ADOPTION OF IMPROVED TECHNOLOGY IN ETHIOPIA

By

Assefa Admassie and Gezahegn Ayele[1]

Abstract

One of the means by which farm level productivity can be increased is through the introduction and dissemination of improved agricultural technologies to farmers. This is possible if and only if, information on the adoption and risk taking behaviour of farmers is known in advance. While some studies have attempted to assess the factors behind the adoption behaviour of farmers, they have either been limited in scope or they focused on few selected locations and/or commodities. The objective of this study is to identify the factors, which exert significant influence on the adoption behaviour of farmers and the intensity of adoption from a nation survey. A total of 1920 farm household heads drawn from four National Regional States were included in the survey. The result shows that younger farmers, famers with larger land size, farmer living closer to market, and farmers who had closer contact with the extension system are more likely to adopt new technology and use it more. The result underscores the need for research and extension programs to be sensitive to the needs of farmers when developing and disseminating technologies that are relevant to their agro-ecologies.

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1. Introduction

The ultimate goal of any rural or agricultural development strategy or program is to improve the welfare of rural households. This goal is achieved among other things by increasing productivity at farm level and by raising farmer's income and by improving their welfare. This is possible if and only if improved agricultural technologies are properly transferred and disseminated to farmers so as to deepen and intensify their production. Institutions that are involved in generating agricultural technology need to have the capacity to carry out studies that document the process of adoption and help in explaining the rationale for framer's decisions.

Adoption studies can be useful for several reasons. First, such information can be used to provide helpful feedback from farmers and help in refining the technology generation and dissemination efforts. Second, it will also be useful to assess the effectiveness of a technology transfer strategy and improve the flow of information between research and extension on the one hand, and policymakers on the other. Finally it helps to document the impact of technology generation or extension. Farmer's adoption of a technology is largely affected by the supply of extension services. The farmer, however, has a demand for new technology that is governed by factors related to his/her household characteristics and socio economic circumstances.

Agricultural development projects can be successful if evidence on factors responsible for adoption patterns and risk taking behaviour are known in advance. Accordingly appropriate measures can be taken to mitigate the effect of risk and provide complementary inputs and outputs. It will not be possible to increase the involvement of producers in development programs that involve new production technologies unless they are convinced with the benefits expected from the participation.

Several modern technology packages have been introduced in Ethiopia over the past four decades. While some studies in the past have attempted to assess the factors behind the adoption behaviour of farmers, they were either restricted to piece meal or location/commodity specific approaches. As a result, the adoption and diffusion of these technologies has not been satisfactorily and comprehensively assessed at a national level. So, the objective of this study is to identify the factors, which exert significant influence on the adoption behaviour of farmers. In addition, the study also aims at investigating the intensity of adoption of modern technologies in Ethiopia. The results of such studies will indicate which particular socio economic factors should be given due considerations in project design and implementation such as the delivery of extension services in Ethiopia.

The rest of this paper is organized into six sections. Section two discusses the nature and structure of technological packages. The third section highlights the process of diffusion of technologies and the resulting curves for fertilizer adoption. Section four discusses the main hypothesised factors influencing farmers' adoption behaviour while section five presents the results of the discrete model analysis. Section six discusses the analysis with regard to the intensity of technology adoption while section seven presents the concluding remarks.

2. The Structure of the Technological Packages

Before embarking upon a study on the adoption behaviour of farmers of a given technology, it is necessary to briefly provide the nature of the technological package that is available. Since 1995, the PADEP extension approach, which used to be agro ecology based was replaced by the Participatory Demonstration & Extension Training System [PADETS]. Compared to the previous strategies of extension, the three core essential and two other features of the PADETS strategy were focused on sizeable demonstration plots in the field of the farmer himself/herself instead of the fenced government plot, the provision of input credit under local government collateral arrangement and institutional linkages with rural development committees. With its stated objectives focused on increased incomes and levels of living, fostering food security and improved health, the extension packages cover food crops - 11 maize, 14 wheat, 6 teff, 2 barley, 6 sorghum and 3 millet varieties. The high value commercial crops include beans, peas, peanut, potatoes, onions, tomatoes, cabbages, carrots, sweet potatoes and coffee.

In the livestock sector 5 varieties of bulls are promoted in conjunction with Artificial Insemination (AI) services and 12 types of fodder. The post-harvest package encompasses animal drawn carts, maize and kocho (flat bread made of Enset crop-Enset ventricosum) processing equipments and improved storage facilities. Improved animal drawn farming tools are also demonstrated. The natural resources utilization and conservation component includes the multiplication and distribution of seedlings, planting different types of trees; the rehabilitation of denuded areas and the dissemination of better management practices for water and soil resources.

Since the 1995/96 crop season when PADETS became operational in all regional states and ecological zones of the country, the two main inputs, fertilizer and improved seeds have witnessed widespread and increasing rates of adoption despite the removal of all input subsidy since 1997/98. Between 1995 when the PADETS became operational and the latest evaluation report for 1999, the consumption of fertilizer increased from 35,272 to 2,168,756 quintals. For the same period, the data for the other major input of the package, seed, were 11,043 and 177,783 quintals. The nature of some of the technologies is inherently indivisible in nature while some are divisible. Certainly fertilizer and seed are divisible inputs and can be applied in various quantities, although each technology has its own specificity with the recommended level on per hectare basis. Farmers often make their own decisions either by way of inputs substitutions or complementing resources. Compelementarity of input often takes place between land and other scarce inputs such as fertilizer, which is a typical characteristic of highland mixed farming.

The number of participating farmers leaped from 31,256 to 3,731,217 covering nearly 40% of the farming population. The value of credit, which began at 8.1 million, has reached 150.2 million birr. Demonstration plots on the fields of farmers covered by the package now stand at 3,807,658. In terms of its spread in hitherto unknown areas, adoption rates of new varieties and fertilizer, diffusion and increased yield rates, some have begun to speak of green revolution albeit in maize.

As is the case in many developing countries with an agrarian economy, agricultural technology adoption has got a number of processes. It has both spatial and temporal dimension. It is argued that technology adoption is not a one-off static decision rather it involves a dynamic process in which information gathering, learning and experience play pivotal roles particularly in the early stage of adoption and diffusion. Farmers move from learning to adoption to continuous or discontinuous use over time. The characteristics of both the user and the technology are important in explaining adoption behaviour and the pathway for adoption. The lag between learning and adoption, and the possibility of discontinuation imply that a longer period will be required for the majority of farmers to use the technology than if adoption was a one off decision leading to continuous use. This picture has been clearly demonstrated by the adoption process of the technology in the four regions of Ethiopia considered in this study.

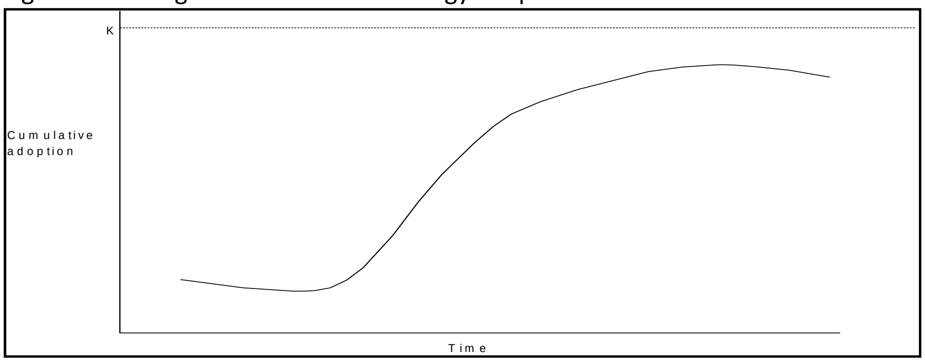
3. The Adoption and Diffusion Process of Technology

It is useful to distinguish between adoption, which is measured at one point in time, and diffusion, which is the spread of a new technology across a population over time (Thirtle and Ruttan, 1987). As it was stated in the foregoing, adoption is not a static process. Early adopters might be non adopters at a later time. On the contrary, late adopters might join the adopters group and would be potential adopters. As a result, many adoption studies go beyond an analysis of current practices and attempt to document adoption history. Information about past seasons requires more time to obtain, but can be very useful. Ideally, information on past practices and adoption history would come from baseline surveys but such information is often not available. Such analysis can be useful for several purposes. It may help project future demand for input, determine whether extension needs to be strengthened or quantify the change in the number of technology users over time to assess impact on households or regions.

Supporting this argument much of the literature on diffusion assumes the cumulative proportion of adoption follows an S shaped curve in which there is slow initial growth in the use of the new technology, followed by a more rapid increase and then a slowing down as the cumulative proportion of adopting approaches its maximum (which may be well below 100% of the farmers).

The most common function used to portray the curve is the logistic function. For technology adoption, the Y-axis represents the proportion of farmer or area adoption, a technology and the X-axis represents time.

Figure 1: The logistic curve for technology adoption



Source: Thirtle, C.D. and Ruttan, V., 1987.

This curve can be described mathematically as

$$Y_t = \frac{K}{(1 + e^{-a-bt})}$$

Where Yt = the cumulative percentage of adopters or area at a time t.

K = the upper bound of adoption

b = is a constant, related to the rate of adoption, and

a = is a constant, related to the time when adoption begins.

If we have sufficient observation on Yt we can estimate the three unknown parameters, K, a, and b with a non-liner regression. For practical purpose, however, this very difficult technique can be replaced with an ordinary least squares regression if we have at least three observations on Yt and we can estimate K (the maximum adoption expected) independently. In this case, we note that the equation of the logistic curve can be transformed to:

$$\ln(\frac{Y_t}{K - Y_t}) = a + bt.$$

Simple ordinary least square regressions of the transformed variable ln (Y / (k-Y) on a constant and time will then yield estimate of a and b (Gricliches, 1957). This kind of calculation is easy to do with many spreadsheet packages. One could also fit a curve without regression with only two observations, although information from only a few observations is likely to be limited.

There are several methods of estimating K. The first is simply to plot the data and to choose the level that appears to be the upper bound of adoption. A second method is to run the regression using different values of K and choose the one that maximizes R2 (Note that in general R and t statistics from these regressions have no statistical meaning. This technique helps to choose K to get a fairly close fit to the data). To reduce the time spent selecting K, a combination of simple plotting and experimental regressions might be used.

Although the logistic curve is the most common way of representing technology diffusion, it is well to remember that it is based on certain assumptions about diffusion, and that the fixed parameters estimated for the curve imply that the relevant t price ratios, infrastructure, and the technology itself have remained constant over the period when the curve is fitted.

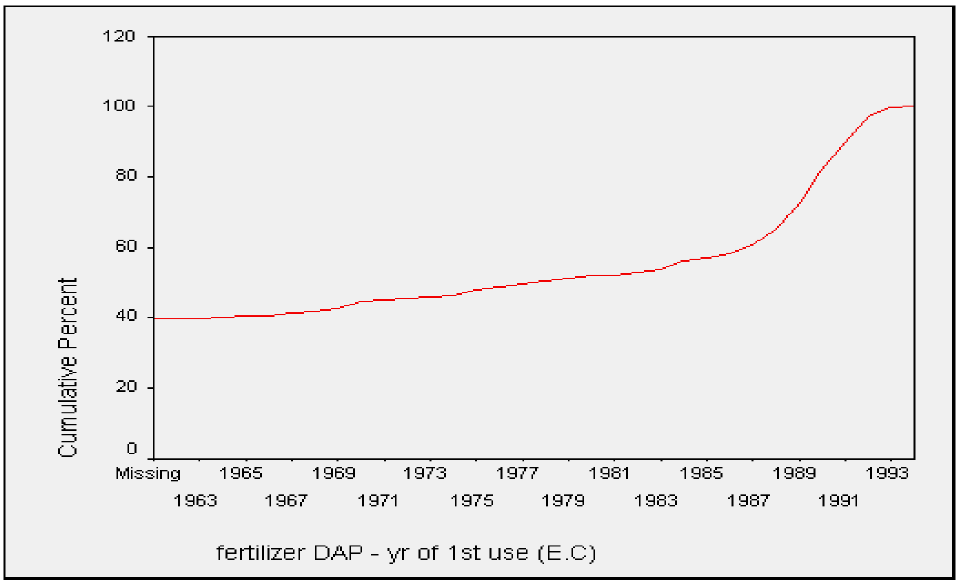
Putting the logic to our data base, the two most important inputs in the extension services promoted and adopted in Ethiopia are inorganic fertilizers in the form of Urea and DAP and improved seeds of wheat and maize with varying degree of management practices. Adoption does not translate itself into a linear relationship with diffusion. Some households under the study have never tried any of the technologies, some have discontinued the use of the technology and few have re-adopted. Such tandem process might have been a reflection of agro-ecological diversity. Agro-ecological diversity also gives rise to differences in farming systems, where we can observe the mixed-maize; the teff-wheat based farming systems etc. Reflecting the agro-ecological diversity, the regional spread would have reflected the variation in the levels of application among the improved seeds and fertilizer rate. However, this is not the case here in this study basically for two major reasons: first, the sample size is not large enough to capture the diversity across agro ecologies statistically and second, the differential adoption rate of improved seeds and chemicals is very low among regions and makes it difficult to conduct agro-ecology based analysis as discussed in the adoption and diffusion part of the report.2

The following figures (figure 2 and figure 3) show the actual adoption history and fitted logistic curves for the DAP and Urea technologies considered in this study,

[2] A much more detailed version of the analysis has been provided in "agricultural extension, adoption, and diffusion in Ethiopia" EDRI, Research Report 1. 2004

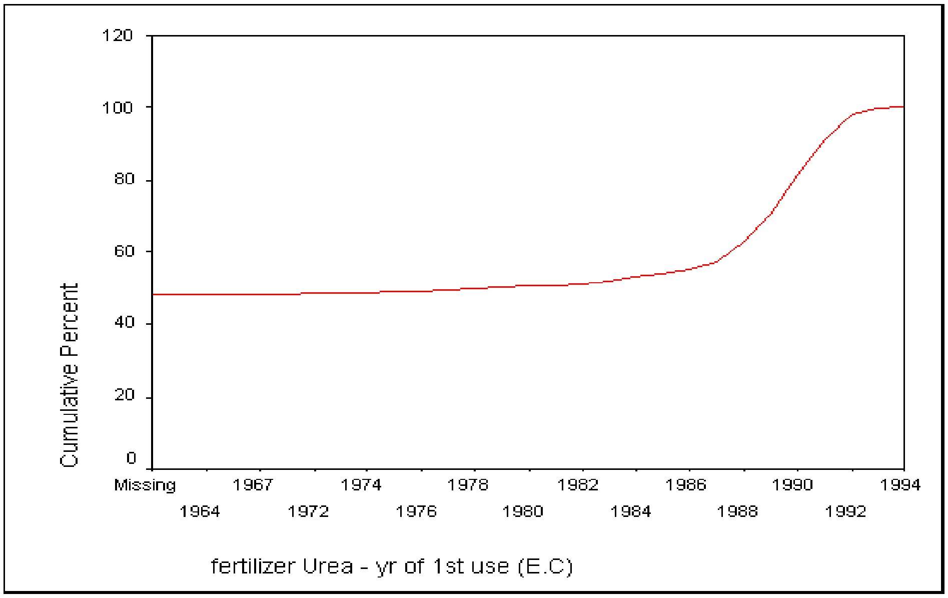
respectively. The two figures portray that the post-PADET period of extension service adoption and intensity is much higher than pre-PADET phase of extension, which confirms the importance of the government's strategy of increasing agricultural production to achieve a sustainable food security in the country.3 Although subsidy on fertilizers was removed during this period, the adoption rate for both Urea and DAP dramatically increased during the PADET phase.

Figure 2: Logistic curve for DAP fertilizer



The two curves also indicated that the post-PADET period was largely characterized by increased intensity of fertilizer use, greater variety of application and more advanced farming practices/management. The horizontal transmission of knowledge and farming practices between farmers themselves may also have contributed to the increased usage. Between 1987/88-2000/01, the adoption of the package of the technologies increased at an average of 35% per annum until the price collapse of the latter years beginning from 1997/98. The only year of negative rate of adoption was the crop year following the political transition of 1991/92. In the middle of the PADET years before the steady decline from 1998/1999 onwards, the average increase in the rate of adoption was over 80% after which the average negative rate was about 30 percent, which is indicated as the culminating point on both curves .

Figure 3: The Logistic curve fitted for Urea Adoption



4. Explaining Farmers' Adoption Behaviour

When making their decisions about the adoption of a given technology farmers are assumed to weigh the consequences of adoption of innovations against their economic, social and technical feasibility. If we assume that social values or technical progress are reflection of the level of economic achievement, then framers evaluate in these terms, the incremental benefits of using a new technology.

Discrete choice models are often used to explain farmer's adoption behaviour. The application of qualitative choice models in explaining different socio economic phenomena are not new. Qualitative choice models are important in analysing relationships involving a discrete dependent variable. In such relationships, the probability of an event occurring is a function of a set of non-stochastic explanatory variables and a vector of unknown parameters. The two most popular functional forms often used are the probit (the standard cumulative distribution function) and the logit (the logistic distribution functional) models. Both logit and probit models are techniques for estimating the probability of an event (such as adoption) that can take one of two values (adopt, don't adopt).

The basic difference between the two models is that logit assumes the dependent variable follows a logistics distribution while the probit model assumes a cumulative normal distribution. For most simple problems the interpretation of the same data, whether estimated by probit or logit will be very similar, with noticeable differences occurring only in tails of the distribution. In general, probit analysis is appropriate for designed experiments, whereas logit regression is more appropriate for observational studies. The probit analysis procedure reports estimates of effective values for various rates of response (including median effective dose), while the logit procedure reports estimates of odds ratios for independent variables.

4.1. The Dependent Variable

The dependent variable is a categorical variable, which takes the value of 1 if the farmer has adopted fertilizer, improved seeds or chemicals over the last two years and the value of 0 if the farmer has not adopted any of these technologies.

4.2. The Factors that Influence Framers' Adoption Decisions

It is assumed that farmers' decision to adopt or reject a technology at any time is influenced by the combined effect of a number of factors related to their objectives, opportunities and constraints. The list of factors that may influence adoption could be very long. These factors can be categorized under some major headings. The following three categories of factors were hypothesised to affect the adoption behaviour of farmers in this particular study.

4.2.1. Farmer Specific Characteristics

This group constitutes those factors that are related to the farmer's personal attributes. These factors may include variables such as education, age, sex, wealth position that may predispose a farmer to take an interest in new technology. Such farmer characteristics occupy a major part of the literature on adoption. Analysis of this kind of factor can be used for an assessment of the impact and distributional consequences of adoption and whether the new technology restricted to certain sectors of the farming population or not.

Much of the literature on adoption assumes that new technology is necessarily good and concretes on analysing those characteristics of individual farmers that make them more receptive to these innovations. The main factors considered in this study are described below.

Education level of the head of the household: Many adoption studies examine the relation between a farmer's formal education and adoption behaviour and most show the existence of some relationship between technology adoption and the education level of a farmer. The more complex a technology is the more likely is that education play a role. Education improves the access to information and new ideas and inputs provided by extension workers. Education may make a farmer more receptive to advice from an extension agency or more able to deal with technical recommendations that require a certain level of numeracy or literacy. These skills are, of course, not necessarily perfectly correlated with years of schooling and some adoption studies go so far as to include a small test of farmers' skills (for example, of mathematics necessary to calculate a dosage of herbicides).

Informal education may be important as well, and in certain cases adoption studies enquire about such things as attendance at short courses organized by extension service. Education could be measured either as a categorical variable or as a continuous variable. Sometimes it may be necessary to differentiate between simple literacy and numeracy and formal education attendance.

Age of the farm household head: another farmer characteristic that is often examined in adoption studies is the age of the household head. Age of the household head is usually taken as a proxy for experience with farming. A farmer's age may influence adoption in one of several ways. The direction of influence is not however, very clear and there are always mixed results from empirical analysis. Older farmers may have more experience, resource, or authority that would allow them more possibilities for trying a new technology. On the other hand it may be that younger farmers are more likely to adopt a new technology, because they have had more schooling than the older generation or perhaps have been exposed to new ideas and more risk takers.

Gender of the household head: women farmers are often forgotten in official agricultural statistics. Because women play key role in the agricultural system it is important that adoption studies consider the degree to which a new technology reaches women farmers. Women headed households are usually less likely to adopt new technology since they are usually endowed with less resource and are less exposed to new information and ideas.

Ethnic, religious and community factors: in many cases a technology is introduced to an area that includes farmers of different customs and traditions. These differences may be most notable between communities or between members of several groups living in the same community. It will not be surprising to note that adoption pattern may differ among these groups. So, it would be advisable to control for such factors when undertaking adoption studies.

Wealth position of the farmer: This variable captures the social status of the household within the community. Wealth status of the household was derived on the basis of the perception of the community and development agents, which classifies households as poor, average or better off households. It is often expected that wealthier farmers may be the first to try new technology, especially if it involves purchased inputs. This variable indicates the social status of a farmer in the society with respect to his/her asset holdings and other forms of social status deemed important within the community. It is more of a value judgment rather than being quantified stratum.

4.2.2. Farm Resources

The resource base of the household could also be an important factor influencing the household's technology adoption behaviour. Factors like farm size, access to credit, availability of labour, etc., are expected to influence the adoption behaviour of farmers.

Farm size: The size of the farm owned by the household may be an important factor in a technology adoption study. It is often assumed that farmers with larger farm size will be more likely to adopt a new technology, especially if the innovation requires an extra cash investment. It may also be that a certain threshold farm size may be necessary before the investment in a technology is worthwhile. In addition, on larger farms different management practices may be tried. Farm size is also related to access to information or credit that would facilitate the adoption of a recommendation. On the other hand, certain technologies may be appropriate for the intensive management characteristic of smaller farms.

Labour: Different technologies have different characteristics with respect to their labour requirement; some reduce the amount of labour required for growing the crop, while others significantly increase the demand for it. Increased production may also require an increased involvement of household members. Household size may be a proxy for the labour availability within the household. Household size represents the number of potential active family members. Labour also includes labour that could be supplemented from other sources such as hired and migrant labour. The later form of labour is emerging type of labour after which a restriction of labour movement by the Derg regime has been lifted or banned. Still such types of labour arrangements are not well-structured forms of labour in rural Ethiopia.

Availability of credit facility: credit may be an important factor in determining technology adoption. If a recommendation implies a significant cash investment for farmers, its adoption may be facilitated by an efficient credit program. If the majority of adopters use credit to acquire the technology this is a strong indication of credit's role in diffusing the technology. Credit availability is, therefore, expected to have a positive impact on extension participation.

Number of oxen: The number of oxen owned by the household is another important factor affecting the adoption of a technology. Oxen are the most important drought power in the Ethiopian agriculture. It is a customary practice to lend or rent oxen whenever, a farm operator has none or one ox. Farm operators with two or more oxen are better adopters of a new technology than farmers with no or single oxen. The number of oxen owned by a farm household is, therefore, hypothesized to influence technology adoption positively.

4.2.3. Market Arrangements and Access to Information

The adoption of a technology may be hindered or enhanced by the organization of input and output markets. A technology may lead to a significant increase in crop production but unless the inputs needed are readily available or if the extra production cannot be utilized effectively then the technology may be rejected.

Distance of the household's residence from the main road, market centres or demonstration place is another important factor influencing the adoption of a technology. The closer the household is to market centres and/or road the better it would be to access information about technology and prices and hence is positively related to technology adoption.

Access to information: In order for farmers to adopt a new technology they must know it. It is, therefore, important to examine the degree to which farmers have received the necessary information. Access to information may be captured by extension contact. This may help in analysing the degree to which low adoption may not be a function of the technology itself, but rather of the information that is available. This analysis is useful for improving extension policies and programs.

4.2.4. The Empirical Model and the Definition of the Variables

The Empirical Model

As pointed out earlier adoption studies usually use the discrete choice models to identify the determinant of technology adoption. Very often the Logit and the Probit models are specified to explain the technology adoption behaviour of farmers. The technical details of the two models are provided in Annex 1.

The estimated probability of adoption of a technology in a logit model is given by F(β'x), where;

$$F(\beta^1 x) = \frac{1}{1+\varepsilon^{\beta^1 x}}$$

, which follows the cumulative logistic probability distribution.

The expression β1x is defined as:

β1x = β0 + β1x1 + β2x 2+ βk xk

where the βs are the unknown parameters to be estimated and the Xs are the explanatory variables identified.

Definition of the variables used in the study.

The logit and probit models specified for the study included one dependent variable and several explanatory variables. The dependent variable is specified as 1 if the farmer had adopted the technology and 0 otherwise. The explanatory variables considered in this study are as follows:

SOC_ST1 = dummy variable representing the socioeconomic status of household = 1 if household is poor; 0 otherwise

SOC_ST2 = dummy variable representing the socioeconomic status = 1 if the household is classified as an average, 0 otherwise.

HH_SIZE = the hhousehold size

SEX = dummy variable representing the sex of the household head = 1 if male, 0 if female

AGE = represents the age of the household head.

Literacy = dummy variable representing the literacy level of the head of the household. = 1 if literate, 0 otherwise

Education = the level of formal education or the actual formal grade completed by the head of the household.

Orthodox = dummy variable for being an orthodox Christian: = 1 if household head is orthodox Christian, 0 otherwise

Moslem = dummy variable for being a Moslem: = 1 if household head is Moslem, 0 otherwise.

Farm Size = represents the total farm size of the household in hectare.

Distance = stands for the distance of household from development agent and input delivery system (km)

Extension Contact = dummy variable for extension contact: = 1 if household had extension contact over the last 2 years; 0 otherwise

Credit = dummy variable for credit: = 1 if the household had taken loan; 0 otherwise.

Oxen = represents the total number of oxen the household had.

5. Results and Discussion

There could be several household and socio economic characteristics that affect the behaviour of a farmer. Identifying the factors affecting the adoption of a technology is an important exercise, which will have important policy implications. Thus, this analysis was undertaken with the aim of isolating the main factors that influence farmers' adoption behaviour. In order to examine this fitting a dichotomous choice model is necessary. In the dichotomous choice models utilized in this study, a household or a farmer is considered as an adopter if the household had used improved technology such as fertilizer, variety or herbicides, etc. over the past two years prior to the survey.

The information for this study came primarily from a household survey conducted in four National Regional States (Amhara, Tigray, SNNPR and Oromiya). From each National Regional State a sample of Woredas, classified on the basis of their modern technology usage were selected from which samples of peasant associations were identified. In the final stage of the sampling procedure, farm households were selected from the selected peasant associations. A total of 1920 farm household heads were included in the survey. Detailed information on production, technology use, land and livestock resource, as well as on farming practices was collected through a structured questionnaire.

Table 1 presents the descriptive statistics for some of the variables used in this study. As can be observed from the table, the average family size is around six persons. The average age of the household head has been a little more than 45 years. The mean level of formal educational grade completed by the household head has been about 1 year. The average land size owned by a household has been found to be just above one hectare with a standard deviation of about 3 hectares. The average distance of a household from an input delivery center has been about 4 kilometres. Finally the average number of farm oxen owned by a household was around one. A little more than 50 percent of the farmers had some extension contact over the last two years preceding the survey.

Table 1: Descriptive Statistics

Variable	N	Minimum	Maximum	Mean	Std. Deviation
SOC_ST1)	1918	0	1	.65	.476
SOC_ST2	1918	0	1	.28	.451
HH_SIZE)	1918	1	20	5.59	2.483
SEX	1920	0	1	.80	.403
AGE	1916	4	100	45.25	14.955
Literacy	1918	0	1.00	.1168	.32125
Education	1918	0	12.00	1.184	2.65569

Orthodox	1915	0	1.00	.5906	.49185
Moslem	1915	0	1.00	.2078	.40586
Farm Size	1871	0	6.00	1.135	2.01651
Distance	1499	0	60.00	3.905	4.93486
Extension Contact	1908	0	1	.53	.499
Credit	1850	0	1	.28	.450
Oxen	1247	1.00	8.00	1.641	.79275

Source: Survey data

As discussed in the analytical section of this paper, the discrete choice models i.e. probit and logit models has been fitted for the data. The two models have been fitted for the purposes of comparing them. In general the results are comparable.

The summary statistics for the probit and logit models are given in Table 2. A maximum of 6 iterations were required for convergence of the Probit and the logit models. The likelihood ratio test indicates that the models as specified explained significantly non-zero variations in factors affecting farmers' technology adoption behaviour. The test is significant at 1 percent level and implies that the independent factors taken together influenced the adoption of the technology by farers in the study areas. The parameter estimates are asymptotically consistent and efficient. The two models have, correctly classified more than 79 percent of the farmers adopting new technology over the last two years. All these imply that the specification of the logit and probit models and the conclusion drawn on the basis of the analysis are valid.

Table 2: Summary statistics of the Probit and Logit Model estimations

Statistics	Probit	Logit
Log likelihood function	-463.1280	-462.1375
Restricted Log likelihood	-617.6484	-617.6484
Percentage of farmers correctly classified	79.33	79.53
Total number of iterations	6	6
Chi-squared	311.0219	311.0219
Degrees of freedom	14	14
Significance level	0.0000	0.0000

The estimated coefficients of the parameters of the probit and logit models are given in Tables 3 and 4, respectively. The marginal effects of the variables on the probability of the farmer's adoption of the technology, which were calculated on the mean values of the variables, are also presented in the same tables. The results of the two models were evaluated on the basis of the a priori expectations of the coefficients of the variables included in the models in terms of signs, magnitude and their statistical significance.

Table 3: Maximum Likelihood Estimates for the Probit model

Variable	Coefficient	St. error.	P(t) > T	Marginal effect	P(t) > T
Constant	0.1109	0.3335	0.7396	0.0369	0.7393
SOC_ST1	-0.1492	0.1847	0.4190	-0.0496	0.4191
SOC_ST2	0.0159	0.1879	0.9324	0.0053	0.9324
HH_SIZE	0.0843	0.0228	0.0002	0.0280	0.0002
SEX	-0.0805	0.1501	0.5919	-0.0267	0.5918
Age	-0.0110	0.0036	0.0023	-0.0037	0.0022
Literacy	0.2186	0.1388	0.1154	0.0727	0.1149
Education	-0.0128	0.0197	0.5159	-0.0043	0.5160
Orthodox	-0.7373	0.1538	0.0000	-0.2451	0.0000
Moslem	-1.3014	0.1814	0.0000	-0.4326	0.0000
Farm size	0.2014	0.0637	0.0016	0.0669	0.0012
Distance	-0.0210	0.0092	0.0221	-0.0069	0.0224
Extension contact	1.3368	0.1065	0.0000	0.4444	0.0000
Credit	0.1561	0.1109	0.1593	0.0519	0.1588
Oxen	0.0806	0.0685	0.2394	0.0268	0.2397

Source: Computed from survey data

Based on the sign borne by the coefficients and their statistical significance in both models, the results indicate that older farmers are significantly less likely to adopt the combination of technologies considered in this study. This implies that, on the average, older farmers are more likely to stop adopting the technology as their physical ability to participate actively in farming activities declines with increasing age. While older farmers may be less inclined to try new farm practices, younger farmers exposed to improved technologies will have increasing likelihood of adoption, ceteris paribus, as they become more aware of the benefits of adoption and have the opportunity to adjust productive resources over time. Thus, younger and progressive farmers should be the primary targets of extension services regarding new technology. However, while younger farmers are said to have greater flexibility in accepting new ideas and in dealing with risks, it is not clear what upward bounds can be set on this age level.

Similarly the coefficient of farm labour represented by household size is statistically significant and has a positive association with technology adoption. This result confirms to the a priori expectation that farmers with larger family size do not face labour shortage to adopt the technology and mange it. In other words, families with a regular supply of labour do not face shortage of labour that may be needed to manage the increased output as a result of technology adoption.

Table 4: Maximum Likelihood Estimates for the Logit model

Variable	Coefficient	St. error.	P(t) > T	Marginal effect	Probability
Constant	0.3004	0.5842	0.6071	0.0580	0.6062
SOC_ST1	-0.2729	0.3263	0.4029	-0.0527	0.4028
SOC_ST2	0.0236	0.3324	0.9433	0.0046	0.9433
HH_SIZE	0.1429	0.0400	0.0004	0.0276	0.0004
SEX	-0.1496	0.2600	0.5652	-0.0289	0.5651
Age	-0.0187	0.0062	0.0025	-0.0036	0.0024
Literacy	0.3842	0.2436	0.1147	0.0742	0.1138
Education	-0.0256	0.0341	0.4524	-0.0049	0.4524
Orthodox	-1.3605	0.2790	0.0000	-0.2627	0.0000
Moslem	-2.3339	0.3270	0.0000	-0.4506	0.0000
Farm size	0.3469	0.1109	0.0018	0.0669	0.0012
Distance	-0.0351	0.0154	0.0224	-0.0068	0.0226
Extension contact	2.2762	0.1873	0.0000	0.4394	0.0000
Credit	0.2602	0.1921	0.1756	0.0502	0.1751
Oxen number	0.1410	0.1213	0.2450	0.0272	0.2454

Source: computed from survey data

The other variables that are highly significant in both models are the factors that are related to religion. The result suggests that both Moslems and orthodox Christians are less likely to adopt new technology when compared to farmers practicing other religions. One may argue that orthodox Christians and Moslems are relatively more conservative than other types of religious practices and thus resists change or changes are slow. However, it would be very difficult to provide a rational explanation for this result as this has to be further verified using some more empirical analysis.

The result shows that farm size is strongly and positively related to technology adoption. Land is one of the most important inputs into any farming business. In the case of Ethiopia, farm size is an indicator of the level of economic resources owned by the farmer. Greater land size serves as a security against the risk of crop failure. Farmers with more plots of land may be able to allocate part of their land for the new technology and thus are more likely to adopt new technology than those who have small farm size. Land being a scarce factor of production, farmers with small plots of land often do not take the risk of adopting a technology, which is unknown to them. They often learn and follow the progressive farmers with larger farm size and who adopt a technology faster than those with smaller land sizes. Some technological inputs may also require a given economic size of land to be adopted.

Distance to the market center has a strong and negative effect on technology adoption. This means those framers who live away from service centers such as demonstration place, development agent, market place are less likely to adopt the technology. Distance could be a barrier to technology adoption. Farmers who live far away from demonstration canters could have less access to information on improved technologies and hence are unlikely to adopt new technology. Distance in this particular case could also mean, distance from urban centres, which serves as market outlets for the produce of the farmers. Distance may also be a covariate with access to services and other employment opportunities.

The coefficient of the variable representing farmers' contact with extension agents came out to be statistically significant with a positive sign. The positive and highly significant coefficient of the extension contact variable indicates that provision of regular and frequent extension services by development agents within the farmer development centre plays a fundamental role in the dissemination and adoption of a technology. This means that farmers who had some kind of extension contact are strongly and positively motivated to adopt modern technology. The extension contact helps the smallholders to raise their awareness about the characterization and attributes of the technology and use and impact.

Most of the other variables although they are not statistically significant have the expected signs. For example, the coefficient of literacy is positive although not significant. This shows that literate farmers are more likely to adopt modern technology than illiterate ones. Literate farmers could have better access to information, which is critical in technology adoption. Similarly, the number of oxen owned by the household was positively related to the probability of adoption as expected although it was not significant. The parameter of the credit variable is positive as expected, although not statistically significant. This means that the availability of credit from either formal or informal sources encourages the use or adoption of modern technology. Most farmers in the study area use, in one way or another, credit from either formal or informal sources. The informal sources of credit are difficult to quantify and know the amount. The delivery of modern agricultural inputs is supported through financial credit facilitated through regional

Governments serving as collateral. In general, formal credit is not a major constraint for those adopting packages of the technology.

Finally, although not statistically significant the negative sign borne by the coefficient of formal education indicates that farmers who have undergone formal education are less reluctant to adopt farm technology. It appears that farmers with formal education are mostly youngsters who are farming rented or shared land or family land and less likely to stay in the farming business. They often migrate to urban areas in search of jobs or engage themselves in other business than their counterparts who have not undergone any formal education.

As stated earlier, the marginal effects provide the change in the probability of adoption with respect to the given values of the variables included in the model. The marginal effects are computed at the mean levels of the variables. The marginal effects of household size, age, religion, farm size, distance of household from service centers, and extension contact were statistically significant at least at 5 percent level in both models. Hence, when family size increases by one more member the probability of farmers becoming an adopter increases by about 3 percentage points. It appears that family labour is an important aspect in the adoption process of farm households. Adoption of a technology has clearly increased the demand for household labour, particularly for harvesting and weeding activities. It has also increased the demand for seasonal labour particularly in teff and Maize production. Labour for weeding comprises the highest labour share nearly in all farm activities in the study areas. Teff claims the highest labour, per hectare, in all the regions, except Tigray, for the adopters group.

Similarly the probability of being an adopter declines by about 0.4 percentage points as the age of the household increases by one more year. As farm size increase by one unit the likelihood of becoming an adopter increases by nearly 7 percentage points. This shows that land size plays an important role in increasing the number of adopters in a given period of time. The result seems also consistent with the survey that most farmers also indicated that farmland is another constraint in adoption process of a technology. Extension contact is also an important variable. Farmers who had some extension contact are about 44 percentage points more likely to adopt a technology than those who do not have any contact. Extension contact is an important factor for more and fast adoption of a technology in any technology adoption process.

6. Factors Affecting the Intensity of Fertilizer use

Factors affecting the intensity of adoption are estimated by examining their influence on areas planted with improved seed and/or those receiving fertilizer. Areas planted with improved seed and areas receiving fertilizer or agricultural chemicals have censored distributions since they are zero for those not adopting the technologies. This suggests that ordinary least squares regression is not appropriate and that Tobit estimation should be used (Tobin, 1958).

The Tobit model is as follows (McDonald and Moffit, 1980). Let IA represents intensity of adoption of an improved technology, IA* represents the solution to the utility maximization problem of intensity of adoption subject to a set of constraints per household and conditional on being above a certain limit. IA0, is the minimum technology adoption intensity per household. Here, IA0 = 0 hectares planted with improved seed or amount of fertilizer or amount of chemicals applied per hectare of land. Therefore,

$$IA = IA^* \text{ if } IA > IA0$$

$$= 0 \text{ if } IA^* \leq IA0$$

The above equation represents a censored distribution of intensity of adoption since the value of IA for all non adopters equals zero. Following Tobin (1958) the expected intensity of adoption of a given technology E(IA) is:

$$E(IA) = X\beta F(z) + \sigma f(z)$$

Where X is a vector of explanatory variables, F(z) is the cumulative normal distribution of z, f(z) is the value of the derivative of the normal curve at a given point (i.e., unit normal density), z is the Z score for the area under normal curve. β is a vector of Tobit maximum likelihood estimates, and σ is the standard error of the error term.

6.1. Results of the Tobit Analysis

The dependent variable in the Tobit analysis has been the amount of DAP and urea fertilizers applied during the agricultural season considered. The results of the Tobit model presented in Table 5 gives the maximum likelihood parameter estimates of the amount of fertilizer applied.

According to the result of the Tobit model analysis, household size has been found to be a significant variable affecting the amount of fertilizer adopted positively. Households with larger family size are expected to apply more fertilizer in order to produce more food for the family. On the other hand larger family size minimizes the shortage of labour and the need for non-family labour thereby enabling the household to purchase and use more fertilizer.

The results also show that farm size significantly and positively influences the adoption of fertilizer. This implies that farmers with larger farm size adopt more fertilizer as expected since they are likely to have more opportunities to learn about new technology, have more incentive to adopt it, and are able to bear risks associated with early technology adoption (Feder et al, 1985; Feder and Slade, 1984). Farmers with larger holding may also have more land to try the new technology.

Controlling for other factors, which affect adoption of fertilizer technology, literacy level has a statistically significant influence (at 10%) on the willingness of farmers to adopt the fertilizer technologies as we have expected. However, unlike our expectations formal education has not been a significant determinant of fertilizer. In fact, it negatively affected the amount of fertilizer adopted. Farmers who have undergone formal education are less likely to remain in the farming business.

Having extension contact has been highly significant and in fact has the highest positive effect on the intensity of fertilizer use. Development agents are important sources of information for the rural economy. They also provide advise to farmers regarding the optimum amount of fertilizer to be applied on the other hand. Hence the positive and strong effect of extension contact on farmers' fertilizer's use has not been unexpected.

From among the household head attributes age has been found to be an important determinant of fertilizer use. Age was found to have a negative and strong influence (significant at 10 percent) on the intensity of fertilizer use. As argued earlier older farmers are less likely to adopt new technology. So, the relationship between age and fertilizer use has been inverse.

Distance as measured by the distance of the household's residence from market and development centers had a negative and significant influence on the fertilizer use. As expected, the farther the household lives from such centers the less likely for the farmer to intensify the use of fertilizer. So, proximity to market centers has a strong influence on the amount of fertilizer to be adopted and used.

As before the two variables representing the influence of religious factors on the intensity of fertilizer adoption have significant and negative effect on the intensity of fertilizer use. The other variables have not been found to be significant in general.

Table 5: Maximum Likelihood Estimates for the Tobit model

Variable	Coefficient	St. error.	B/std error	Probability
Constant	0.0641	0.1487	0.4310	0.6615
SOC_ST1	0.0399	0.0796	0.5020	0.6155
SOC_ST2	0.1055	0.0797	1.323	0.0037
HH_SIZE	0.0278	0.0096	2.902	0.5621
SEX	0.0401	0.0692	0.580	0.0099
Age	-0.0042	0.0016	-2.578	0.0727
Literacy	0.1067	0.0594	1.795	0.2120
Education	-0.0099	0.0079	-1.248	0.0000
Orthodox	-0.2624	0.0603	-4.350	0.0000
Moslem	-0.5302	0.0776	-6.831	0.0241
Farm size	0.0340	0.0151	2.255	0.0007
Distance	-0.0149	0.0044	-3.382	0.0000
Extension contact	0.7778	0.0529	14.707	0.3699
Credit	0.0428	0.0477	0.897	0.5630
Oxen number	0.0165	0.0286	0.578	0.0000
σ	0.6072	0.0192	31.561	0.0000

Source: computed from survey data

7. Concluding Remarks

The objective of the first part of this study was to explain the factors that are important in subsistence farmer’s decisions to adopt improved technologies in Ethiopia. Although this study does not reflect agro ecological differentiation (because of the nature of the sampling) it was observed that on aggregate levels there are farm and farmer specific attributes that explain the technology adoption behaviour of farmers. For instance, older farmers have lower probability of adopting a new technology as compared with younger farmers. Thus, it would appear that younger farmers were more likely to bear the risk associated with the new technologies. Farmers with larger operating area are more likely to be technology adopters when compared to those with smaller land holdings. Similarly, proximity to extension service centres may be an important factor in improving the adoption of new technology. Information is a crucial determinant of the adoption of a technology. Hence, extension contact has been found to be an important variable in explaining the adoption behaviour of Ethiopian farmers

The result implies that benefits from extension would be maximized by focusing extension activities on those factors that are important in subsistence producers' adoption behaviour of improved technologies. Thus, polices for strengthening the extension service delivery capabilities of national institutions through technical support and short and long-term training programs are important.

The second part of the study has shown that the intensity of the use of improved technologies like fertilizer by farmers in Ethiopia is affected by household characteristics and the amount and type of resources owned by the farmers. The result of the study suggests that factors like land size owned by the household, age of the farm household head, household size, religion, distance from market and service centers, extension contact and literacy level of the household head are important in determining the amount of input technology (fertilizer) to be used. Those with larger farm size are more likely to increase the intensity of use of the technology. Such farmers may be better informed and could be better prepared to bear the risk associated with a greater usage of the new technology.

In terms of policy implications this underscores the need for research and extension to be sensitive to the needs of small farmers by developing and disseminating technologies that are relevant to agro-ecologies. Thus, interventions should take into account not only the biophysical environment but also the socio economic environment of the farmers.

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