



ADDIS ABABA UNIVERSITY
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**THE DETERMINANTS OF MODERN AGRICULTURAL
INPUTS ADOPTION AND THEIR PRODUCTIVITY IN
ETHIOPIA**
(The Case of Amhara and Tigray Regions)

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ABBREVIATIONS

ADLI: Agricultural Development Led Industrialization.

AISCO: Agricultural Input Supply Corporation.

AISE: Agricultural Input Supply Enterprise.

CPP: Comprehensive Package Program.

CSA: Central Statistics Authority.

DAP: Di Amonium Phosphet.

EARO: Ethiopian Agricultural Research Organization.

EDRI: Ethiopian Development Research Institute.

EEA: Ethiopian Economic Association.

FAO: Food and Agricultural Organization.

FFYP: First Five Year Plan.

GDP: Gross Domestic Product.

HYVS: High Yielding Variety Seeds.

MDG: Millennium Development Goals.

MOA: Ministry of Agriculture.

MPP: Minimum Package Programs.

OLS: Ordinary Least Square.

PADEP: Peasant Agricultural Development Extension Program.

PADETS: Participatory Demonstration and Extension Training System.

SFYP: Second Five Year Plan.

SNNP: Southern Nations and Nationalities Peoples.

TFYP: Third Five Year Plan.

Abstracts

The role of the agricultural sector in terms of its contribution to the Ethiopian economy is very immense. Further, the success and failure of the Ethiopian economy is highly correlated to the performance of this sector. But, still now, the sector is operated by traditional means of production and well known for its backwardness. Hence, to accelerate the sector's growth and increase its contribution to the overall economic growth and securing the food self sufficiency objective of the country, the application of modern inputs in the sector plays a great role.

This paper mainly aims at identifying those factors which significantly contribute to the adoption decision of modern agricultural inputs by the farmers and their productivity. To this end, the data collected by EDRI in 2001/2002 is used. In order to identify the significant factors contributing to the farmers' adoption decision, the logit model is used. The factors contributing to productivity are identified using the Cobb-Douglas production function model.

It is found that farmers endowed with better resources are better adopters in both Amhara and Tigray regions. The distance of input delivery institutions from the household, extension contact of the farmers and agro-ecological conditions are also major determinants of the adoption decision in both regions. Further, the socio-economic status of the farmers and the education levels of the household head's are significant in Amhara regions.

The impact of land size, the ownership of oxen and agro-ecological conditions to the productivities of farmers in both regions are significant. Further, other sources of income than agriculture, access to credit and ownership of radio are significant determinants of productivity in Tigray. But in the case of Amhara region, whether the farmer is adopter or not, whether there is sick family member in the household and the socio-economic status affect the productivity of farmers.

CHAPTER I

INTRODUCTION

1.1. Background

The agricultural sector has always been an important component of the Ethiopian economy. Despite the marginal decline in its share in GDP in recent years, it is still the single largest sector in terms of its contribution to GDP, employment and source of foreign exchange. Its impact on the overall performance of the economy is also significant. For instance, agriculture's growth by 2.2 percent contributed 18.5 percent to the 5.3 percent growth in GDP registered in 1999/2000. Similarly, the sectors growth by 11.4 percent contributed 64.9 percent to the 7.7 percent growth in GDP in 2000/2001. On the other hand, a 3 percent and 12 percent decline in the growth rate of agriculture in 2001/2002 and 2002/2003 negatively affected the performance of the overall economy by 112 percent and 140 percent, respectively. However, the growth in the industry and service sector offset some of the negative effects of the decline in the agricultural sector (EEA, 2004).

The country has a moderate agricultural potential which has not yet been used appropriately. The total land area of the country is 112 million hectares out of which 65 percent have agricultural potential, but only 22 percent of it has been used. The country's agriculture is highly dependent on the vagaries of nature, especially the availability of rain fall. Even if the country is said to have high irrigation potential, only less than 5 percent of it is used (Beyene, 2004). It is mentioned in many literatures

that, the countries diversified types of soils and climates, which are mainly the result of high range in altitude, have a major advantage of producing different types of crops and livestock.

Out of the total production of agriculture, about 70 percent comes from crop production and the rest 30 percent comes from the livestock sub-sector (CSA, 2003). Out of the total temporary and permanent crops produced in the country, more than 85 percent comes from three major food crops; cereals, pulses and oilseeds.

Despite its paramount importance in the economy and its potential for growth, however, Ethiopia's agricultural sector has performed poorly in terms of both production and productivity in the last four decades (Mulat, 1999; Beyene, 2004). About 40 percent of the population still lives below poverty line. Critical food shortage and recurrent famine led to a need for massive food aid and imports (FAO, 2002). According to Mulat (1999), food aid accounted for as much as 10.7 percent of the domestic production during the period 1985 to 1996. The report of Ethiopian Economic Association (2004) also stated that in the year 2004, about 7.2 million Ethiopians have required relief assistance to meet their minimum food requirement.

The major reason behind the poor performance of the sector is the backwardness of the technologies used in the production. Moreover, because of the rapid population growth in the country, the rural land holdings are decreasing from time to time. According to Mulat (1999), 36 percent of the rural land holdings are less than 0.5 hectare. In addition, the low productivity of the sector makes the farmer subsistent

with no or little surplus for investment and input purchase resulting in the vicious circle in the lives of the farmers.

The sector is dominated by small scale farmers cultivating about 96 percent of the total area under crop, producing more than 90 percent of total agricultural output and 97 percent of food crops (EEA, 2004). And the majority of the poor in Ethiopia resides in this sector. So in order to achieve one of the Millennium Development Goal (MDG) of the United Nations, to achieve food security and alleviate severe poverty by half in 2015, the agricultural sector could play a great role. Many empirical evidences suggest that small farms are desirable not only because they provide a source of reducing unemployment, but also because they provide a more equitable distribution of income as well as an effective demand structure for other sectors of the economy (Bravo-Ureta et al., 1994; Dorner 1975)

1.2. Agricultural Development Strategies and Modern agricultural Inputs in Ethiopia

The first economic development strategy in Ethiopia was declared in 1957, when the First Five Year Plan (FFYP) (1957-1961) was prepared. In this plan, the attention given to peasant agriculture was very limited. Even in the Second Five Year Plan (SFYP) (1962-1966), which relatively gave better emphasis to the agricultural sector, the main objective was commercialization of the sector by encouraging big private farms than small holders. It was the Third Five Year Plan (TFYP) (1967-1971) which gave appropriate consideration to small farmers with out ignoring the large scale commercial farms. In this plan, the objective was to increase the productivity of small

farmers through the package program in selected areas. At the time, both the Comprehensive Package Project (CPP) and the Minimum Package Project (MPP) were launched, but the result obtained was not satisfactory because of lack of finance and the low level of participation of tenants resulting from the existing land tenure system (Assefa, 1987; Geremew, 2000).

When Derg took power in 1974, it declares the public ownership of rural land to cease the feudalistic system which was the main bottleneck for the growth of the agricultural sector. At the time the government pushes the farmers to establish peasant association and service cooperatives to socialize the rural economy. Further, the private commercial farms established before the revolution were nationalized. In order to help the peasant farmers, the Peasant Agricultural Development Extension Program (PADEP) was developed and declared by the Ministry of Agriculture (MOA) that focused on improving extension service and redirecting agricultural resources to the peasant sector. But at the time, the emphasis was to the socialized sector and the small farmers not incorporated in the socialized sectors were discriminated (Mulat, 1999)

The current government adopted the Agricultural Development Led Industrialization (ADLI) strategy as the overall development strategy of the country since 1995. One of the main facets of this strategy in the agricultural sector has been the generation, adoption and diffusion of new farm technologies in the form of new and improved inputs and practices. In the mobilization of small farmers and the dissemination of better farming practices, the agricultural development practices has been

operationalized through Participatory Demonstration and Extension Training System (PADETS) (EDRI, 2004).

According to Mulat (1999), all the development strategies undertaken by all the three governments were highly dependent on external source of finance, which may have contributed for the unsatisfactory results obtained from the policies.

The commonly used modern agricultural inputs in Ethiopia are chemical fertilizers, improved seeds and chemicals like pesticides and insecticides to a limited extent. Even after the efforts exerted by the current government, the national adoption rate of the modern inputs is very low, even by African Standards. According to Mulat (1999), it is only 35 percent of the total cereal production areas receive chemical fertilizer. Further, the amount of fertilizer applied by most of the farmers is below the recommended level. After the year 2001/2002, the consumption of fertilizer has shown a declining trend mainly because of the removal of the government subsidy (EEA, 2004). It is less than 5 percent of the Ethiopian farmers using improved varieties and the use of chemicals like pesticides and insecticides is very negligible (Legesse, 1998).

Most of the agricultural researches in Ethiopia are undertaken by Ethiopian Agricultural Research Organization (EARO), Regional Research Centers and Biodiversity Institute. But the contributions of the higher learning institutions like Alamaya University of Agriculture, Awassa College of Agriculture, Jimma College of Agriculture and Ambo College of Agriculture is also significant. Sometimes, the

Ministry of Agriculture also conducts some adaptive research as part of its extension program (Befekadu and Birhanu, 1999).

Most of the improved seeds in Ethiopia are produced and distributed by the government owned Ethiopian Seed Enterprise (ESE). The two dominant seeds produced by the enterprise are wheat and maize (EEA, 2004).

Concerning the distribution of fertilizer, during the Derg regime the state owned Agricultural Input Supply Corporation (AISCO) had a monopoly over the market. At the time the fertilizer price were regulated and remained low mainly because of the overvalued currency and subsidy from the government. The distribution system at the time was inefficient since shortage and delay were common. But, after the reform in 1991, the market is liberalized and AISCO was renamed as the Agricultural Input Supply Enterprise (AISE) and restructured to operate as a competitive firm with no subsidy from the government. After the liberalization, other private and government affiliated institutions like Ethiopian Amalgamated limited (EAL), Fertiline Private Limited Company, Guna Trading Enterprise operating in Tigray, Ambasel Trading House Private Limited Company operating in Amhara, Dinsho Trading Enterprise of the Oromia and Wondo Trading Enterprise operating in the southern region become the major importer and distributors of fertilizer in Ethiopia (Befekadu and Birhanu, 1999)

1.3. Statement of the Problem

Ethiopia, once expected to be the bread basket of Africa is now suffering from a severe shortage of food for its citizens and chronic poverty. The major reason behind is mainly the backwardness of the dominant economic sector of the country, agriculture. Land, traditional tools, draft animals and family labor are still the most important factors of production (Beyene, 2004). Compared to global agricultural practice, the use of chemical fertilizers and improved seeds at national level is negligible even by African standard. For instance, Mulat (1999) stated that only 35 percent and 2 percent of the total cereal area receives chemical fertilizer and improved seeds respectively.

Looking at historical data of Ethiopian food crop production, the improvements in production and land productivity are mainly the result of expansion of cultivated area and ideal weather, especially rain fall.

There are two conventional, non exclusive ways of increasing agricultural production. The first is through expansion of resource use, particularly by bringing more land under cultivation and making use of the abundant rural labor force. The second is through increasing the productivity of farm resources through technological and efficiency improvements. Although the first option is likely to be feasible only in the short term from the point of view of sustainability because of scarcity of land, studies

have shown that the later option is encouraging and gains are enormous (Shultz, 1964; Timmer, 1988).

Even in the years that the Ethiopian Government adopted a new extension policy called Participatory Demonstration and Extension Training System (PADETS) after 1995, except some annual fluctuations, all the important indicators for the performance of the agricultural sector such as yield, per capita production and agricultural incomes indicate that the sector didn't show any improved performance.

Despite all the efforts the government exerts to modernize the Ethiopian agriculture; fertilizer use is negligible and continuously declining after 2001/2002, the distribution of improved seeds is also declining in recent years, the per capita grain production is still low in Ethiopia even as compared to many African countries and declining through time (it is 150 Kg/person as compared to 200 Kg/person during the 1970s). Moreover, the rapid population growth combined with the degradation of the quality of soil is threatening the future of the country.

Hence, the paper aims at identifying the major reasons behind the very low adoption rate of modern agricultural inputs in the country and measuring their productivity.

1.4. Objective of the Study

The major objective of the paper is to identify the major factors that influence the adoption of modern agricultural inputs and their productivity in the two regions.

The specific objectives of the paper are:

- To observe the impact of social, economic and agro ecological characteristics on the adoption of modern agricultural inputs.
- To identify factors that influence productivity in Ethiopian agriculture and to see the existence of incentives in terms of productivity gain to use modern agricultural inputs on a sustainable basis.
- To draw policy recommendation that will help to increase the adoption of modern agricultural inputs and the productivity of the agricultural sector.

1.5. Significance of the Study

The significant productivity growth in the agricultural sector of the world mainly comes from the technological improvements. It is proved from the Asian countries that the Green Revolution is able to increase the productivity of the farmers very significantly.

Hence, in countries like Ethiopia where agriculture is the mainstay of the economy, there is a severe poverty and food shortage, the role of productivity enhancing technologies is enormous. So, identifying those factors which contribute for the adoption decision and productivity of the farmers can play an important role. Knowing the factors can contribute to accelerate the adoption process of the technologies and get the maximum possible benefits out of it.

In order to use the modern inputs continuously, there should be appropriate incentives for those who adopt the technology. Hence, analyzing the productivity

gains from the modern inputs is also vital. It is observed that, in most African countries, the technologies imitated from Asian countries do not contribute to the productivity growth of the sector. So analyzing the productivity effect of the technologies may give an insight to the necessary customization to the specific country's agro-climatic conditions.

Further, the study can also give some evidences to the policy makers, which could be used in their decision making process. In addition, the paper is also believed to contribute for the existing literature in the area and initiates further researches.

1.6. Scope and Limitation of the study

The main purpose of the study is to show those factors which significantly affect the input adoption decision of the farmers and their productivity. To achieve this objective, the study uses a secondary data obtained from EDRI. As a result, the output obtained from the study must be interpreted very carefully. First, the households are classified as a dichotomous variable, adopters and non adopters, but nothing is mentioned about the intensity of the adoption of the inputs. Second, only those farmers producing the major cereal crops are used for estimation purpose for the sake of convenience. Lastly, the data doesn't have the price information for both inputs and outputs; as a result, it is taken as constant for all the farmers even if it may be wrong. Even, in order to convert the farmers physical output in to values, so that to measure all the outputs in the same unit of measurement, the average retail price for each Woreda published by CSA is used.

One has also to know that the data is collected from a purposefully stratified sample, using a slightly different questioner for adopters and non adopters. The strata are done based on the agricultural potential of the sample areas, one from high potential area and the other from low potential areas.

Further, the regions used for analysis are only Tigray and Amhara, which may have different socio-economic and agro-climatic conditions than other parts of the country. Hence, with out further investigations, it may be difficult to infer about the other regions of the country.

CHAPTER II

LITERATURE REVIEW

2.1. Definition of Technology, Adoption, Productivity and their Measurement

Technology is a stock of available technique or a state of knowledge concerning the relationship between inputs and a given physical output. Hence, a technological change is an improvement in the state of knowledge such that production possibilities are enhanced, i.e. technical change results in a reduction in the quantity of resources required to produce a given output or alternatively, an increase in the output which can be produced with the same amount of input (Colman and Young, 1989). Technological change in the agricultural sector as defined by Ellis (1993) is the adoption of new method of production by farm households which always increase the efficiency of productivity of one or more resource.

Much of the technological changes which have taken place in the agricultural sector have been biased, often being labor saving (like machines and pesticides) or land saving (like fertilizer and HYVS). But this doesn't necessarily imply that less of these resources will be used, rather because of these technologies, the producer will use less of them for a given output level. However, as the marginal cost of production has fallen, the producer will increase output to maximize its profit and hence employ more of the resources. There will then be a trade off between the initial displacement due to the technological change and the increased employment due to increased production. Here, the net effect depends on the relative price ratios of the inputs. If the price ratio

remains constant, the farmer will increase the use of all inputs, but that is not the case in most developing countries where governments subsidize the use of modern technologies and affect the relative prices (Colman and Young, 1989).

For example, adoption study by McInerney and Donaldson (1975) in Pakistan reported that a tractor adoption had displaced between 7.5 and 11.8 full time workers per each tractor used where the government had highly subsidized the tractor and allow the tractors to be imported free of tax.

There are three major sources of technological changes in the agricultural sector. The first is learning by using which is a function of experience and time. But such kind of invention requires active and educated farmers, which is not the case in most developing countries. According to Ellis (1993) new methods should not be expected only from formal research, rather the farm household can adopt to changing circumstances, utilizing their own know how as well as opportunities presented to them. The second is from Research and Development activities by private and public institutions in the country. Most of the Research and Development activities in the agricultural sector are under taken by government agencies because the private sector is not willing to engage in since it is not commercially viable. The difficulty in commercializing agricultural researches comes mainly from its difficulty to patent, its being costly to disseminate information on a new process, and a new technology may take several years to develop. The third and a very common source of technological change in developing countries is imported technologies (foreign Research and Development). But foreign technology may not always be appropriate to the needs

and conditions of the recipient countries, so there is a need for subsequent modification, through adaptive research to suit local conditions (Colman and Young 1989)

Adoption refers to the decision to use or not to use a new technology, method, practice, etc. by a firm, farmer or consumer. Rogers (1983) defined adoption behavior as the process by which a technology is communicated through certain channels overtime among the members of a social system. In the context of this study, adoption refers to the decision of an individual farmer to use or not to use a modern agricultural technology at a point in time. According to Colman and Young (1989) adoption always presuppose that the innovation exists and studies of adoption analyze the reason or determinants of whether and when adoption takes place.

The measurement of adoption of a given technology depends on whether the technology is divisible or not. If a technology is divisible, its adoption can be measured at the individual level in a given period of time by the share of the farm area under the new technology or by the per hectare quantity of input used in relation to the resource recommendation (Feder et al, 1985). In the case of non divisible agricultural technologies, the extent of adoption at the farm level at a given period of time is dichotomous i.e. adoption and non adoption. Thus, aggregate adoption of lumpy technologies can be measured by calculating the percentage of farmers using the new technology within a given area. In this study, the focus is only on technologies of divisible nature, especially fertilizer, HYVS and Chemicals.

The farmers' decision of whether or not to adopt a given new technology is based on a careful evaluation of many factors. Among which, the first is the nature of the technology. The more technologically complex the technology, the less attractive it may be to many farmers. Further, if the technology is divisible like fertilizer herbicides, HYVS, Pesticides and the likes, the farmers are able to try out the innovation on a small scale and will be willing to adopt but if it is lumpy, small scale trials are not possible and the farmer may be more reluctant to adopt. The second factor considered in the adoption decision is economic which includes yield, cost of production and profit. Mostly the economic impact of a new technology is uncertain when the decision is made and hence the decision depends on the farmer's attitude towards risk. Lastly, the characteristics of the farmer and the farming enterprise like age, experience, education, purchasing power, access to credit, information, poor communication links with product and input markets, the availability of complimentary inputs in the quantity and at the time required affect the decision of a farmer to adopt a given technology (Colman and Young, 1989).

Concerning the modes of adoption of agricultural technology, there are two approaches in the literature. The first approach emphasis the adoption of the whole packages and the second one stresses the sequential or stepwise adoption of components of a package. The former approach is often advocated by technical scientists while the later is advanced by participatory research groups.

There is a great tendency in agricultural extension programs to promote technologies in a package from where by farmers are expected to adopt the whole package like the

Ethiopian Comprehensive Package Program (CPP) and Minimum Package Programs (MPP). But mostly such kind of adoption is costly and constrained by resource limitation in Less Developing Countries (Legesse 1998).

Mostly Farmers do not adopt technologies as a package, but rather adopt a single component or a few suitable techniques. The principal reasons given for sequential adoption of a package of technologies are profitability, riskiness, uncertainty, lumpiness of investment and institutional constraints. For example, Ryan and Subrahmanyam (1975) argue that this type of choice is a rational choice for farmers with limited cash. As farmers accumulate cash from their previous adoption of a technology package, they will further adopt another component of the technology package based on the relative advantage and its compatibility under conditions they are operating. This process will continue until the whole package is fully adopted.

Rauniyar and Goode (1996) stated that the relationship between technologies may be independent, sequential or simultaneous and the patterns of adoption follow the relationship between the technological components. Based on this premise, they suggest that if the technologies or practices are independent of one another, the adoption pattern of farmers is largely random. If farmers adopt technologies in a specific order, the adoption pattern is sequential. This implies the probability of adopting a technology is conditional on adoption of a technology that precedes it in the sequence. On the other hand, if more than one technology is adopted as a package and no specific adoption of a technology precedes or follows the adoption of another technology the adoption pattern becomes simultaneous.

Looking at the adoption of technologies, when mapped overtime, resembles to S-shaped curve and will have a ceiling. In the beginning of the adoption process, only a few potential adopters adopt the technology and the slope of the curve slowly increases. The adoption will increase at accelerating rate until it reaches the inflection point; approximately half of the potential adopters adopted the technology. The remaining potential adopters need more time for adoption and the rate of adoption increases at a decreasing rate and at a certain time the technology will be adopted by all the potential adopters (Rogers, 1983; Mosher 1979; Beyene, 2000; Legesse, 1998; Assefa and Gezahegn, 2004).

Models that generated S-Shaped curves include that logistic function, the Gompertz function, the modified exponential function, the cumulative normal distribution function, and the cumulative log-normal distribution function. Among these models the logistic distribution function is the most widely used function in adoption studies (Beyene, 2000)

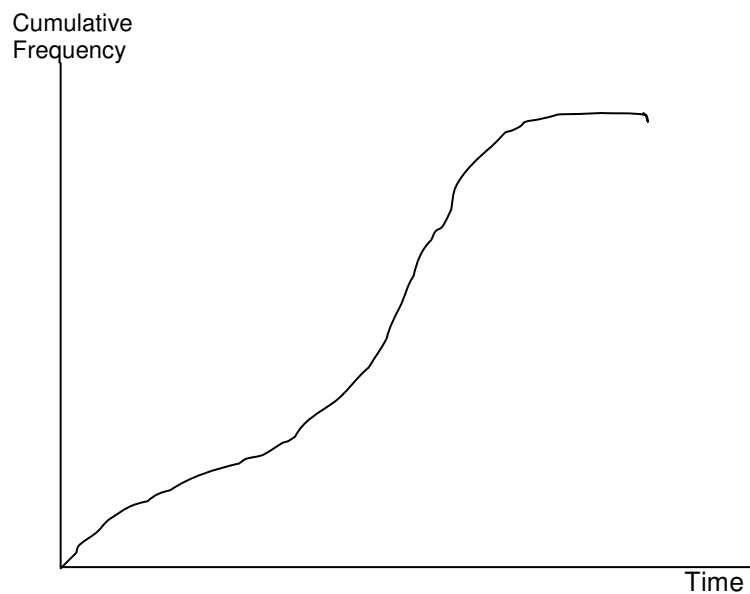


Figure 2.1: The S-shaped Logistic Distribution Function

The S-shaped pattern of diffusion is explained in terms of communication channels and various social characteristics of the potential adopters comprising age, education, attitude towards risk, etc (Rogers, 1983; Rogers and Shoemaker, 1971; Mosher, 1979; Beyene, 2000; Legesse, 1998). They note that the S-shaped curve results from the fact that only a few numbers of farmers adopt a new technology in the early stage of the diffusion process. At this state, only a few farmers will have full information about the potential advantage of the technology and even if they get full information about the potential advantage of the technology, fear of the possible risk associated with the new technology will make the adoption speed low. But after a subsequent time period, potential adopters will acquire full information about the potential advantage of the technology, and the degree of riskiness associated with it becomes clear so that adoption become rapid. The adoption increases gradually and begins to level off, ultimately reaching an upper ceiling.

Mansfield (1961), Griliches (1957), Gutkind and Zilberman (1985) and Bera and Kelley (1990) attributed the S-shaped diffusion curve to the spread of information as well as to economic factors. The adoption rate of a given technology mainly depends on its profitability, the amount of investment required to adopt it, the degree of uncertainty associated with it and its availability.

It is a common phenomenon that large farmers tend to adopt new technology first, followed by small farmers (Ruttan, 1977; Lipton and Longhurst, 1989). They further argued that this pattern of adoption allows large farmers to capture the excess profit available in the early stage of adoption, since by the time small farmers adopt the

technology, the output supply shift to the right and pushes the output price downwards.

According to Rogers (1983), Rogers and Shoemaker (1971) and Mosher (1979), all farmers do not adopt a given technology at the same time, rather they adopt in order time sequence. Based on the time when farmers first begin using a new technology, they identified and described five possible adopter categories in any social system: innovators, early adopters, early majority, late majority, and laggards. In describing the characteristics of these groups, Rogers suggest that the majority of early adopters are expected to be more educated, venture some, and willing to take risks. In contrary to this group the late adopters are expected to be less educated, conservative, and not willing to take risks.

The long run upper limit or ceiling of the diffusion curve is also determined by the economic characteristics of the new technology and other economic, social and agro climatic factors and hence differs across regions (Griliches, 1957 and 1980; Dixon, 1980; Jansen et al., 1990)

According to Ellis (1993) there are two kinds of innovation that can enhance the productivity of farmers. The first is a process innovation which changes the amount, combination, quality, or types of inputs required to produce the same kind of output. Most innovations in agriculture are process innovation where the output produced remained unchanged. But sometimes, such a process innovations may change the test and size of agricultural outputs. The second type of innovation is a product

innovation where the nature of the output changes and it is usually considered more prevalent in industry than agriculture. But still the product innovation in the industrial sector like tractors and fertilizers can be used as an input in the agricultural sector.

There are two opposing arguments about technical changes. For the standard neoclassical theory, technical change is treated as exogenous to the economic system, since it is not explained by any economic forces. But for others, technical change is the result of induced innovation. Especially, most of the technical changes in the agricultural sector are induced which results from change in relative price of factors and hence firms search for a production method which use less of the resources which become more expensive (Hayami and Ruttan, 1985). Hence, this approach makes technical change an endogenous response to changes in key economic variables like relative factor prices and changing size of market for different agricultural inputs and outputs.

But the concept of induced innovation is not as such acceptable in less developing countries where the market doesn't work well and mostly technologies transferred from developed countries to developing countries where there is less room for endogenous technological change (Ellis, 1993). Moreover, in most of Less Developing Countries, agricultural innovations are imposed on farmers from above rather than conforming to the idea of choice between market driven alternatives (Burmesiter, 1987).

Productivity growth can be defined as the net change in output due to change in efficiency and technical change, where the former is understood to be the change in how far an observation is from the frontier of technology and the latter is understood to be shift in the production frontier (Grosskopf, 1993). For Mahabub (1984), the productivity of an economic system can be defined as the ratio between the output of wealth produced and the inputs of resources used up in the process of production, i.e. it is the functional measure of output per unit of associated input in the production process.

Productivity can be measured in two ways; partial productivity and total productivity. Partial productivity measures the productivity of each input in the production process, like the productivity of fertilizers, HYVS, pesticides and so on, whereas total productivity measures productivity in relation to all inputs.

According to Cheema (1978) productivity growth is an absolute requirement in developing countries and fundamental requisite in many forms of planning irrespective of the stage of development and economic and social system. Productivity is the major component of growth and its importance in economic development is universally recognized. The economic achievement of most of the developed countries is attributed to increase in productivity rather than to any thing else. The importance of productivity change in less developed countries can be further argued by the availability of limited resource supply which has high social opportunity cost.

In light with the high growth of population and exhausted possibilities of expanding arable land in developing countries, a shift from a resource based to a more science based system of agriculture will have to play an increasingly important role in improving agricultural productivity (Umali, 1995). The growth in agricultural production in Sub Saharan Africa in the past was achieved by expanding the amount of land cultivated, but today there is little scope for increasing the area under cultivation. Further increase in agricultural production in the area could be achieved only by increasing the productivity of land and labor (Venkatensan and Kampen, 1998). But this requires a generation of effective and efficient agricultural technologies. Moreover, the government of SSA countries should adopt appropriate policies so that farmers apply these technologies to increase productivity (Ibid).

Agricultural productivity of a given farm household depends on many factors in the literature. Ellis (1993) argued that small farms in terms of land size are more productive than large farms and his recommendation that agricultural development strategy based on the promotion of small rather than large farms can serve both growth and income distribution objectives are based on this argument. Empirical studies have also arrived on the same conclusion (Berry and cline, 1979; Bhalla, 1979). But still there are also counter arguments which says large farms perform better than the small one.

Other factors like fertilizer, HYVS, pesticides, herbicides, mechanization and the likes have also contributed a lot for productivity growth in different countries. But According to Ellis (1993), the relative success of such technologies depends on an array of

natural and socio-economic factors, among which the way market work is of critical importance. A practical example in this regard is the works of Grfftin (1979). He reported that Green Revolution has significantly increased productivity in many Asian and Latin America countries over the last four decades. But that is not the case in Africa because African farmers shown litter interest in these technologies. Adoption of HYVS is not typical to Africa because these varieties generally perform well only under a controlled environment where there is no shortage of water (using irrigation) and where chemical inputs can be widely used. In general, there is little irrigation available and inputs are scarce in Africa. So the problem is not so much of developing HYVS that need a lot of care, but of growing varieties that can adapt to a difficult environment and eventually develop resistance to several diseases.

The paper doesn't deal with all modern agricultural inputs, rather is restricted to HYVS, fertilizers and chemicals. HYVS are those seeds which have not only higher yield, but also resist disease and pest, tolerate draught and have shorter growing period. Such seeds have resulted in a substantial increase in out put in many countries, but to realize their potential, they highly depend on complimentary purchased inputs. The potential of HYVS is not affected by farm size, scale or Socio-economic status because they are infinitely divisible (Ellis, 1993). But locational endowments like natural soil, water, irrigation, infrastructural disparities affect their potential. For example, Chambers et al. (1989) stated that HYVS are less successful in resource poor and semi arid environment like in Africa.

Concerning fertilizer, mainly used to improve the fertility of soil which is degraded because of over production are of two types; organic and inorganic. The organic one is mainly animal dung and green manure which are available to the farmer at his/her disposal. But the inorganic fertilizers are the purchased chemical fertilizers like DAP and Urea. Just like HYVS fertilizers are also divisible technologies. But when we see its application in most developing countries, because of many constraints, is below the recommended rate with sub-optimal use which let alone to improve soil fertility, it will not maintain the previous fertility which results in decrease in the productivity of the soil. Further, countries should not stick to the blanket recommendation of fertilizer application; rather have to develop their own rate depending on their own socio-economic and agro ecological environments (Nigussie and Mulat, 2003; Feder et al., 1985).

Lastly, insecticides and pesticides are chemicals used to protect production from pest and insects which could damage yield because of disease and low productivity.

2.2. Theoretical Models for Analyzing Adoption and Productivity

2.2.1. Theoretical model for analyzing the adoption process

In the economic models of adoption behavior, the farmer's choice between alternative technologies depends on different socio-economic and agro-climatic factors. According to Rahm and Huffman (1984) and Legesse (1998), farmers' adoption decisions are assumed to be based on the objective of utility maximization.

If we represent a technology by k , where $k = 1$ for new technology and $k = 2$ for the old technology, the underlying utility function that ranks the i^{th} farmers' preference for the new and old technologies is given by $U(Z_{ki}, N_{ki})$. Z_{ki} denotes a vector of farm and household head's characteristics and N_{ki} is a vector of attributes like profitability, riskiness, divisibility and the likes associated with the technology. Hence, the utility derivable from a new technology depends on variable vectors Z and N . Though the utility is unobserved, the relation between the utility derivable from a K^{th} technology is postulated to be a function of vectors of observed farm and household head's characteristics and the technology's specific attributes.

The relationship can be described as:

$$U_{ki} = \alpha_k F_i(Z_i, N_i) + \varepsilon_{ki} \text{ -----1}$$

Where: $k = 1, 2$

$i = 1, 2 \dots n$

F = a distribution function

ε_{ki} = error term with zero mean

The distribution F can assume linear or non linear relations. The farmers choice of the technology will be according to their utility maximization objectives, i.e. the i^{th} farmer will select option $k = 1$, if and only if $U_{1i} > U_{2i}$.

If the qualitative variable Y indexes the adoption decision, i.e. $Y = 1$ for the adoption of new technology and $Y = 0$ for non-adoption, the non-observable random variable $Y = U_{1i} - U_{2i} > 0$ when adoption occurs, where zero is a threshold value. The probability

that Y_i takes one, the farmer adopts the new technology can be expressed as farm and household head's characteristics and attributes of the technology.

$$\begin{aligned} P_i &= \Pr(Y_i = 1) = \Pr(U_{1i} > U_{2i}) \\ &= \Pr[\alpha_1 F_i(Z_i, N_i) + \varepsilon_{1i} > \alpha_2 F_i(Z_i, N_i) + \varepsilon_{2i}] \\ &= \Pr[\varepsilon_{1i} - \varepsilon_{2i} > F_i(Z_i, N_i)(\alpha_2 - \alpha_1)] \end{aligned}$$

Reparameterizing and assuming symmetry

$$\begin{aligned} P_i &= \Pr[\mu_i > F_i(Z_i, N_i)\beta] \\ &= F_i(\beta X_i) \text{-----2} \end{aligned}$$

Where X is matrix of explanatory variables and β is vector of unknown parameters including constant. $\Pr[\mu_i > F_i(Z_i, N_i)\beta]$ is a probability function, μ_i is a random error term, and $F_i(\beta X_i)$ is the cumulative distribution function for the disturbance term (μ_i) evaluated at β_{xi} . Thus the probability of the i^{th} farmer adopting the new technology is that the probability that the utility of the new technology is greater than the utility of the old technology. Estimation of equation 2 requires the knowledge of the form of F and the distribution of F is determined by the distribution of the disturbance term $\mu_i = \varepsilon_{1i} - \varepsilon_{2i}$. Mostly, μ_i is either normally or logistically distributed (Amemiya, 1981; Rahm and Huffman, 1984).

2.2.2. Theoretical model for measuring productivity

Production function can be estimated from a given set of data about inputs and outputs. Generally, there are two approaches to estimate such a production functions

called the parametric approach and the non-parametric approach. In the parametric approach, the coefficients of the production function are estimated statistically using econometric approach while in the non-parametric approach using mathematical programming. It is the parametric approach commonly used in the estimation of production functions while the non-parametric approach used in efficiency analysis (Coelli et al., 1998)

For the analysis of agricultural productivity, the Cobb-Douglas production function found to be theoretically and empirically more plausible, since it is easy to estimate and mathematically manipulate and possible to test the significance of the estimated elasticities using standard test statistics such as t-ratios and f-ratios. But according to Coelli et al. (1998) it has also many restrictive properties imposed on the production structure like fixed returns to scale and elasticity of substitution always equal to unity.

Following Nigussie and Mulat (2003), the Cobb-Douglas production function can be specified as

$$Y = F(X, E)$$

Where: Y= Yield response

X= a vector of technological inputs like fertilizer, insecticide, HYVS and the likes.

E= vectors of physical inputs such as sex, age, education level of the house hold head, farm size, family size, and the likes.

Hence the Cobb-Douglas production function can be expressed as

$$Y_i = \pi \left(X_{ij}^{\beta_j} E_{ij}^{\delta_j} \right) e^{\alpha + \varepsilon_i}$$

Where: Y_i = yield response of the i^{th} plot

X_{ij} = the use of the i^{th} plot of the j^{th} technological input

E_{ij} = the use of the i^{th} plot of the j^{th} physical input

To measure the work effect of each physical and technological input, the Cobb-Douglas production function may be specified in a logarithmic form as follows:

$$\ln Y_i = \alpha + \sum_j \beta_j \ln X_{ij} + \sum_j \delta_j \ln E_{ij} + \varepsilon_i$$

According to Coelli et al. (1998) the other commonly used forms of production functions include the translog production function, the constant elasticity of substitution production function and the Zellner-Revankar production functions. The translog production function makes the restriction imposed by the Cobb-Douglas function flexible but at the cost of having a form which is more difficult to mathematically manipulate and suffers from degrees of freedom and multicollinearity problems.

The translog production function can be specified as:

$$\ln Y = b_0 + b_1 \ln X_1 + b_2 \ln X_2 + (1/2)[b_{11}(\ln X_1)^2 + b_{22}(\ln X_2)^2] + b_{12} \ln X_1 \ln X_2$$

The constant elasticity of substitution production function relaxes the assumption of unitary elasticity of substitution of the Cobb-Douglas production function and is given by:

$$Y = A \left[b x_1^{-g} + (1-b) x_2^{-g} \right]^{-1/g}$$

And the Zellner-Revankar production functions which allows the returns to scale to vary across output levels is given by:

$$Ye^{\theta_y} = Ax_1^{b_1} x_2^{b_2}$$

In all the above production functions, Y is the output produced and X's are the inputs used in the production process.

2.3. Empirical Literatures

Factors determining technology adoption and productivity differ from one sector to the other and from one region to the other in the same sector. Especially, dealing with agricultural technologies where the sector has its own peculiar characteristics like seasonality of production and its high dependence on the vagaries of natures makes it different from the other sectors. More over, there is a significant difference in terms of the characteristics of agriculture in developing and developed countries. In developing countries, the agricultural sector is characterized by its high dependence on natural phenomenon, highly constrained by shortage of resources and undertaken by less educated farmers.

As a result, the empirical literature part covered in this paper emphasizes only on adoption and productivity studies undertaken in developing countries agricultural sector. This part has two parts, the first deals with different adoption and productivity

studies in developing countries and the second concentrates on adoption and productivity studies in Ethiopia.

2.3.1. Adoption and productivity studies in developing countries

Most of the adoption studies in developing countries are under taken in Asia and Latin American countries where the Green Revolution took place and was successful.

Different authors have emphasized on different factors as a significant determinants of adoption decision. Perrin and Weinkelman (1976) summarized adoption studies on wheat and maize in six countries, namely Kenya, Colombia, El-Salvador, Mexico, Tunisia, and Turkey and reported that the difference in adoption rates in these countries are explained by difference in information, agro-climatic and physical environments, availability of inputs, difference in market opportunities for the crops, and difference in farm size and farmers' risk aversion characteristics.

For the detail analysis of the factors determining agricultural technology adoption, this part of the literature is classified in to household head's characteristics, farm characteristics, institutional and agro-climatic factors and the characteristics of the technology.

In relation with the household head's characteristics, the two most important variables considered in most literatures are education and age. Most of the adoption studies undertaken in developing countries, using the probit model show that education level of the household head has a positive and significant effect on the adoption decision of

modern agricultural technologies (Jha et al, 1990; Strauss et al, 1991; Lin, 1991; Akinola and young, 1985). But other researchers like Shakya and Flinn (1985) and Pitt and Sumodiningrat (1991), using the same probit model found the impact of education on technology adoption to be non-significant.

It could be argued that the role of education on technology adoption may not be an important factor in the case where there is effective extension service and the technologies are simple like fertilizer and HYVS. But in the absence of effective extension service and complex technologies, education becomes an important factor in determining the farmer's decision.

Concerning age of the household head, different authors have reported opposing results using the same probit model. For Jha et al. (1990), Akinola (1987) and Akinola and Young (1985) reported negative relationship between technology adoption and the age of the household head. But Zegeye (1989) and Mahabub (1988) found a positive relationship between technology adoption and the household head's age. They argued that older farmers have more experience and hence better knowledge of the use of the technologies than younger farmers.

The effect of age as a determinant of adoption decision depends on experience and education level. Older farmers may have experience and resource that would allow them more possibilities for trying a new technology. On the other hand, younger farmers are more likely to adopt new technology because they have had more schooling than the older generation. Therefore, the effect of age on adoption depends

on specific conditions in the population and area where the new technology is introduced. Hence, in developing countries where most of the farmers are uneducated, the role of experience should not be underestimated.

Coming to farm characteristics, the two most common variables considered are family size (which is mostly used as proxy to labor availability) and farm size.

The impact of family size on the technology adoption decision of a farmer mainly depends on the characteristics of the technology. If a technology is labor saving like tractors, harvesters, pesticides and the like its impact will be negative, while if a technology is labor intensive like fertilizer and HYVS, its impact will be positive.

Shields et al. (1993) and Green and Ng'ong'ola (1993), found a positive association between family size and fertilizer adoption in Swaziland and Malawi respectively using the logit model. But Akinola (1987), using the probit model and Igodan et al. (1988), using the logit model found negative relationship between family size and technology adoption. Their argument is that in rural areas, subsistence pressure is more on large households and this pressure has a negative implication for technology adoption both in terms of ability to purchase the inputs and their attitude towards risk.

Looking at farm size, Akinola (1987), David and Otsuka (1990), and Jha et al. (1990), found positive and significant effect on the adoption decision of the farmer using a probit model. But others like Low (1982), Mann (1989), and Alauddin and Tisdell (1988), using both OLS and logit have found a negative relationship. There are other

like Ramasamy et al. (1992), using a probit model and Adesina and Zinnah (1993), using tobit model who found farm size to be non significant determinant of adoption decision. Further, the inverse relationship between farm size and productivity is reported by many researchers like Carter (1984), Rao and Chotigeat (1981) and Deolalikar (1981).

Here, whether farm size affects the adoption decision depends on the characteristics of the new technology. If the technology is of divisible nature, it is scale neutral and hence small farmers can adopt it as large farmers do. But in the case of lumpy technologies, there is a high probability for large farmers to adopt than small farmers do. But for Feder and O'Mara (1981), even if divisible technologies are neutral to scale, the record of adoption and diffusion experiences through out the world show that adoption rates and the time patterns of adoption are related to farm size. The argument for this is the differences in information acquisition costs, which is higher for small farmers than large farmers which may discourage adopting the technology.

For Ruttan (1977), farm size plays a significant role at the early stage in the adoption process. It is true that large farmers adopt technology early because of the relative advantage they have, but as adoption progresses, their relative advantage will diminish and the small farmers will catch up. Hence at the latter stage of the adoption process, farm size will be a non- significant factor.

In the institutional and agro-climatic factors, we have extension service, credit, off farm income, input and output prices and climatic and infrastructural factors.

To start with the impact of extension service on the adoption of modern agricultural technologies, many authors reported a positive and significant effect using the probit model (Igoda et al. 1988; Gerhart, 1975; Shakya and Flinn, 1985; Feder and Slade, 1984).

Further, Binswanger and Braun (1991) stated that extension is the major instrument to speed up the adoption process. Lack of knowledge about correct crop fertilization and low level of the extension service are the most important determinants of fertilizer use in the context of developing countries (Anthieu and Verga, 1978). At the beginning, lack of knowledge is an obstacle to the adoption of modern technologies and hence the role of extension service is so crucial. But once farmers started technology adoption, knowledge disappears as a problem and same for the role of the extension service.

Hence extension service provided by effective and efficient institutions can contribute for the fast adoption process of a given technology, especially in developing countries where farmers are less educated.

In developing countries, where farmers have only limited capacity to finance investment in new technologies, the role of credit can not be overestimated (Feder et al., 1985; Bhalla, 1979). Almost all the literatures reviewed found a positive and very strong relationship between availability of credit and the farmer's decision to adopt a new technology in developing countries (Akinola, 1987; Pitt and Sumodiningrat, 1991;

Shakya and Flinn, 1985) using the probit model and (Green and Ng'ong'ola, 1993) using the logit model.

Off farm income, which could increase the farmer's cash income for the purchase of modern inputs have also the same effect as credit. This is supported by the empirical works of Low (1986) and Parton (1993).

Taking the farmer as a profit maximizing firm, the price of inputs and outputs has a significant effect on the farmer's adoption decision. The theory suggests that lower input price and higher output prices encourage the farmer to adopt the technology. The study by Kimuyu et al. (1991), using OLS method and Shields et al. (1993), using the logit model has concluded as the theory do. But in most adoption studies, the ratio of the two prices is assumed to be constant. The same is true in this study since the data used are cross sectional where there is less room for price fluctuation.

The availability of infrastructures (like roads, transportation, irrigation and the likes) and good agro-climatic conditions (like rainfall, soil fertility, salinity, and the likes) have also a positive impact on the adoption of modern technologies, while drought has a negative impact on the adoption decision (Pitt and Sumodiningrat, 1991; Jansen et al., 1990), using the probit and logit model respectively.

Lastly, concerning the characteristics of technology, the farmer's preference, evaluation of the varieties characteristics and perception of specific traits like test, yield, cooking quality and the like strongly affect the farmer's decision to adopt the

new technology (Smale et al., 1995 and Adesina and Zinnah, 1993), using the tobit model and (Heisay et al., 1993), using the multinomial logit.

2.3.2. Adoption and Productivity Studies in Ethiopia

Most of the adoption studies in Ethiopia are not regional or countrywide, rather undertaken in specific areas, especially in the areas where the package and the extension approach are applied as a model. For the sake of convenience, in this part, the reviewed articles are presented chronologically.

A study by Tesfai (1975), using the probit model in Arsi zone reported that the probability of the adoption of improved varieties and fertilizer strongly increase with farm size and extension service. The availability of cash for down payment, membership in local association and literacy also increase the probability of adoption but less strong than the above two factors. He further reported that tenants are less likely to adopt improved varieties and fertilizer as compared to owner cultivators.

The study in Bako and Jimma area by Bisrat (1980), reported that the difference in the rate of adoption of fertilizer between regions is explained by profitability and risk associated with fertilizer use. He also reported that the effect of farm size on the rate of adoption was not significant.

Itana (1985) studied factors influencing agricultural technology adoption in Holenkomi and Woliso areas of the central Ethiopia using the probit model and reported that literacy, farm size, price of farm inputs, adequacy of rainfalls, availability of cash for

down payment, and extension center positively affect the adoption of new technologies. But family size had no effect on the adoption decision.

Yohannes et al. (1991), using the logit model in Tegulet and Bulga area of North Shewa zone found that the adoption of modern technologies are positively affected by farm size, family size, education, farm and off farm income, exposure to out side information and experience as represented by age. But debt and degree of risk aversion had a negative influence.

According to Legesse (1992) using the probit and tobit models, access to credit, expected yield, cash availability for down payment, participation in farm organization as a leader and close exposure to technology had positive impact on the probability of adopting HYVS, intensity of fertilizer and herbicides.

Mulugeta (1994) studied the relative importance of the variables influencing farmers' adoption decision in Arsi zone using the logit and tobit models and found that access to credit, herbicide use and timely availability of fertilizer were the most important determinants of fertilizer adoption. Farm size, family size, number of oxen owned, extension contact and application of herbicide had also significant effect on adoption and use of fertilizer. But age of the household head was negatively related to the adoption of fertilizer.

Similarly, Chilot et al. (1996) studied the adoption of wheat technologies in Welmera and Addis Alem areas using both the probit and logit models and found that

profitability of the new wheat technology and timely availability of fertilizer and herbicide have significant effect on the farmers' adoption decision. They also found that distance of respondents from the extension center negatively affect the adoption decision. But farm size and experience of farmers doesn't have significant effect.

In Lume district of the central Ethiopia, Teressa (1997), using the logit model found that extension service, oxen, labor, access to credit and off farm income were the major variables contributing to fertilizer adoption and intensity of its use.

According to Lelissa (1998) the most important determinants of fertilizer use and intensity in Ejere district of west Shewa zone are agro-climatic conditions, land tenure systems, credit, extension service, oxen ownership, age of the farmer, family size, farmers level of education, manure, ratio of price of crops to fertilizer cost, distance to fertilizer distribution center and cropping pattern.

Legesse (1998) studied adoption and diffusion of agricultural technologies in East and West Shewa zones using probit and tobit models and found that location, oxen ownership, distance to market, credit, gender and degree of risk aversion had significant impact on the adoption decision of the new technologies. But education and the index of awareness had no effect on the adoption decision. He also found that the impact of increase in output price on the probability of adopting modern technology is very high.

Beyene (2000), using the probit model, reported that in West Shewa and East Wallaga zone, the most significant determinants of farmers' technology adoption decision are distance from the road, family size, number of oxen, farm size, household head's education level, access to credit, access to extension service and availability of package. But, household head's age was found to be non significant determinant.

Lastly, a study by Assefa and Gezahegn (2004) on the adoption of improved technologies in Ethiopia, using probit and logit models reported that age of the farmer and the distance of the farmer from the market center had a negative impact on the adoption decision of the farmer. On the other hand, household size, farm size and farmers contact with extension agent had strong and positive effect on the adoption of improved technologies in Ethiopia. They further reported that religion is also an important factor in the adoption decision. According to this study, both Muslim and Orthodox farmers are less likely to adopt new technologies as compared to farmers practicing other religions. But literacy, formal education, number of oxen owned and credit were found to be non significant determinants in the adoption decision of the farmer.

As compared to studies on adoption, the works on productivity are very limited in Ethiopia. Moreover, most of them are studied in recent years.

A study by Geremew (2000) using Cobb-Douglas production function model, in two districts of Sidama zone, namely Aroressa and Hula reported that in Aroressa,

distance from all weather road and price of output are the most important determinant of productivity while in Hula, number of ploughings, farm size and wealth are major determinants of productivity.

Nigussie (2001) using the Cobb-Douglas production function model, reported that land under extension rarely resulted in better yield response than non extension in three villages of Ethiopia, namely, Sribana-Godeti, Eteya and Shashemene. But improved seed varieties, recommended rate of DAP and Urea, farm management practices and environmental factors had significant impact on productivity. This study further showed that most farmers didn't use improved seed varieties and the recommended rate of fertilizer which could enhance productivity.

Mulat and Bekele (2003), using the Cobb-Douglas production function model studied the determinant of yield of major cereals in 18 sites of the four major regions in Ethiopia, namely Amhara, Tigray, Oromiya and Southern Nations and Nationalities Peoples (SNNP). They reported that, DAP and Urea alone are not solutions for the productivity problems in Ethiopian agriculture and the contribution of extension to yield is not significant, holding other factors constant. According to this study, farmers' education is one of the explanatory variables with consistently significant and positive coefficient in determining productivity. The rate of fertilizer application, quantity of labor used, use of herbicide and sex were found to be significant determinants of the productivity of teff and wheat but ownership of oxen were not significant. In the case of barely, fertilizer coefficient was not significant but contact with extension, literacy, farm size, seed rate and labor intensity positively affects the productivity.

CHAPTER III

DATA SOURCES AND METHODOLOGY

3.1. Data Sources

To achieve the stated objectives, the data is obtained from Ethiopian Development Research Institute (EDRI), collected in 2001/2002. The data was collected using a household survey questionnaires administered to the farming household with slight variations between adopters and non adopters. The data is collected from a purposeful and stratified sample in to high potential and low potential from which randomly selected households were interviewed.

Even if the data is available for the four regions; Tigrai, Amhara, Oromia and SNNP, this paper considers only the case of Tigrai and Amhara. These two regions are selected for two major reasons; first they are well known for being the major cereal producers of the country and second, these regions are highly affected by soil degradation because of overproduction which results in high food insecurity. Because of these two basic reasons, the need for applying modern agricultural inputs in the regions must be a priority over other areas.

The total sample size of households interviewed from each region is 480. From each region, two zones are selected, from each zone two Woredas and from each Woreda two Farmers' association are included in the sample. The selection of the sample is based on their agricultural potential, one from high potential area and the other from

low potential area. But for the purpose of determining factors contributing for adoption of modern inputs, only 395 households from Tigray and 238 households from Amhara are used after cleaning the data for estimation. The number of households used to estimate the productivity of farmers is 360 from Tigray and 228 from Amhara.

From Tigray region, the Western Zone and Eastern Zone are selected. From the Western Zone Tselemti and Medabai-Zana Woredas are included in the sample where the Farmers' associations are Mai Ayni and Sekotamariam from the former and Adi Kebdi and Embatsaed from the latter Woreda. From Eastern Zone, Ganta-Afeshum and Wukero Woredas are included in the sample and the respective farmers' associations are Ala Genhat and Gahigoti from Ganta Afeshum and Mai Quhia and Gemad from Wukero Woreda.

From Amhara region, East Gojjam and South Wollo zones are selected. From East Gojjam, Hulet Ej Enese and Enbise Sar Midir Woredas are included. The farmers' associations from the two Woredas are Addis Zemen and Beza Bizuhan and Goffa Tidma and Kil Meda respectively. From South Wollo, Jama and Ambasel Woredas are selected and from each Woredas Fagi and Degelo and Robit and Gulbo farmers' associations are included in the sample respectively.

3.2. Methodology

In order to achieve the objectives mentioned both descriptive and quantitative analysis will be made. First, the variables will be described using simple statistical measurements like mean and standard deviations and some statistical comparisons will be made between adopters and non adopters within a region and between the regions. Then, using the econometric estimations, the significant factors that affect farmer's modern input adoption decision and their productivity will be identified.

3.3. Model Specification

3.3.1. Model used to determine determinants of the adoption of modern inputs

The data set obtained from EDRI, 2001/2002 has classified the households in two categorical variables based on whether the farmer has adopted fertilizer, improved seeds and chemicals over the last two years or not. Hence, since it is a limited dependent variable, the appropriate method of estimation is the maximum likelihood estimation method.

The two computing models commonly used in the adoption studies are the probit and logit models. But the results obtained from the two models are very similar since the normal and logistic distributions from which the models are derived are very similar¹. As a result, only the logit model will be reported in the paper even if both models will be estimated for the purpose of comparison.

¹ See Woodlridge (2003), Gujarati (2003)

Following Gujarati (2003) the logit model can be specified as:

$$\begin{aligned}
 P_i &= E(Y_i = 1 / X_i) = F(\alpha + \beta X_i) \\
 &= \frac{1}{1 + e^{-(\alpha + \beta X_i)}} \\
 &= \frac{1}{1 + e^{-Z_i}}, \text{ where } Z_i = \alpha + \beta X_i \\
 &= \frac{e^{Z_i}}{1 + e^{Z_i}} \text{----- the cumulative logistic distribution function.}
 \end{aligned}$$

Where $P_i = P(Y_i = 1)$ is the probability that the farmers adopt the technology.

X_i = are different factors that affect farmer's adoption decision.

α is the constant term.

β 's are the coefficient of parameters.

The estimation of the model is, first the probability of non adoption is given by:

$$1 - P_i = \frac{1}{1 + e^{Z_i}}$$

And the odds ratio which tells the ratio of the probability of the farmer will adopt the modern input to the probability the farmer will not adopt the technology can be written as:

$$\frac{P_i}{1 - P_i} = \frac{1 + e^{Z_i}}{1 + e^{-Z_i}} = e^{Z_i}$$

Hence,

$$L_i = \ln\left(\frac{P_i}{1 - P_i}\right) = Z_i = \alpha + \beta X_i, \text{ where, } L_i \text{ is the log of the odd ratio.}$$

The model can be written as:

$P(y=1) = F(\text{labor, Sex, Age, land_size, no_ox, credit, inpu_dis, ext_cont, radio, other income, Woreda, religion, socioeconomic status, change in lifestyle as compared to last year, change in lifestyle as compared to before five year ago, educational status})$

Definition of variables used in the model:

Dependent variable

Hh_type= 1 if the farmer had adopted fertilizer, improved seeds or chemicals over the past two years; 0 otherwise.

Explanatory variables and their expected sign

Labor = represents labor measured in man days². It is expected to have a positive effect on the farmers' adoption decision (Shields et al., 1993; Green and Ng'ong'ola, 1993; Mulugeta, 1994 and Yohannes et al., 1991).

Sex= a dummy variable for the household head's sex: =1 if male and 0 if female. Because of the allocation of resources in the community is biased towards males, they are expected to be better adopters (Legesse, 1998).

Age= the age of the household head. Older household heads are expected to be less educated and hence less adopters (Jha et al., 1990; Akinola, 1987; Akinola and Young, 1985; Mulugeta, 1994 and Assefa and Gezahegn, 2004).

Land_size= the total land size of the household in hectare. Farmers with large farm size can try the new inputs on some part of their land and see the benefits of adoption, hence expected to be better adopters (Akinola, 1987; David and

² The conversion is made following Storch et al. as cited in Beyene et al. (2000). The conversion factor gives a weight of 0.2 for both males and females in the age bracket 10-13 years; 0.5 and 0.4 for those between the age

Otsuka, 1990; Jha et al., 1990; Itana, 1985; Yohannes et al., 1991 and Beyene, 2000).

No_ox= the total number of oxen the household had. Since ox is the major means of production in the country, it is expected to have a positive effect on adoption (Mulugeta, 1994; Teressa, 1997; Lelissa 1998; Legesse, 1998 and Beyene, 2000).

Credit= a dummy variable for access to credit: =1 if the household had access to credit and 0 otherwise. Those farmers having credit access are better adopters since they will have cash for the purchase of the inputs (Akinola, 1987; Pitt and Sumodiningrat, 1991; Shakya and Flinn, 1985; Green and Ng'ong'ola, 1993; Beyene, 2000 and Legesse, 1998).

Inpu_dis= the distance of the household from input delivery institutions in km. Its sign is expected to be negative (Lelissa, 1998; Beyene, 2000 and Assefa and Gezahegn, 2004).

Ext_cont= a dummy variable for extension contact: =1 if the household is contacted by an extension worker in the last two years; 0 otherwise. Farmers having extension contact knows the source and possible benefit of the technologies and hence expected to be better adopters (Binswanger and Braun, 1991; Anthieu and Verga, 1978; Mulugeta, 1994; Lelissa, 1998; Beyene, 2000 and Assefa and Gezahegn, 2004).

group of 14-16 for males and females respectively; for the age group between 17-50, the conversion factor for male is 1.0 and for female 0.8. Over 50 years, the male was given 0.7 and the female 0.5.

Radio= a dummy variable for the ownership of radio: =1 if the farmer had radio, 0 otherwise. Radio is assumed to give information about the modern inputs to the farmers and hence affect the adoption decision positively.

Woredadum1= 1if the farmer is in Tselemti, 0 otherwise in the case of Tigray.

=1if the farmer is in Hulet Ej Enese, 0 otherwise in the case of Amhara.

Woredadum2=1if the farmer is in Medabai-Zana, 0 otherwise in the case of Tigray.

=1if the farmer is in Enbise Sar Midir, 0 otherwise in the case of Amhara.

Woredadum3=1if the farmer is in Ganta Afeshum, 0 otherwise in the case of Tigray.

=1if the farmer is in Jama, 0 otherwise in the case of Amhara.

Woredadum4=1if the farmer is in Wukero, 0 otherwise in the case of Tigray.

=1if the farmer is in Ambasel, 0 otherwise in the case of Amhara.

So_econodum1³=1 if the farmer is poor; 0 Otherwise. The poor households are expected to be lower adopters of the modern inputs because of financial constraint (Itana, 1985 and Legesse, 1992).

So_econodum2=1 if the farmer is average; 0 Otherwise.

So_econodum3=1 if the farmer is better off; 0 Otherwise. This group of the farmers is expected to be better adopters (Itana, 1985 and Legesse, 1992).

Religionum1=1 if the household is Orthodox; 0 otherwise.

Religionum2=1 if the household is Moslem; 0 otherwise.

Religionum3=1 if the household is Catholic; 0 otherwise.

³ The socio-economic status of the households is determined by the perception of the community and development agents.

Religion₄=1 if the household belong to other religions or does not have a religion
; 0 otherwise.

Lstyr_chdum1=1 if the households life has improved as compared to last year;
0 otherwise. The expected sign is positive.

Lstyr_chdum2=1 if the households life is the same as compared to last year;
0 otherwise.

Lstyr_chdum3=1 if the households life has got worse off as compared to last year;
0 otherwise. The expected sign is negative.

Ago5_chdum1=1 if the households life has improved as compared to the previous five
years; 0 otherwise. The expected sign is positive.

Ago5_chdum2=1 if the households life has is the same as compared to the previous
five years; 0 otherwise.

Ago5_chdum3=1 if the households life has got worse off as compared to the previous
five years; 0 otherwise. The expected sign is negative.

Ago10_chdum1=1 if the households life has improved as compared to the previous
ten years; 0 otherwise. The expected sign is positive.

Ago10_chdum2=1 if the households life has is the same as compared to the previous
ten years; 0 otherwise.

Ago10_chdum3=1 if the households life has got worse off as compared to the
previous ten years; 0 otherwise. The expected sign is negative.

Illiterate=1 if the household head is illiterate, 0 otherwise.

Read_write=1 if the household head can read and write, 0 otherwise. Positive sign is
expected (Jha et al, 1990; Strauss et al, 1991; Lin, 1991; Akinola and young,
1985; Yohannes et al., 1991; Lelissa, 1998 and Beyene, 2000).

Elementary=1 if the household head had an elementary education, 0 otherwise.

Positive sign is expected (Jha et al, 1990; Strauss et al, 1991; Lin, 1991; Akinola and young, 1985; Yohannes et al., 1991; Lelissa, 1998 and Beyene, 2000).

Highschool=1 if the household had a high school education, 0 otherwise. Positive sign is expected (Jha et al, 1990; Strauss et al, 1991; Lin, 1991; Akinola and young, 1985; Yohannes et al., 1991; Lelissa, 1998 and Beyene, 2000).

Otherinc= represents the amount of other incomes the farmer obtained other than agriculture. It is expected to contribute positively in the adoption process (Low, 1986; Parton, 1983 and Yohannes et al., 1991).

3.3.2. Model used to determine factors contributing to the productivity of the households.

To identify factors which contribute to the productivity of the farm households, the Cobb-Douglas production function model is used. Despite its limitation in terms of its restrictive properties imposed on the production structure like fixed returns to scale and elasticity of substitution always equal to unity, it is chosen for its simplicity.

The model can be specified as

$$\begin{aligned} \text{Lnperha} = & \beta_1 + \beta_2 \text{lnlabor}(+)^4 + \beta_3 \text{lnage}(+) + \beta_4 \text{lnland_size}(-) + \beta_5 \text{lnno_ox}(+) + \beta_6 \text{lninpu_dis}(-) \\ & + \beta_7 \text{lnotherinc}(+) + \beta_8 \text{hh_type}(+) + \beta_9 \text{sex}(+) + \beta_{10} \text{credit}(+) + \beta_{11} \text{ext_cont}(+) + \\ & \beta_{12} \text{radio}(+) + \beta_{13} \text{sick_memb}(-) + \beta_{14} \text{woredadum1} + \beta_{15} \text{woredadum2} + \beta_{16} \text{woredadum3} \\ & + \beta_{17} \text{woredadum4} + \beta_{18} \text{so_econdum1}(-) + \beta_{19} \text{so_econdum2} + \beta_{20} \text{so_econdum3}(+) + \end{aligned}$$

⁴ The signs in the bracket show the expected signs of the coefficients.

$$\beta_{21}\text{religion dum1} + \beta_{22}\text{religion dum2} + \beta_{23}\text{religion dum3} + \beta_{24}\text{religion dum4} + \beta_{25}\text{illiterate}(-) \\ + \beta_{26}\text{read_write}(+) + \beta_{27}\text{elementary}(+) + \beta_{28}\text{highschool}(+)$$

Definition of variables

The dependent variable

Lnyperha= is the logarithm of the value of output produced per hectare in birr.

Explanatory variables not defined in the earlier model

lnlabor= represents the logarithm of labor in man days available in the household.

lnage= the logarithm of age of the household head.

lnland_size= the logarithm of the total land size the household own in hectare.

lnno_ox= the logarithm of the total number of oxen the household had.

lninpu_dis= the logarithm of the distance of the household from input delivery institutions in km.

lnotherinc= represents the logarithm of the amount of other incomes the farmer obtained other than agriculture.

Sick_memb= represents a dummy: =1 if a family member was sick in the previous production period; 0 otherwise.

CHAPTER IV

RESULTS AND DISCUSSION

4.1. Descriptive Analysis

This part of the discussion gives some descriptive analysis of the characteristics of the sample farm household heads. Comparison is made between the two groups of adopters and non adopters of the modern agricultural inputs in their production process based on different variables. For the sake of convenience and simplicity, the comparison is made in three categories namely demographic characteristics, resource characteristics and economic status and living standards. In the tables bellow, the mean of each variable of each groups are given including the standard deviations in the bracket. The statistical test for comparisons between the groups is undertaken using the usual T-test at the commonly used 5 percent level of significance.

4.1.1. Demographic characteristics

Table 4.1 gives the demographic characteristics of the sample farm household heads. The table presents the mean and standard deviations for each variable for adopters,

non-adopters and the total sample in each region. P-values are also presented for the statistical comparison of the mean values between adopters and non-adopters.

The average family size of the sample households in Tigray is 4.9 while that of Amhara is 5.03. In both regions, the mean family size of adopters is statistically greater than that of non-adopters. Concerning the sex of the household heads, in Tigray 67 percent of the sample household heads are male while in Amhara 90 percent of the sample households are male headed. In both regions, the proportions of male headed households who adopt the technology are statistically more than those who didn't.

Table 4.1: Demographic characteristics of the sample households

VARIABLE	TIGRAY				AMHARA			
	Total N=400	Adopters N=198	Non-Adopters N=202	P-value	Total N=239	Adopters N=154	Non-Adopters N=85	P-value
Hh_size	4.90 (2.21)*	5.30 (2.13)	4.50 (2.22)	0.000	5.03 (1.86)	5.19 (1.77)	4.72 (2.00)	0.031
Sex	0.6725 (0.46)	0.7929 (0.40)	0.5544 (0.49)	0.000	0.9037 (0.29)	0.9480 (0.22)	0.8235 (0.38)	0.000
Age	48.51 (13.72)	49.38 (12.68)	47.66 (14.65)	0.110	40.79 (12.76)	38.82 (12.55)	44.37 (12.42)	0.000
Illiterate	0.7425 (0.44)	0.6969 (0.46)	0.7871 (0.41)	0.019	0.5564 (0.49)	0.4870 (0.50)	0.6823 (0.47)	0.002
Elementary	0.0825 (0.27)	0.1060 (0.31)	0.0594 (0.24)	0.045	0.1966 (0.40)	0.2012 (0.40)	0.1882 (0.39)	0.404
read_write	0.1675 (0.37)	0.1969 (0.40)	0.1386 (0.35)	0.059	0.2259 (0.42)	0.2987 (0.46)	0.0941 (0.29)	0.000
High school	0.0075 (0.09)	0 (0)	0.0148 (0.12)	0.042	0.0209 (0.14)	0.0129 (0.11)	0.0352 (0.18)	0.125
Orthodox	0.9525 (0.21)	0.9393 (0.24)	0.9653 (0.18)	0.112	0.7238 (0.45)	0.8441 (0.36)	0.5058 (0.50)	0.000

Moslem	0.0425 (0.20)	0.0555 (0.23)	0.0297 (0.17)	0.101	0.2719 (0.44)	0.1558 (0.36)	0.4823 (0.50)	0.000
Catholic	0.0025 (0.05)	0.0050 (0.07)	0 (0)	0.156	0 (0)	0 (0)	0 (0)	1.000
Others	0.0025 (0.05)	0 (0)	0.0050 (0.07)	0.161	0.0041 (0.06)	0 (0)	0.0117 (0.11)	0.089

Source: Computed from survey data.

** The values in the bracket are standard deviations.*

The average household's age in Tigray is 48.51 years and the corresponding figure in Amhara is 40.79 years. In Tigray, there is no statistical difference between the average household head's age of adopters and non-adopters. But in Amhara, the average age of the household head's for adopters is statistically lower than those of non-adopters.

Concerning the educational status of the sample household heads, in Tigray, 74 percent are illiterate, 17 percent can read and write, 8 percent have attained elementary education and the rest less than one percent has reached high school education. In the case of Amhara, 56 percent are illiterate, 22 percent can read and write, 20 percent have attained elementary education and the rest 2 percent have got high school education.

In both regions, the proportions of illiterate household heads who adopt the technology are statistically lower than the non-adopters. But those household head's who can read and write and attained elementary education are observed to be statistically better adopters. The effect of high school education in Tigray is found to be negative for adopting the new technology while statistically insignificant in the case

of Amhara region. This could mainly because of the small number of household heads attaining high school education in the sample of both regions.

Coming to the religious composition of the household head's, around 95 percent belongs to Orthodox, 4 percent belongs to Moslem and the rest one percent belong to Catholic and other religions in Tigray. In the case of Amhara region, 72 percent follows Orthodox, 27 percent follows Moslem and the rest one percent belong to other religions.

In Tigray, there is no significance difference between the proportions of adopters and non-adopters based on their religious believe. But in Amhara, the proportions of Orthodox followers who adopt the technology are statistically greater than those who didn't and the proportion of Moslems who adopt the technology are found to be statistically lower than those who didn't adopt. The impact of being Catholic is not significant on the adoption of the technologies. But those who belong to others are found to be statistically significant non-adopters in Amhara (at $P < 0.1$) while the difference is not significant in Tigray.

4.1.2. Resource

Table 4.2 presents the characteristics of the sample farm households in terms of their resource holding. The nature of the Table is just like Table 4.1 which presents mean and standard deviations for each variable and a P-value for statistical comparison of means between adopters and non-adopters in each region.

As can be shown from the table, the average land size of sample households in Tigray is 0.8 hectare while in Amhara it is 1.02 hectare. The comparison of mean land size between adopters and non-adopters reveals that in both regions, the holding of adopters is statistically greater than that of non adopters.

Table 4.2: Resource endowments of the sample households

VARIABLE	TIGRAY				AMHARA			
	Total N=400	Adopters N=198	Non-Adopters N=202	P-value	Total N=239	Adopters N=154	Non-Adopters N=85	P-value
land_size	0.80 (0.52)	0.87 (0.56)	0.74 (0.47)	0.007	1.02 (0.68)	1.14 (0.70)	0.80 (0.58)	0.000
no_ox	1.12 (0.97)	1.35 (1.01)	0.89 (0.87)	0.000	1.23 (0.86)	1.5 (0.76)	0.74 (0.81)	0.000
Other income	125.72 (577.7)	107.68 (467.85)	143.46 (668.91)	0.267	28.69 (95.65)	19.92 (84.74)	44.58 (111.57)	0.028
Credit	0.95 (0.22)	0.9797 (0.14)	0.9207 (0.27)	0.003	0.8075 (0.39)	0.8896 (0.31)	0.6588 (0.47)	0.000
Inpu_dis	11.93 (9.37)	10.40 (8.46)	13.43 (9.97)	0.000	3.58 (2.96)	3.17 (2.33)	4.31 (3.77)	0.002
ext_cont	0.49 (0.50)	0.7828 (0.41)	0.2029 (0.40)	0.000	0.665 (0.47)	0.8116 (0.39)	0.40 (0.49)	0.000
Radio	0.1275 (0.33)	0.1414 (0.34)	0.1138 (0.32)	0.205	0.1046 (0.30)	0.1233 (0.33)	0.0705 (0.28)	0.104

Source: Computed from survey data.

** The values in the bracket are standard deviations.*

The average number of oxen per household is 1.12 and 1.23 in Tigray and Amhara respectively. For both regions, the average number of oxen for adopters is statistically greater than that of non adopters.

In Tigray the average household earns 126 birr per year as other income, in addition to their agricultural production. But the corresponding figure in Amhara is only 29 birr per year. There is no significant difference of other incomes between adopters and non-adopters in Tigray while in Amhara, the average other income for adopters is statistically lower than that of non-adopters.

Concerning the availability of credit, 95 percent of the households have access in Tigray while only 81 percent in Amhara. Comparing the two groups, in both regions the proportion of adopters who had access to credit is statistically greater than that of non-adopters. The average distance of input supplying institutions from the household in Tigray is 12 km while in Amhara is only 4 km. In both regions, the average distance is statistically lower for adopters than non adopters.

The proportion of farmers visited by extension workers in the last two years is only 49 percent of the sample in Tigray while it is 67 percent in Amhara. The proportions of adopters who are visited by extension workers are found to be statistically greater than non adopters in both regions.

Concerning the availability of radio in the household that could be taken as a source of information about the modern technologies for the farmers, about 13 percent and 10 percent of the sample households have it in Tigray and Amhara respectively. But, in both regions, there is no statistical difference in terms of the availability of radio between adopters and non adopters.

4.1.3. Economic status and change in life style

Table 4.3 gives the proportion of the sample farm households in terms of their economic status and change in their life styles as compared to the previous one, 5 and 10 years.

Table 4.3: The economic status and change in life styles of the sample farm households.

Variable	Tigray				Amhara			
	Total N=400	Adopters N=198	Non- Adopters N=202	P-values	Total N=239	Adopters N=154	Non- Adopters N=85	P-values
Poor	0.7125 (0.45)	0.5656 (0.49)	0.8564 (0.35)	0.000	0.6025 (0.49)	0.5714 (0.50)	0.6588 (0.48)	0.093
Average	0.2600 (0.43)	0.3991 (0.49)	0.1238 (0.33)	0.000	0.3096 (0.46)	0.3506 (0.48)	0.2352 (0.43)	0.032
Better off	0.0275 (0.16)	0.0353 (0.18)	0.0198 (0.14)	0.174	0.0878 (0.28)	0.0779 (0.27)	0.1058 (0.31)	0.233
Lstyr_chdum1	0.11 (0.31)	0.1262 (0.33)	0.0940 (0.29)	0.152	0.1841 (0.38)	0.1948 (0.40)	0.1647 (0.37)	0.283
Lstyr_chdum2	0.5025 (0.50)	0.5606 (0.49)	0.4455 (0.50)	0.010	0.4728 (0.50)	0.4480 (0.50)	0.5176 (0.50)	0.152
Lstyr_chdum3	0.3875 (0.48)	0.3131 (0.46)	0.4603 (0.50)	0.012	0.3430 (0.47)	0.3571 (0.48)	0.3176 (0.47)	0.270
Ago5_chdum1	0.225 (0.42)	0.2474 (0.43)	0.2029 (0.40)	0.143	0.3723 (0.48)	0.3831 (0.48)	0.3529 (0.48)	0.322
Ago5_chdum2	0.3925 (0.48)	0.4545 (0.49)	0.3316 (0.47)	0.006	0.2510 (0.43)	0.2467 (0.43)	0.2588 (0.44)	0.418
Ago5_chdum3	0.3825 (0.48)	0.2979 (0.46)	0.4653 (0.50)	0.000	0.3765 (0.49)	0.3701 (0.48)	0.3882 (0.49)	0.391
Ago10_chdum1	0.2775 (0.44)	0.2878 (0.45)	0.2673 (0.44)	0.323	0.3891 (0.49)	0.3766 (0.49)	0.4117 (0.50)	0.297
Ago10_chdum1	0.31 (0.46)	0.3535 (0.48)	0.2673 (0.44)	0.031	0.2133 (0.41)	0.2337 (0.42)	0.1764 (0.38)	0.151
Ago10_chdum1	0.4125 (0.49)	0.3585 (0.48)	0.4653 (0.50)	0.015	0.3974 (0.49)	0.3896 (0.49)	0.4117 (0.49)	0.369

Source: Computed from survey data.

** The values in the bracket are standard deviations.*

Out of the total sample households, 71 percent, 26 percent and 3 percent are classified as poor, average and better off respectively in Tigray. In Amhara, 60 percent are poor, 31 percent are average and 9 percent are better off. The proportions of adopters being poor are statistically lower than that of non adopters in both regions. But the proportions of average households adopting the technology are statistically greater than that of the corresponding non adopters for both Tigray and Amhara regions. There is no statistical difference between the proportions of adopters and non adopters for the better off sample households.

In Tigray, out of the total respondents, 11 percent, 50 percent, and 39 percent reported that their life has improved, the same and got worse off respectively as compared to the last year. Comparing their life with that of before 5 years, 23 percent, 39 percent and 38 percent and before 10 years 28 percent, 31 percent and 41 percent reported that their life has improved, the same and worse off respectively.

The corresponding figures in Amhara shows that; 19 percent, 47 percent and 34 percent reported that their life has improved, the same and worse off as compared to that of last year. Comparing their life with that of before 5 years, 37 percent, 25 percent and 38 percent and before 10 years, 39 percent, 21 percent and 40 percent reported that their life has improved, the same and worse off respectively.

In Tigray, having better life as compared to the previous one, 5 and 10 years doesn't statistically affect the proportion of being adopter or not. While having same life style as compared to the previous periods statistically increases the proportions of

adopters as compared to non adopters and those households whose life got worse off and adopters are observed to be statistically lower than that of non adopters in the same category. But the change in life style as compared to the previous one, 5 and 10 years does not have any statistically significant effect on the proportion of adopters and non adopters in Amhara regions.

4.2. Regression Analysis

The econometric analysis of the paper mainly deals with the analysis of major factors that contribute for the adoption of modern agricultural inputs and the productivity of the sample farm households.

4.2.1. Determinants of modern agricultural input adoptions

There are many demographic, socio-economic and agro-climatic factors that contribute in the modern technology adoption decision of a farm household. In order to identify the significant factors, both the logit and probit models are applied on the data set for both Tigray and Amhara regions. But the outputs obtained from the two models are almost identical for both regions and hence only the logit model results will be presented and discussed.⁵ The possible multicollinearity problem is treated by observing the pair wise correlation coefficients and the variance inflation factor (VIF).⁶

4.2.1.1. Tigray

To identify those factors which contribute significantly for the adoption of modern agricultural inputs in Tigray, a logit model with a sample size of 395 household heads

⁵ For the interested reader, the result of the probit model is presented in Appendix I.

were applied. The model is found to be strongly statistically significant (at $P < 0.01$). Further, the model has correctly classified 80 percent of the farmers. The results obtained from the model are presented in table 4.4.

As can be shown from the table, among many variables that contributes to the farmers decisions of modern input adoption, the distance of input delivery institutions from the household affect the decision negatively and significantly (at $P < 0.01$). The marginal effect shows that, an additional one kilometer distance of the input delivery institutions decreases the probability of being an adopter by 1.3 percent. This could be mainly because of the associated transportation costs aggravated by the poor communication and transportation infrastructures in the area. The household distance from the input delivery institutions could also be taken as a proxy for other distances like distance from development agents, distance from major urban areas and the likes where the farmer can get information about the availability and use of the modern inputs. Hence the distance of the household from the input supplying institutions could be taken as a major obstacle for farmers in Tigray from adopting the modern agricultural inputs.

The other positive and strongly significant (at $P < 0.01$) factor in the input adoption decision of the farmer is an extension contact. Those farmers who are contacted by an extension worker in the last two years are found to be better adopters. A farmer being contacted by an extension worker increases the probability of being adopter by 56 percent which is very strong. This is mainly because the extension workers can

⁶ According to D. N. Gujarati (2003), one can suspect multicollinearity problems if the pair wise correlation

give detailed information about the source, use and importance of the modern inputs to the farmers. Even in some places, the extension workers could be the only sources of information about modern technologies in the rural areas. The role of an extension contact can not be undermined in the adoption of modern agricultural inputs, especially in countries like Ethiopia where the majority of the farmers are uneducated.

Table 4.4: Determinants of modern input adoption in Tigray

Log likelihood = -171.55876				Number of obs = 395	
Correctly classified 80.00percent				LR $\chi^2(22)$ = 204.47	
				Prob > χ^2 = 0.0000	
				Pseudo R ² = 0.3734	
Variables	Coefficient	Std. Err.	P>z	Marginal effect	P>z
Labor	-0.0001163	0.0712641	0.999	-0.0000291	0.999
Sex	0.3305004	0.3645279	0.365	0.0824002	0.363
Age	0.008335	0.0106201	0.433	0.0020836	0.433
land_size	0.2364647	0.3371269	0.483	0.0591127	0.483
No_ox	0.2549261	0.1745236	0.144	0.0637277	0.144
Inpu_dis	-0.0520238	0.0165905	0.002*	-0.0130052	0.002*
Ext_cont	2.545529	0.2894204	0.000*	0.5623357	0.000*
Credit	1.081452	0.794103	0.173	0.2508071	0.111
Otherinc	-0.0002385	0.0002743	0.385	-0.0000596	0.385
Radio	-0.5903709	0.4461216	0.186	-0.1450336	0.169
woredadum1	0.6922845	0.4607195	0.133	0.1700593	0.124
woredadum2	1.479656	0.4184238	0.000*	0.3437518	0.000*
woredadum3	0.8351647	0.4504013	0.064***	0.2026275	0.050***
So_econodum1	-1.011579	0.3488342	0.004*	-0.2446075	0.002*
So_econodum3	0.3498889	0.9167108	0.703	0.0865474	0.697
religionum1	-0.7684705	0.7376282	0.297	-0.1837698	0.256
Lstyr_chdum1	0.1630555	0.496122	0.742	0.0406783	0.742
Lstyr_chdum3	0.0077069	0.3544507	0.983	0.0019266	0.983

coefficients are in excess of 0.8 or VIF in excess of 10.

Ago5_chadum1	-0.2975243	0.429404	0.488	-0.0741649	0.485
Ago5_chadum3	-0.9487492	0.405617	0.019**	-0.2323774	0.014**
read_write	0.2759543	0.4029475	0.493	0.0686824	0.490
Elementary	0.38981	0.5506095	0.479	0.0963889	0.471
_cons	-1.641477	1.39395	0.239		

Source: Computed from survey data.

*, ** and *** represents the coefficients are significant at 1, 5 and 10 percent respectively.

Concerning the Woreda dummies, which are taken as a proxy for agro-climatic conditions, it is found that the farmers in Medabai-Zana (at $P < 0.01$) and Ganta Afeshum (at $P < 0.1$) being better adopter than the farmers in Wukero. But there is no statistical difference between farmers in Tselemti and Wukero. Being in Medabai-Zana increases the probability of adopting the new technology by 34 percent as compared to being in Wukero. While being in Ganta Afeshum increases the probability of adopting the technology by 20 percent than the Wukero counterparts. This shows the effect of agro-climatic conditions like weather, soil fertility, availability of rain fall and the likes.

One can take the population densities of the Woredas as a proxy to the suitability of the Woredas for agricultural production. Mostly, a household whose main life stream is agriculture resides in the areas where there are suitable agro-climatic conditions such as soil and appropriate rain fall density for their production and results in high population density in the area. The result perfectly corresponds to this fact that the

population density of Medabai-Zana and Ganta Afeshum are greater than that of Wukero and Tselemti.⁷

The other factor considered in the regression is the economic status of the households. It is found that the poor households are statistically (at $P < 0.01$) lower adopters as compared to the average households. As shown in the table, being poor reduces the probability of being adopter by 24 percent as compared to households in the average economic status.

This is mainly because adoption of the new technologies requires cash investment that the poor households can not afford. That is main ground for intellectuals in the area arguing that such technologies are not pro-poor, at least in the initial stages. It could also be argued that poor households are not willing to take any risk related to the adoption of the new technologies as compared to their corresponding average households. The risk associated with modern technologies is very immense since their yield response is very dependent on other complimentary inputs and favorable agro-climatic conditions. As a result, the poor are not willing to adopt such risky technologies since a very small risk may question their survival.

The last factor that is found to be a significant determinant of the decision of the household to adopt modern agricultural inputs in Tigray is the change in life style dummy before 5 years. Those households whose life got worse off as compared to the previous 5 years are found to be statistically lower adopters (at $P < 0.05$) as compared to those households who are leading the same lifestyle as the previous 5

⁷ The population density of Medabai-Zana=109.3 persons/km², Ganta Afeshum = 291.4 persons/km², Tselemti =

year. This shows the impact of change in lifestyle as compared to the previous period on the farmers' adoption decision.

But all the rest factors like labor, sex, age, land size, number of ox, credit, other income, radio, the religion dummies, change in life style as compared to last year and the educational dummies are found to be non significant determinants of the modern input adoption in the region.

4.2.1.2. Amhara

The logit regression for Amhara region is applied on a sample size of 238 farm households. The model is found to be statistically significant (at $P < 0.01$) and it classifies 89 percent of the farm households correctly, which can show the strength of the model to explain the adoption behavior of the farmers in the region. The result of the model is presented in Table 4.5.

In Amhara region, the number of oxen owned by the household is found to have a significant and positive (at $P < 0.05$) effect on the adoption decision of the farmers. Having an additional ox will increase the probability of being adopter by 15 percent. This is mainly because; ox is the major means of production in the agricultural sector of the area. Hence, having more oxen may mean being able to plough the land at the appropriate time than waiting for hired oxen. As a result, farmers having more oxen

46.5 persons/km² and Wukero = 106.4 persons/km² (CSA, 2001).

can plough their land at the right time and extract higher yield which could be an incentive and source of income for adopting the modern inputs.

Like the case of Tigray region, input distance and extension contact are also significant determinants of the farmers' adoption decision in Amhara region. The impact of the distance of the input delivery institutions from the household is negative and statistically significant (at $P < 0.05$) and a kilo meter increase in the input distance will decrease the probability of being adopter by 3.2 percent. While having an extension contact in the last two years increases the probability of being adopter by 27 percent which is statistically significant (at $P < 0.05$) as compared to those who did not have the contact.

Table 4.5: Determinants of modern input adoption in Amhara

Log likelihood = -51.726011			Number of obs = 238		
Correctly classified 89.50 percent			LR $\chi^2(22)$ = 205.59		
			Prob > χ^2 = 0.0000		
			Pseudo R^2 = 0.6652		
Variables	Coefficient	Std. Err.	P>z	Marginal effect	P>z
Labor	0.1002453	.1537123	0.514	0.0157561	0.520
Sex	0.5967492	.9191233	0.516	0.107445	0.564
Age	-0.017933	.0254488	0.481	-0.0028187	0.493
Land_size	0.1709108	.4284019	0.690	0.026863	0.692
No_ox	0.9761806	.4399685	0.027**	0.1534318	0.050***
Credit	0.0150112	.7251231	0.983	0.0023528	0.983
Inpu_dis	-0.200645	.094005	0.033**	-0.0315366	0.069***
ext_cont	1.498686	.6011935	0.013**	0.2692071	0.026**
other_inc	0.0056796	.0044532	0.202	0.0008927	0.243
Radio	-0.779060	1.394513	0.576	-0.1449322	0.624
Woredadum1	3.139577	1.27194	0.009*	0.3900084	0.000*

Woredadum2	0.059424	0.883620	0.946	0.0092464	0.946
Woredadum4	-6.305479	1.545343	0.000*	-0.911027	0.000*
So_econodum1	-0.630848	.7699461	0.413	-0.0954656	0.410
So_econodum3	0.3555728	1.0366	0.732	0.0608818	0.750
Religionum1	-0.316458	.7640452	0.679	-0.0475915	0.664
Lstyr_chdum1	0.5192494	.8952745	0.562	0.0736901	0.520
Lstyr_chdum3	1.645543	.7776829	0.134	0.2234295	0.139
ago5_chadum1	-0.183215	.8155635	0.822	-0.0292045	0.825
ago5_chadum3	-1.027693	.8032334	0.201	-0.1737164	0.232
Read_write	2.780614	1.098387	0.011**	0.2857692	0.005*
Elementary	1.660432	.8496612	0.051***	0.1918399	0.023**
_cons	-7.232194	2.453251	0.003		

Source: Computed from survey data.

*, ** and *** represents the coefficients are significant at 1, 5 and 10 percent respectively.

The Woreda dummies also show statistically significant difference on the adoption behavior of farmers in Amhara region. It is found that the farmers in Hulet Ej Enese Woreda are statistically better adopters (at $P < 0.01$) than the farmers in Jama Woreda. Being in Hulet Ej Enese Woreda increases the probability of being adopter by 39 percent as compared to the farmers in Jama. The farmers in Ambasel are also found to be significantly (at $P < 0.01$) lower adopters as compared to Jama. But there is no statistical difference between Jama and Enbise Sar Midir in terms of farmers adoption of the modern inputs. The argument is synonymous with that of Woredas in Tigray region.⁸ Despite the population density, the significant agro-climatic difference between the Woredas from Wollo and Gojjam has also its own contribution for the result.

The other factors which play a positive and significant role in the adoption decision of farmers in Amhara region is the educational status of the household heads. Those farmers who can read and write are found to be statistically better adopters (at $P < 0.05$) as compared to their illiterate counterparts. Being able to read and write increases the probability of adopting the modern inputs by 29 percent as compared to those illiterate farmers. Having elementary education have also a positive and significant ($P < 0.10$) effect with 19 percent higher probability than that of the illiterate farmers to adopt the modern technology.

But all the rest factors like labor, sex, age, land size, credit, other income, radio, the socio-economic status of the household, the religion dummies, and change in life style as compared to last year and before five years are found to be non significant determinants of the modern input adoption in the region.

4.2.2. Determinants of productivity of the farm households

In order to identify the factors which contribute for the productivity of the farm households, the Cobb-Douglas model is applied to the data set. The model is tested for possible problems of multicollinearity and heteroscedasticity problems. The multicollinearity problem is detected using the same method as the data prepared to estimate the determinants of modern input adoption.⁹ In order to test the heteroscedasticity problem, the Breusch-Pagan-Godfrey test of heteroscedasticity is

⁸ The population density of Hulet Ej Enese = 172.5 persons/km², Enbise Sar Midir = 125.6 persons/km², Jama=109.7 persons/km² and Ambasel = 145.1(CSA, 2001).

⁹ See footnote 4.

applied for the models used in both regions and found there is no problem of heteroscedasticity.

4.2.2.1. Tigray

To determine those factors which contribute for the productivity of farmers in Tigray significantly, the Cobb-Douglas model is applied for 360 sample farm households. The results obtained show that the model in general is significant (at $P < 0.01$). Further, the Adjusted $R^2 = 0.4136$ tells all the explanatory variables together explains 41 percent of variations in the farmers productivity. The regression results obtained are presented in table 4.6.

As can be seen from the table, land size is found to have very significant and negative impact on the farmers' productivity (at $P < 0.01$). A percentage increase in land size reduces the productivity of the farmers by 0.81 percent. This shows the very strong inverse relationship between land size and productivity. The major reasons behind such inverse relationship are mainly with the application of the variable input, especially labor. In countries like Ethiopia, where the market for agricultural labor is almost unavailable and imperfect, the small holders can use their family labor to maximize their land productivity while farmers with large farm size may not able to do so.

The number of oxen the household owned is also found to be a positive and significant (at $P < 0.1$) determinant of the farmer's productivity. A percentage increase in the number of oxen the household had results 0.13 percent change in the

productivity of the farmers. This shows the important role of oxen in agricultural production of the region. The productivity gains from oxen could be explained by the ability of the farmers having oxen can undertake their production activity timely.

The distance of input supplying institutions from the household is also found to be a significant (at $p < 0.05$) and negative factor in the productivity of farm households. It is shown in the table that a percentage increase in the distance of input supplying institutions reduces the productivity of the household by 0.07 percent. This shows, despite the impact of distance on the adoption of the modern inputs, it has also a negative impact on the productivity of the farmers. This is mainly associated with the farmers' access to information. Mostly, the input delivery institutions are located in the major urban and semi-urban areas and hence the distance can be taken as a good proxy to distance from major urban areas. The further the household is from the major urban areas, the lower the access for information contributing for productivity growth.

Table 4.6: Determinants of productivity in Tigray

Number of obs = 360				
F(22, 337) = 12.51				
Prob > F = 0.0000				
R-squared = 0.4495				
Adj R-squared = 0.4136				
Variables	Coefficients	Std. Err.	t	P>t
Lnlabor	0.0053358	0.06614	0.08	0.936
Lnage	-0.0533471	0.1141712	-0.47	0.641
Inland_size	-0.8137692	0.0680605	-11.96	0.000*
lnno_ox	0.1326087	0.0793058	1.67	0.095***
lninpu_dis	-0.0674757	0.0332791	-2.03	0.043**
Lnotherinc	0.0450316	0.0141202	3.19	0.002*
hh_type	0.1014326	0.079115	1.28	0.201
Sex	-0.0426418	0.0860781	-0.50	0.621

Credit	0.3072395	0.1402914	2.19	0.029**
ext_cont	-0.0185174	0.0755517	-0.25	0.807
Redio	0.1650611	0.0932042	1.77	0.077***
Sick_memb	-0.0655427	0.0643418	-1.02	0.309
Woredadum1	0.3824912	0.0946782	4.04	0.000*
Woredadum2	0.106154	0.0911599	1.16	0.245
Woredadum3	0.0064894	0.1045757	0.06	0.951
So_econodum1	-0.0330332	0.077236	-0.43	0.669
So_econodum3	-0.0613737	0.185905	-0.33	0.742
Religionum1	-0.0600445	0.1598143	-0.38	0.707
Religionum3	-0.2362696	0.6043426	-0.39	0.696
Religionum4	-0.3072531	0.6038308	-0.51	0.611
read_write	0.0317091	0.0910583	-0.35	0.728
Elementary	0.0486722	0.1184998	0.41	0.682
_cons	6.205963	0.5167676	12.01	0.000

Source: Computed from survey data.

*, ** and *** represents the coefficients are significant at 1, 5 and 10 percent respectively.

Farmers having higher other sources of income than agriculture are also found to be more productive. It is found that a farmer having a percentage higher other income have 0.05 percent gain in productivity that is significant (at $P < 0.05$). This indicates other income enhances the productivity of the farmers in Tigray. The contribution can be in terms of using the cash income for productivity enhancing expenses like health, education, the purchase of tools and the likes.

The farmers owning radio in the region are also found to be better productive than those who do not (at $P < 0.1$). This indicates the effectiveness of the local radio stations in the region in terms of providing the necessary information to increase productivity of the farmers.

It is also found that the farmers in Tselemti are more productive than other Woredas. A farmer being in Tselemti increases the productivity of the farmer significantly (at $P < 0.01$). This shows, even if Tselemti is not a better adopter area, its productivity is higher. This may be due to the favorable agro-climatic condition endowed with the Woreda like better soil, topography, rainfall, etc.

The other significant determinant of productivity in Tigray is credit. The impact of credit in enhancing productivity is found to be significant (at $P < 0.05$) in the region. Having access to credit increases the productivity of the household by 31 percent. This is mainly due to the use of credit as a cash source for productivity enhancing activities. Here credit will break the vicious circle of low productivity.

All the other variables considered in the regression model are found to be non significant. Although labor has the expected positive sign, its effect is statistically insignificant on the productivity of the farmers. The sign of age of the household head, although negative it is insignificant. The sign of the impact of education on the productivity of the household is positive as expected but observed to be statistically insignificant. Further, the sex of the household head, whether there is sick family member in the last production year or not, the socio-economic status of the households and religions are insignificant determinants of the farmers' productivity in Tigray.

Concerning the variables representing the use of modern technologies like the household type indicating whether the household is classified as an adopter or not,

extension contact and the availability of radio doesn't have any significant effect on the productivity of the farmers in Tigray, even if they have got the expected positive sign. This show applying the modern inputs without customizing to the particular condition may not result the expected productivity gain, indicating the high need for adaptive research. Especially, the return from such modern technologies in arid and semi-arid zones like the case in Tigray is very low unless it is accompanied by the necessary complementary inputs like irrigation.

Further, it should be noted that the data classified the farmers only as dichotomous variable, adopters and non adopters. But, the productivity of the farmers mainly depends on the intensity of the inputs used.

4.2.2.2. Amhara

In order to estimate the productivity effects of different factors in Amhara region, a sample of 228 farm households are selected who are convenient for the model. Then the Cobb-Douglas production function model is applied to the data set. The output obtained from the regression shows that the model in general is significant (at $P < 0.01$). The adjusted $R^2 = 0.4747$ indicates that all of the explanatory variables in the model explains 47 percent of variations in the productivity of the farm households in the region.

The estimation results of factors determining the productivity of farm households in Amhara are presented in Table 4.7. Just like the case in Tigray, the impact of land size on the productivity of the farm households is negative and very strong (at

P<0.01). A percentage increase in land size decreases productivity by 2.2 percent in Amhara.

The number of oxen owned by the household is also another significant (at P<0.05) and positive determinant of productivity of farmers in Amhara region as it did in Tigray. It is shown on the table that a percentage increase in the number of oxen owned by the household increases the productivity of the farmers by 0.31 percent.

Being adopter results in a positive effect on the productivity of the farmers in Amhara region, which is significant (at P<0.1). This indicates the response of productivity enhancing capacity of the disseminated modern technologies in the region. The contribution of fertilizer and the other modern technologies in enhancing the productivity of the households in the region is mainly because of repeated production; the natural soil nutrients are already exploited and reduce the productivity of the land with out these modern inputs.

Table 4.7: Determinants of productivity in Amhara

Number of obs = 228
 F(20, 206) = 10.77
 Prob > F = 0.0000
 R-squared = 0.5233
 Adj R-squared = 0.4747

Variables	Coefficients	Std. Err.	T	P>t
Lnlabor	0.0519793	0.1268327	0.41	0.682
Inland_size	-2.175914	0.2136924	-10.18	0.000*
Lnage	0.0458619	0.1630818	0.28	0.779
Inno_ox	0.3088925	0.1353737	2.28	0.024**
Lninpu_dis	-0.0373413	0.0731541	-0.51	0.610
Lnother_inc	0.0424158	0.027092	1.57	0.119

hh_type	0.2688128	0.1420471	1.89	0.060***
Sex	0.0652567	0.1653388	0.39	0.693
Credit	0.1713771	0.1298557	1.32	0.188
ext_cont	-0.0129552	0.1037485	-0.12	0.901
Radio	-0.0976255	0.1534799	-0.64	0.525
sick_memb	-0.1654481	0.0936911	1.77	0.079***
Woredadum1	0.7621583	0.2094771	3.64	0.000*
Woredadum2	0.3839952	0.1883457	2.04	0.043**
Woredadum3	0.3513881	0.1689431	2.08	0.039**
so_econodum1	-0.2749776	0.1036005	-2.65	0.009*
so_econodum3	0.0646448	0.1698113	0.38	0.704
Religionum1	0.0722566	0.1235972	0.58	0.559
read_write	-0.0742476	0.1172258	-0.63	0.527
Elementary	0.0472004	0.1203326	0.39	0.695
_cons	7.380794	0.6448932	11.44	0.000

Source: Computed from survey data.

*, ** and *** represents the coefficients are significant at 1, 5 and 10 percent respectively.

Having a sick family member in the household who visits the health service institutions has a negative and significant (at $P < 0.1$) effect on the productivity of the farmers in Amhara region. This could be because of the possible labor shortage since the sick member can't work and the other members will also spend a significant time to protect the sick family member. It is also found that there is a significant difference in productivity between different Woredas of the region. The productivity of the farmers in Hulet Ej Enese is higher by 76 percent than that of Ambasel which is significant (at $P < 0.01$). The farmers in Enbise Sar Midir and Jama are also more productive than the farmers in Ambasel by 38 percent and 35 percent respectively, which is significant (at $P < 0.05$).

In Amhara region, the economic status of the farmers has also its own implication on the productivity of the farmers. The poor farmers are found to be statistically lower in productivity (at $P < 0.01$) as compared to the average farmers. This is mainly related to the farmer's purchasing power of the productivity enhancing inputs. The poor farmers often can not afford to purchase and apply the necessary inputs on their farm.

The remaining variables are observed to be insignificant determinants of productivity in the region. Even if the labor, sex and age have the expected positive effects, they are found to be statistically non significant. The impact of extension contact, input distance, other income and radio is also insignificant. All the education dummies included in the regression does not show any significant impact on the productivity of the farmers.

CHAPTER V

SUMMARY, CONCLUSION AND POLICY IMPLICATION

5.1. Summary and Conclusion

The need for applying modern agricultural inputs in Ethiopian agriculture is not debatable. The agricultural sector of the country is well known for its being traditional and use of backward technologies. Hence the application of modern inputs and practices, as evidenced from the Green Revolution Applied in Asia and Latin America, can contribute a lot for productivity enhancement of the sector. The fate of the sector in terms of increasing its contribution to the overall growth of the economy and

securing food self sufficiency depends on the development and application of appropriate technologies.

This paper, using the household data collected by EDRI in 2001/2002 for Tigray and Amhara regions, tries to identify the major factors contributing for the adoption of modern agricultural inputs by the farmers and their productivity.

The analysis is undertaken using both the descriptive and regression analysis. The descriptive analysis reveals that in both regions, households with larger family size, male headed and educated household heads are found to be better adopters. In Amhara region, younger households are found to be better adopters while age has no effect on the adoption decision of farmers in Tigray. It is also observed that there is no significant difference between adopters and non-adopters based on their religious belief in Tigray, but in Amhara, Orthodox believer households are found to be better adopters while Moslems are lower adopters.

Further, farmers having larger farm size, own large number of oxen, had access to credit, located near to input delivery institutions and had extension contact are found to be better adopters in both regions. There is no difference between adopter and non-adopters in Tigray based on the amount of other source of income, but it is higher for non-adopters in Amhara. The ownership of radio is found to have insignificant effect on the adoption decision of the farmers in both regions. In both regions, most of the poor households are found to be non-adopters while the average households are better adopters. But there is no difference between adopters and non-

adopters in the better off household category. In Tigray, having better life as compared to before doesn't have a significant effect on adoption, but those households having the same lifestyle as compared to before are found to be better adopters while most of the households whose life got worse off as compared to before are non-adopters. In the case of Amhara, all the improvement, same or deteriorated life style as compared to before have no impact on the adoption decision of the farmers.

In order to identify the determinants of modern agricultural inputs adoption in the regression analysis, the logit model is applied to the data set. In Tigray, it is found that the distance of input delivery institutions from the household, the household being poor and having worse off life as compared to the previous five years are found to have a negative effect on the adoption of the modern inputs. On the other hand, having contact of an extension worker and being in Woredas like Medabai-Zana and Ganta Afeshum which are relatively suitable to agricultural production have a positive effect on the adoption of the modern inputs. In the case of Amhara region, the number oxen the household own, having extension contact, education level of the household head and being in good agro-ecological Woreda like in Hulet Ej Enese have a positive impact on the farmers adoption of the modern inputs. But the distance of the household from the input supplying institutions and being in resource poor Woreda like Ambasel negatively affects the probability of adopting the technology.

To determine the factors contributing for the productivity of the farmers and see the effect of the modern inputs on the farmers' productivity, the Cobb-Douglas production

function model is applied. The result shows that, in Tigray, land size and input distance negatively affect productivity while the number of oxen the farmer own, other income than agriculture, access to credit, ownership of radio and being in Tselemti Woreda have a positive impact on productivity. But extension contact and whether the household is classified as adopter doesn't have significant effect on productivity. The productivity of farmers in Amhara is negatively affected by land size, having sick family member in the household and being poor. The number of oxen the household own, being adopter of the modern inputs and being in suitable agro-ecological Woredas like Hulet Ej Enese, Enese Sar Midir and Jama as compared to Ambasel positively affect the productivity of the farm households.

In general, it is observed that, even if extension contact has a positive impact on the farmers' adoption decision, its effect in enhancing productivity is not significant. The effect of the modern agricultural inputs on enhancing productivity is also significant only in Amhara region (at $P < 0.1$). This shows the extension workers are just convincing the farmers to use the modern inputs without showing them how to use it so that to increase productivity and this may be mainly because of lack of knowledge of the extension workers and lack of adaptive research which could suit the technologies to the specific situations of the area.

5.2. Policy Implication

The results obtained from the study can be used to show some intervention areas, even if a more detailed study in terms of area coverage and depth is required to arrive at conclusive policy recommendations.

First, it must be understood that Ethiopia's food insecurity problem that were caused mainly by rapid population growth and low productivity could be solved only through high investment in agriculture and expansion of modern inputs which could exploit the maximum yield on existing cultivated land. The possibility of expanding cultivable land is almost exhausted. Hence, there is a need to minimize constraints that hinder farmers from adopting the modern inputs. This includes the establishment of input supplying institutions in the farmers' nearby and developing and providing appropriate credit schemes to minimize the financial constraints of the farmers, which could be used as a means of breaking the vicious circle.

Second, it is shown that the impact of extension contact on the farmer's adoption decision is significant, but the impact on productivity is not. This implies the need for enhancing the knowledge of the extension workers through appropriate training so that they can help the farmers not only to tell to use the modern inputs, but also how to use to benefit from the possible productivity gains.

Third, to increase the productivity of the farmers with large farm size, who are mostly endowed with more resource, there is a need to develop a means to make them able to apply the variable inputs to exploit the maximum benefit out of their land. This could be done through different ways like arranging financial sources that can be

used for the purchase of the variable inputs and developing a framework for off-farm employment opportunities in the rural labor market.

Fourth, since most of the farmers in the country are very poor who can't afford to purchase modern inputs, there is a need to develop and use local productivity enhancing technologies available at the farmer's disposal in addition to the purchased inputs. This includes the use of inorganic fertilizers like animal dung and other technologies like crop rotation.

Finally, the irresponsiveness of the farmers' productivity to the modern technology in Tigray shows the high need for adaptive research. Only applying the technologies may not result the expected result, rather the application rate and the availability of complementary inputs matter. Even, the blanket recommendation, which is recommended with out considering the specific agro-ecological conditions of the area may not work in some conditions. Hence, there is a need to aggressively engage in research and development activities to develop and suit the technologies for the countries specific agro-ecological conditions and needs. The government and donors must support such research activities to the sustainable growth of the sector.

Annex I: Probit Estimates for Determinants of Modern Agricultural Input Adoptions.

A. Tigray

Log likelihood = -171.43708
 Correctly classified 79.75 Percent

Number of obs = 395
 LR $\chi^2(22)$ = 204.71
 Prob > χ^2 = 0.0000
 Pseudo R^2 = 0.3738

Variables	Coefficient	Std. Err.	P>z	Marginal effect	P>z
labor	0.0033058	0.0411771	0.936	0.0013188	0.936
Sex	0.1486067	0.2121927	0.484	0.0592217	0.483
Age	0.0049404	0.0060613	0.415	0.0019709	0.415
land_size	0.1258318	0.1908211	0.510	0.0501978	0.510
No_ox	0.1447429	0.101059	0.152	0.057742	0.152
inpu_dis	-0.029834	0.0095903	0.002*	-0.011901	0.002*
ext_cont	1.50278	0.1623099	0.000*	0.5475091	0.000*

Credit	0.5505482	0.4134932	0.183	0.2109407	0.148
otherinc	-0.000144	0.0001609	0.370	-0.000057	0.370
Radio	-0.332128	0.2582196	0.198	-0.131023	0.187
woredadum1	0.4193766	0.2634967	0.111	0.1651606	0.104
woredadum2	0.8521103	0.2387966	0.000*	0.3231474	0.000*
woredadum3	0.4560217	0.2572031	0.076***	0.178646	0.067***
So_econodum1	-0.610999	0.1974175	0.002*	-0.237821	0.001*
So_econodum3	0.1766978	0.5409869	0.744	0.0701049	0.742
religionum1	-0.470279	0.4300109	0.274	-0.181403	0.242
lstyr_chdum1	0.0888458	0.2795106	0.751	0.0354	0.750
lstyr_chdum3	-0.003211	0.2029659	0.987	-0.001281	0.987
ago5_chadum1	-0.162987	0.2440332	0.504	-0.064908	0.502
ago5_chadum3	-0.561253	0.2297558	0.015**	-0.220680	0.011**
read_write	0.1702007	0.2288768	0.457	0.0676751	0.454
elementary	0.2329138	0.3139516	0.458	0.0921978	0.451
_cons	-0.836465	0.7811437	0.284		

Source: Computed from survey data.

*, ** and *** represents the coefficients are significant at 1, 5 and 10 percent respectively.

B. Amhara

Number of obs = 238

LR $\chi^2(22)$ = 206.31

Log likelihood = -51.368355

Prob > χ^2 = 0.0000

Correctly classified 88.66 Percent

Pseudo R^2 = 0.6676

Variables	Coefficient	Std. Err.	P>z	Marginal effect	P>z
hh_size	0.0403529	0.085242	0.636	0.0110912	0.638
Sex	0.4200268	0.5175571	0.417	0.1312217	0.464
Age	-0.009352	0.0144644	0.518	-0.002570	0.524
Land_size	0.1336876	0.2502319	0.593	0.0367446	0.595
no_ox	0.5390995	0.2383049	0.024**	0.1481739	0.030**
Credit	0.0111625	0.4021238	0.978	0.0030771	0.978
Inpu_dis	-0.124096	0.0539808	0.022**	-0.034108	0.038**

ext_cont	0.9123698	0.3290137	0.006*	0.2780713	0.009*
other_inc	0.003123	0.0022923	0.173	0.0008584	0.191
Redio	-0.435431	0.6866164	0.526	-0.136232	0.567
woredadum1	1.784899	0.6226917	0.009*	0.3834722	0.000*
Woredadum2	0.0628376	0.4963802	0.899	0.0170101	0.898
Woredadum4	-3.372896	0.7052542	0.000*	-0.905598	0.000*
so_econodum1	-0.351827	0.4182605	0.400	-0.093631	0.390
so_econodum3	-0.320519	0.5536261	0.563	-0.097675	0.592
religionum1	-0.275307	0.4195151	0.512	-0.071525	0.486
Lstyr_chdum1	0.4124547	0.4794869	0.390	0.1004685	0.329
Lstyr_chdum3	0.8775054	0.4275087	0.040**	0.212276	0.027**
ago5_chadum1	-0.084247	0.4514029	0.852	-0.023365	0.853
ago5_chadum3	-0.623811	0.4466381	0.163	-0.181426	0.181
read_write	1.526674	0.5898226	0.010**	0.2821355	0.001*
elementary	0.8619152	0.4597499	0.061***	0.1841696	0.017**
_cons	-3.838206	1.274369	0.003		

Source: Computed from survey data.

*, ** and *** represents the coefficients are significant at 1, 5 and 10 percent respectively.

Annex II: Econometric Tests

In dealing with cross sectional data, the major problems arising from violation of the basic assumptions are multicollinearity and heteroscedasticity.

To observe the degree of collinearity between the explanatory variables, both the pair-wise correlation coefficients and variance inflation factors (VIF) are considered. Both the tests are routinely done using the stat software. The pair-wise correlation coefficients simply tell us the degree of correlation between any two explanatory

variables. Gujarati (2003) give a rule of thumb to suspect a serious multicollinearity problem when the pair-wise correlation coefficient is in excess of 0.8.

The variance inflation factor (VIF) measures the speed with which variance and covariance increases and simply calculated by:

$$VIF = \frac{1}{(1 - r_{23}^2)}$$

Where r_{23} is the coefficient of correlation between X_2 and X_3 . Again Gujarati (2003) give a rule of thumb to suspect the serious multicollinearity problem when it is in excess of 10.

The heteroscedasticity problem is checked using the Breusch-Pagan-Godfrey test, which stata software computes after a regression. In order to illustrate this test, consider the following K-variable regression model

$$Y_i = \beta_1 + \beta_2 X_{2i} + \Lambda + \beta_k X_{ki} + u_i$$

Assume the error variance σ_i^2 is described as

$$\sigma_i^2 = f(\alpha_1 + \alpha_2 Z_{2i} + \Lambda + \alpha_m Z_{mi})$$

That is, σ_i^2 is some function of the non stochastic variables Z's; some of or all of the X's can serve as Z's. Specially, assume that

$$\sigma_i^2 = \alpha_1 + \alpha_2 Z_{2i} + \Lambda + \alpha_m Z_{mi}$$

That is, σ_i^2 is a linear function of the Z's. If $\alpha_2 = \alpha_3 = \Lambda = \alpha_m = 0$, $\sigma_i^2 = \alpha_1$, which is a constant. Therefore, to test whether σ_i^2 is homoscedastic, one can test the hypothesis that $\alpha_2 = \alpha_3 = \Lambda = \alpha_m = 0$.

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