel steeply sloped, 3 all flat)	-0.0489	0.0937	0.0109	0.0009	-0.0035	-0.0082
Average altitude index(1=all parcel much above 5=all much below	.2998***	0.0746	-0.0665	-0.0056	0.0216	0.0505
Use of manure in kg	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
Primary cooperative membership dummy	.2870***	0.0754	-0.0637	-0.0053	0.0207	0.0483
Livestock ownership in TLU	.0713***	0.0146	-0.0158	-0.0013	0.0052	0.0120
Credit dummy(1=credit access, 0 otherwise)	.4644***	0.0630	-0.1031	-0.0086	0.0335	0.0782
Log of value of production asset	.2214***	0.0458	-0.0491	-0.0041	0.0160	0.0373
Log of age of the household head	-0.6516	0.6887	0.1446	0.0121	-0.0470	-0.1097
Log Age square of the household head	0.1613	0.3442	-0.0358	-0.0030	0.0116	0.0272
Log of family labor(age > 14)	-0.0833	0.0653	0.0185	0.0015	-0.0060	-0.0140
Log of off-farm income	-.01534*	0.0071	0.0034	0.0003	-0.0011	-0.0026
Log of parcel in hectare	.6697***	0.0469	-0.1486	-0.0125	0.0484	0.1127
Log of Expected output	1.9525***	0.1314	-0.4333	-0.0363	0.1410	0.3287
Variance of output	-0.0631***	0.0037	0.0140	0.0012	-0.0046	-0.0106
Skewness of output	-0.0156***	0.0025	0.0013	0.0001	-0.0004	-0.0009
cut1	15.0544**	1.0467				
cut2	16.077***	1.0529				
cut3	17.358***	1.0653				

The joint significance test of location dummy chi2(3) = 228.50 Prob > chi2 = 0.0000

Wald chi2(21) 1389.42 prob Chi 2 0.0000

Log pseudo likelihood - 2179.326 Pseudo R2 0.277

5.4 Conclusion and policy implication

In general, the emergence and development of modern agricultural technology, increases in productivity for both land and agricultural labor and production of staple crops. In Ethiopia, however, the use of modern agricultural technologies is still limited and agriculture has remained undeveloped. The study analyzed the determinants of the probability and the level of adoption of multiple improved production technology by smallholder farmers in Ethiopia particularly in Amhara region using the two round EPIICA household survey in 2011 and in 2013. In this research, I used two stage estimation techniques, in the first stage; the production function was regressed with covariate variables for the purpose of generating the risk factors such as expected output, variance and skewness of output. In the second stage, the expected output, variances and skewness of output are incorporated in a household's improved production technologies adoption decision models. The study estimated the improved production technologies adoption decisions using multivariate probit model with FIML and order probit model. The finding revealed that the decisions to adopt improved seed, inorganic fertilizer and chemical input are inter dependent.

The researcher further established that farm characteristics, socio-economic factors, and institutional factors are important in influencing the likelihood of a household adopting inorganic fertilizer, improved seed, and chemical inputs. Production risk is important for determining adoption of individual technology such as; improved seed, fertilizers and chemical inputs as well as the level of adoption of multiple improved production technologies. The expected output increases the probability of adoption decision for inorganic fertilizer, chemical inputs and improved seed and the level of adoption multiple agricultural technology. On the other hand variance of output (yield variability) decrease the probability of adoption decision for inorganic fertilizer and chemical inputs and the level of adoption of multiple improved production technologies. The probability of crop failure (skewness of output) significantly promote the adoption of improved seed. From the result we can argue that households are not only motivated by profit but are also influenced by the level of exposure to "down-side" risk in making agricultural technology adoption decisions. Besides, the individual technology adoption decisions and the combined use of improved seed, inorganic fertilizer and chemical inputs adoption decision are positively affected by land size, percentage of irrigated land, location dummy, and access to credit, membership of local cooperatives and livestock ownership. The study makes the following recommendations based on the finding and conclusions draw. Crop production risk and farmers risk aversion should be consider when designing economic policies to foster technology adoption in order to adequately reflect risk reducing benefits by adopting the technology. The government promotes the combined adoption of improved seed and inorganic fertilizer along with organic manure. The government should give prioritize access to credit which can increase the adoption of technology which consequently will increase the agricultural productivity. Membership of farmers' cooperatives is an important determinant of technology adoption. If so, both non- governmental and government organization should participate in the creation of strong and sustainable local farm cooperatives that will better serve farmers in providing information on improved agricultural practices.

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