ADOPTION AND DIFFUSION OF AGRICULTURAL TECHNOLOGIES: CASE OF EAST AND WEST SHEWA ZONES, ETHIOPIA

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LEGESSE DADI
SCHOOL OF ECONOMIC STUDIES
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No portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.
Dedication

To my late Mother and Father
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Abbreviations

AADP  Ada Agricultural Development Project
AGDP  Agricultural Gross Domestic Product
AMC  Agricultural Marketing Corporation
ASIE  Agricultural Inputs Supply Enterprise
BBM  Broad Bed Maker
CADU  Chilalo Agricultural Development Unit
CBD  Coffee Berry Disease
CBE  Commercial Bank of Ethiopia
CIMMYT  Centro International de Mejoramiento de Maiz Y Trigo
CIP  Coffee Improvement Project
CSA  Central Statistical Authority
CV  Coefficient of Variation
DA  Development Agent
DAP  Dia Ammonium Phosphate
DBE  Development Bank of Ethiopia
ESE  Ethiopian Seed Enterprise
ESTC  Ethiopian Science and Technology Commission
FAO  Food and Agricultural Organization
GDP  Gross Domestic Product
HYV  High Yielding Variety
IAR  Institute of Agricultural Research
ICRISAT  International Crop Research Institute for Semi-Arid Tropics
IFPRI  International Food Policy Research Institute
ILRI  International Livestock Research Institute
IPC  Innovation Possibilities Curves
LPM  Linear Probability Model
LRI  Likelihood Ratio Index
LRT  Log-likelihood Ratio Test
MCTD  Ministry of Coffee and Tea Development
MFC  Marginal Factor Cost
MOA  Ministry of Agriculture
MPP  Minimum Package Programme
MRT  Marginal Rate of Transformation
MSFD  Ministry of State Farm Development
MVP  Marginal Value Product
N  Nitrogen
NARS  National Agricultural Research Systems
OLS  Ordinary Least Square
PA  Peasant Association
PADEP  Peasant Agricultural Development Project
PC  Producer Cooperative
P$_2$O$_5$  Phosphate
PPF  Production Possibilities Frontier
qt  quintal
RELC  Research and Extension Liaison Committee
SC  Service Cooperative
SIDA  Swedish International Development Association
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Abstract

In this study, adoption of improved varieties, fertilizer and herbicide on tef and wheat have been examined. A single visit survey was conducted in four weredas (districts) in the East and West Shewa zones of Ethiopia. A three-stage sampling procedure was applied to select weredas, peasant associations and sample farmers randomly. Data were collected from 200 farmers and farmers' adoption decisions on improved varieties, fertilizer and herbicide were modelled using these data and probit, tobit, Heckman and duration models. Fertilizer was adopted by 92% and 61% of farmers on 93% and 84% of their tef and wheat fields. Improved varieties were adopted by only 20% and 43% of farmers and herbicide by 74% and 44% of farmers on 70% and 48% of their tef and wheat fields. Regarding mode of adoption most farmers adopted components of a package of the three types of technology in a step-wise manner.

The estimated econometric models show that location, oxen ownership, distance to market, credit had a significant impact on adoption and intensity of use of the technologies on both crops. Gender and risk aversion were significant in only one or two of the models estimated. Their impact on adoption and intensity of use of technologies were not strong. Education and the index of awareness had no effect on the intensity of use of fertilizer and herbicide as they were not significant in any models. Among the variables examined in duration models, output price, oxen ownership, location and distance to market were significant in more than two models. An increase in the output price and number of oxen owned increases the conditional probability of adopting the technologies and hence shortens the time taken to adopt them. Distance to market appears to have a strong negative impact on the conditional probability of adopting herbicide. With the exception of the impact of the age of household heads on fertilizer adoption on tef, personal characteristics are not important in influencing durations of adoption.

Our results suggest that an increase in output price increases the probability of adopting fertilizer and herbicide, thereby reducing the duration farmers wait to adopt them. This implies that early adoption can be encouraged and productivity thereby increased by providing farmers with adequate price incentives. So future efforts to sustain and accelerate adoption require in the short-term public sector intervention in the market through price stabilization schemes and subsidies for selected inputs and farmers. In the context of Ethiopia such polices will be valid until the country is able to solve food insecurity problem through domestic production of food or international trade. Given the results we found, lack of oxen causes negative social and economic consequences for some farmers. Thus, attention should be given to solving the traction power problem through the provision of a medium-term credit programme for oxen purchase. This can be achieved by establishing rural credit cooperatives which can provide credit for oxen purchase. Another result worth noting is the decline in adoption and intensity of adoption as the distance to market increases. The private sector is less interested in providing services in areas far from markets. There is a need for establishing and reinforcing grass-roots institutions, particularly service cooperatives. Moreover, investment in infrastructure and improvement in output and input marketing systems are crucial and would result in high levels of adoption. To sustain the positive impact of credit on adoption, a mechanism should be devised in which the current formal credit scheme be strengthened.
In terms of providing income, employment and foreign exchange, agriculture is the most important economic activity in Ethiopia. However, the country is severely constrained in its ability to feed itself or to import foreign products for domestic consumption and capital goods for the development of other sectors of the economy. Smallholder farmers dominate agricultural production and crop productivity on smallholdings is low, averaging 11.5 qts/ha for cereals, and this low crop productivity at least partly explains why Ethiopia is facing shortfalls in food supply and why food availability per capita is one of the lowest in the world.

Hence, a basic and critical objective for the agricultural development of Ethiopia is to increase productivity and accelerate agricultural growth in order to meet the food needs of the country's rapidly growing population. In theory, agricultural growth could be achieved by expansion of the cropped area or by intensification or both. However, the scope for increasing the area under crops in the central highlands, where much of the country's agriculture is currently practised, is severely limited due to growing population pressure combined with the large livestock population. In the short-term, cropped area expansion is also difficult in the lowland areas due to lack of basic infrastructure (particularly roads), shortage of labour for large commercial farming and malaria. In the Ethiopian context, agricultural production growth and development in the short-term therefore depends on raising productivity on smallholders' farms in the highlands through the application of new agricultural technology.

Agricultural technology has shown great potential for increasing productivity in countries where the "Green Revolution" was successful. In view of this potential, more

\[1\text{ quintal} = 100\text{ kilograms}\]
widespread adoption of technology is an essential component in efforts to increase crop production in Ethiopia and meet food requirements. There are several mutually reinforcing ways of achieving enhanced productivity on smallholders' farms. These include widespread use of improved varieties, greater and more efficient use of chemical and organic fertilizers, application of improved agronomic practices and more efficient weed control and pest management techniques.

So far, various attempts have been made to increase productivity through the application of new technologies. New technologies have been extended to farmers through various projects which were implemented by Ministry of Agriculture (MOA) and through agricultural research centres' outreach programmes. Most notable extension projects and programmes that have been undertaken in the study area include the Food and Agricultural Organization's (FAO) fertilizer programme known as the "Freedom from Hunger Campaign", the Ada Agricultural Development Project (AADP)\(^2\), the Minimum Package Programme (MPP), the Peasant Agricultural Development Project (PADEP) and the outreach programmes of Holetta and Debre-Zeit agricultural research centres. New technologies such as improved varieties of wheat, tef, barley and pulses, fertilizer, weed and pest control practices and other agronomic practices have been disseminated by these projects and programmes.

In spite of the efforts made by these projects, at the national level the adoption rates of these technologies have remained lower than expected. For example, preliminary estimates indicate that fewer than 5% of Ethiopian farmers use improved varieties. Fertilizer use by smallholder farmers is also low. Thus, in 1995, on average only 7 kgs nutrient/ha were used in Ethiopia compared to 48 in Kenya and 60 kgs nutrient/ha in Zimbabwe (World Bank, 1995); in terms of area coverage only 28% of total cultivated land was fertilized and about 1% of cultivated land planted to improved varieties (CSA, 1995).

\(^2\) This project was implemented in Ada wereda (district) only.
Introduction

Such figures clearly indicate that the level of technology adoption is very low and technology dissemination efforts in the past have been only partially successful. It is true that some of the technologies were not available and this contributed to non-adoption. However, in areas where the technologies (particularly fertilizer, herbicide and improved varieties) were available, not all farmers adopted them. Furthermore, if we consider adopters as a group, we observe differences in terms of duration of adoption: some farmers adopted sooner while others waited longer before adopting, and some farmers have not as yet adopted. Moreover, the intensity of use for adopter farmers also varies considerably. For instance, the amounts of fertilizer and herbicide applied by most farmers in Ethiopia are below the recommended levels (Hailu et al., 1992; Legesse et al., 1992; Legesse, 1992).

The above observations lead to the following questions. What is the proportion of farmers using new technologies? Why is it that some farmers adopt fertilizer, improved varieties and herbicide while others do not? Why do some farmers wait longer to adopt than others? What factors influence the intensity and duration of adoption of fertilizer and herbicide? However, few adoption studies have been conducted in Ethiopia to address the questions raised above, and most of these have been limited to attempts to determine the rate of adoption and to explain factors affecting adoption at a given point in time. Thus, with the exception of Bisrat's (1980) study, they have not examined the speed of diffusion and the extent of adoption of technology over time.

Theoretically, prices of output and input are expected to be important factors affecting adoption decisions, but no study has examined the impact of these variables on adoption decisions in Ethiopia. Moreover, no study has systematically investigated dynamic aspects of the adoption process and the effects of time-varying variables were not examined. This is no doubt because information regarding the rate, intensity and duration of adoption and the impact of technology on farmers' income has not been available. Research is therefore clearly
needed in these areas and this study is one step toward this end. The study attempts to address the problems noted above and its overall objective is to assess the adoption and diffusion of technologies using cross-sectional and longitudinal analysis. The rate and intensity of adoption at a given point in time will be examined using probit, tobit and Heckman models. Adoption behaviours of farmers over years will be examined using duration analysis. The latter method enables us to capture the dynamic aspects of the technology adoption process, allows us to compare the speed at which technology spreads among groups of farmers and helps in assessing the pace of adoption of two or more technologies. The specific objectives of this study are:

(i) To examine the rate and intensity of fertilizer and herbicide adoption on tef and wheat.

(ii) To assess the rate of adoption of improved varieties of wheat and tef.

(iii) To identify and quantify the factors that influence the decision to adopt and the intensity of adoption.

(iv) To quantify and examine the factors that determine speeds of adoption of fertilizer and herbicide over time using duration analysis.

Such studies lead to improved understanding of the factors influencing the rate, intensity and duration of adoption, helping institutions involved in technology development and transfer to increase their efficiency and effectiveness in attaining their objectives. Such research should also help rural development planners in setting priorities for investment resource allocation and the formulation of rural development programmes aimed at increasing farmers' income.

In Ethiopia, tef and wheat are the major crops in terms of area and total production. This study therefore attempts to generate information regarding the rate, intensity, patterns of adoption and diffusion of improved varieties, fertilizer and herbicide on these two crops. The
study was conducted in East and West Shewa zones where use of these technologies (particularly fertilizer and herbicide) is more widespread than in other parts of the country\(^3\). East and West Shewa zones are located in the central highlands of Ethiopia, which stretch about 250 kms to the East and West of Addis Ababa.

The thesis is organized in 10 chapters. Chapters 2 and 3 review theoretical and empirical studies and provide the conceptual framework for the adoption analysis presented in the later chapters. They also provide justifications for including particular variables in the empirical models. Chapter 2 defines some basic concepts and provides the conceptual framework required for understanding and analysing the adoption and diffusion processes. It explains the impact of technical change on factor-product, factor-factor and product-product relationships in farm production. It also describes modes of adoption of technologies and the S-shaped diffusion curve. Chapter 3 reviews agricultural technology adoption studies conducted in developing countries but not in developed countries, there being two reasons for doing this. First, agricultural production has peculiar characteristics, such as the seasonality of production and heavy dependence on natural factors, which are not found in other economic activities and which influence the adoption behaviour of farmers. Second, there are differences between farmers in developed and developing countries in terms of the constraints they face and opportunities available to them. The factors affecting adoption and the type of technology examined in developed and developing countries may therefore be expected to be different. Hence, results of adoption studies conducted in developed countries may not be as relevant to this study as technology adoption studies conducted in developing countries.

Chapter 4 deals with the Ethiopian economy and agriculture. The main objective of the chapter is to provide insight into Ethiopian agricultural production systems and the environment into which technologies have been introduced and adopted. It describes the role

\(^3\) Of total fertilizer used in the country, about 45% is consumed in Shewa zones.
of agriculture in the economy, its resource base, production systems, performance and the
government policies that have implications for agricultural technology adoption. Smallholder
farming is the most dominant form of production system in Ethiopia, including the study area.
Therefore, the chapter focuses on describing this production system and policies particularly
important to it. Agricultural policies adopted by the past and present governments are
discussed in Section 4.6.

Chapter 5 gives an overview of the status of agricultural research and extension
systems in Ethiopia. It describes the constraints encountered in developing and disseminating
technologies suitable for smallholder farmers and identifies weak links which exist between
research and extension systems. It also explains why this study has focused on assessing the
adoption of fertilizer, improved varieties and herbicide, and their intensity of use.

Chapter 6 deals with the methods used in data collection and the organization of field
work. A survey method was used to collect data from 200 farmers. The chapter illustrates the
sampling procedures employed and describes how enumerators were selected and interviews
were conducted. It also discusses the limitations of data. The variables to be included in the
empirical chapters are identified and discussed in Section 6.5. The hypotheses to be tested are
also outlined in the same section.

Chapter 7 provides results of the bivariate analysis. The objective of this chapter is to
describe and determine the level of adoption of improved varieties, fertilizer and herbicide
adoption on tef and wheat, and to identify variables that should be included in the econometric
models presented in later chapters. Thus, it describes personal, household and farm
characteristics and institutional factors, and their impact on adoption. The adoption patterns
of farmers in adopting the three technologies are also discussed in Section 7.4. This bivariate
analysis gives an insight into adoption rates and the intensity of use of technology.

Chapter 8 examines factors influencing the decision to adopt or not and factors
influencing intensity of use. Probit, tobit and Heckman models are employed to assess the
effect of explanatory variables on adoption and intensity of adoption. The chapter starts with
the discussions of methodological considerations and explanations of the models. Based on the
review the results of Chapter 3, theoretical explanations of Chapter 6 and bivariate analysis of
Chapter 7, models which predict adoption of improved varieties and adoption and intensity of
use for fertilizer and herbicide are specified and presented in Section 8.3. Estimation results
of the three models are discussed in Section 8.4 and 8.5.

While Chapter 8 investigates the adoption processes in a given year, Chapter 9
examines farmers' adoption behaviour over several years using duration analysis. The chapter
starts with a review of the conceptual framework of duration analysis. Explanations of duration
data and duration distributions and models are provided in Sections 9.2, 9.3 and 9.4. The
importance of the duration techniques in the analysis of time-varying variables and its flexibility
in accommodating censored observations are emphasized in these sections. Duration data have
beginning and end points. The end point of duration data (sometimes called the survival time4)
usually coincides with the occurrence of an event: for example, adoption in technology
adoption studies, death or occurrence of a disease in biomedical research, failure of a machine
or other equipment in engineering studies and employment in unemployment duration studies.
In economic and social studies data are collected through surveys. At the time when data are
collected some spells may not be completed and such spells are usually "censored" at the time
of data collection. The end point for censored data is therefore the censoring time. The
empirical models and estimation results are discussed in Sections 9.5 and 9.6, respectively. The
final chapter summarizes the main findings and draws conclusions. It also discusses policy
implications of this work and indicates future areas for research.

4 Different terminologies are used in different disciplines to describe duration data. These
include failure time, lifetime, time spell, and survival time.
CONCEPTUAL FRAMEWORK FOR THE STUDY OF TECHNOLOGY
ADOPTION AND DIFFUSION PROCESSES

2.1. Introduction

Adoption and diffusion of technology are two related concepts; the first refers to the decision to adopt a technology or not, and the second to the spread of a technology among economic agents over a period of time. Adoption of a technology is not an instantaneous process, since time elapses while a technology spreads among the economic units. The speed of adoption of a technology differs between economic units and regions and between technologies depending on their attributes. An understanding of the processes of technology adoption and speed of diffusion influences the design of effective research and extension programmes. The objectives of this chapter are to define basic concepts used in adoption and diffusion analysis and to review the theoretical studies and provide a conceptual and theoretical framework for the later methodological and empirical chapters. It also seeks to describe the models most frequently used in estimating the diffusion rate and to pinpoint the drawbacks of the models.

The following section outlines basic concepts and definitions of adoption and diffusion processes. Sections 2.3 to 2.7 give the theoretical background of adoption and diffusion processes. The impact of technical change on factor-product, factor-factor and product-product relationships are discussed. Utility maximization is assumed to derive the adoption decision. In addition to describing motives behind technology adoption, this section also contains several hypotheses which may explain the S-shaped curve of the diffusion path and
its ceilings. The various stages of innovation-decision process and categories of adopters are also discussed. Modes of adoption of technologies and argument for and against the modes of adoption are also reviewed. Section 2.8 describes models used in estimating diffusion rates. The characteristics and drawbacks of the standard logistic models are pointed out and an attempt made by researchers to relax some of the assumptions of this model is described. The final section provides a number of concluding remarks.

2.2. Definitions

Innovations are classified into process and product innovation. A process innovation is an input to a production process, while product innovation is an end product for consumption. The agricultural technologies considered in this study fall in the first category. In this study the terms 'innovation' and 'technology' are used interchangeably.

Adoption and diffusion are distinct but interrelated concepts. Adoption refers to the decision to use a new technology, method, practice etc. by a firm, farmer or consumer. The concept of diffusion refers to the temporal and spatial spread of the new technology among different economic units -firms, farmers, and consumers. These two concepts have been defined by many researchers belonging to different academic disciplines.

Among the many definitions, that suggested by Rogers (1983) has been used in several adoption and diffusion studies. Rogers (1983) defined aggregate adoption (i.e. diffusion) behaviour as the process by which a technology is communicated through certain channels over time among the members of a social system. This definition encompasses at least four elements: (1) technology, which represents the new idea, practice, or object being diffused, (2) channel of communication, which represents the way information about the technology flows from change agents (such as extension workers) or technology suppliers to final users or
adopter, (3) time, which represents the period over which a social system adopts a
technology, and (4) social system, which is comprised of individuals, organizations, or agencies
and their adopting strategies (Knudson, 1991). In this study-context the social system consists
of farmers who are potential adopters of technologies. Rogers defined adoption as use or
nonuse of new technology by a farmer at a given period of time. This definition can be
extended to any economic units in the social system.

Feder et al. (1985) suggested a definition that distinguishes between individual
adoption (at the farm level) and aggregate adoption. This distinction is important for
theoretical and empirical analysis at the two levels of economic settings. They defined
individual (farm level) adoption as the degree of use of a new technology in long-run
equilibrium when the farmer has full information about the new technology. They defined
aggregate adoption or diffusion as the process of spread of a technology within a region or
population. This definition implies that the aggregate adoption is measured by the aggregate
level of use of a given technology within a given geographical area.

With regard to the measurement of intensity of adoption, a distinction should be made
between technologies that are divisible and technologies that are not divisible. The intensity
of adoption of divisible technologies can be measured at the individual level in a given period
of time by the share of farm area under the new technology or by the per hectare quantity of
input used in relation to the research recommendation. Feder et al. suggested that this measure
may also be applied at the aggregate level for a region. In the case of non-divisible agricultural
technologies such as tractors and combine harvesters, the extent of adoption at the farm level
at a given period of time is dichotomous (adoption or non-adoption), and the aggregate
measure becomes continuous. Thus, aggregate adoption of lumpy technology can be measured
by calculating the percentage of farmers using the new technology within a given area.
2.3. Theory of Technical Change

In this section we discuss the theory of technical change. The discussion focuses on the impact of technical change on farm production relationships and the influence of factor scarcity and factor price on allocation of resources for research and development and on farmers' technology adoption decisions. The diffusion theory of imitation is important in technology adoption and this will therefore be discussed in the next section.

"Technology" is defined by economists as the stock of available techniques or the state of knowledge concerning the combination of inputs used to produce a given physical output. Technical change is then seen to be an improvement in the state of knowledge such that production possibilities are enhanced. In other words, 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 inputs. The following subsection describes the impact of technical change on farm production relations. Market-level effects of technical change are also discussed.

2.3.1. Impact of Technical Change on Farm Production Decisions

The impact of technical change on production relationships has been discussed among others by Ellis (1993), Colman and Young (1989), Stevens and Jabara (1988) and Thirtle and Ruttan (1987), and can be analyzed in terms of its effect on the factor-product, factor-factor and product-product relationships. The effect of technical change on these relationships is illustrated in Figures 2.1 to 2.4. Figure 2.1 shows the factor-product relationship. The horizontal axis represents fertilizer input, while the vertical axis represents wheat output. As shown in the figure, adoption of new technology (for example, an improved seed variety)
moves the total physical product (TPP) curve upwards, implying that additional output can be obtained from the same amount of fertilizer. Alternatively, if a producer wishes to maintain the same level of output as before adoption, he can reduce his cost by applying X1 amount of fertilizer.

Farrell (1957) distinguished between technical efficiency, as the 'ability to produce as large as possible an output from a given set of inputs', and allocative efficiency as the, 'extent to which a firm uses the various factors of production in the best proportion, in view of their prices', and economic efficiency, being the attainment of both technical and allocative efficiencies. Hence, allocative and economic efficiencies require that the marginal conditions for maximizing profit (marginal value product (MVP) equals marginal factor cost (MFC)) are satisfied. Thus, in Figure 2.1, curve TPP2 is seen to be technically superior to curve TPP1. A farmer who operates at point C on TPP2 is technically efficient but allocatively inefficient, given the ratio of output to input prices. At C, the marginal value product is greater than marginal factor cost and he operates below the marginal conditions required for maximizing profit. Only a farmer operating at point D on TPP2 is seen to be both allocatively and economically efficient (at point D, MVP = MFC) given the prevailing fertilizer and output ratio. A farmer operating on any point on TPP1 is a non-adopter and hence is technically inefficient. At point B, MVP = MFC, so a farmer operating at this point is allocatively efficient.
Farmers make decisions about which technology to use and the amount of input to be used. If a farmer decides to adopt a new technology, this decision alters the method of production and input combinations he has been using. The application of more fertilizer results in increased yield, while application of more herbicide prevents yield loss due to weed attack. However, farmers may not all apply the same levels of such inputs. The reasons farmers apply different levels of fertilizer and herbicide is one of the subjects of this study and will be examined in Chapter 8. At this stage, we merely note that farmers' own subjective evaluations of crop fields' soil fertility and weed infestation level, as well as availability of inputs, access to resources, information and credit, may differ between farmers and this influences the amounts of fertilizer or herbicide that are used.

Another important point to be noted in the analysis of factor-product relationships concerns whether a farmer who has adopted fertilizer and herbicide but is not using the
recommended level, is technically, allocatively and economically inefficient. In figure 2.1, X4
represents a fertilizer level recommended by agronomists. This recommended level of fertilizer
is set by agronomists without paying attention to economic factors such as output and input
prices. A farmer, however, takes into consideration the prices of output and input in
determining the amount of fertilizer to be used. So a farmer who does not use the agronomic
recommended levels of fertilizer or herbicide is technically efficient so long as he operates on
the TPP2 curve, and allocatively and economically efficient if he operates at the optimal point,
D, on TPP2.

Technical change also has an impact on the way two or more factors of production are
combined to produce a given level of output. The factor-factor relationship is illustrated in
Figure 2.2. Isoquant Q1 shows the various combinations of variable inputs which yield the
same amount of output. With adoption of a new technology the isoquant shifts towards the
origin to Q2. This means that with less of each input (in this case labour and land) the same
amount of output can be obtained and implies a reduction in total production cost for given
factor prices, as indicated by the parallel inward shift of the iso-cost line from P1 to P2.

The economically optimal combination of the two inputs is determined by the slope of
the iso-cost line, where the iso-cost line is a line that represents all combinations of the two
inputs that could be purchased for a given cost outlay. For isoquant Q1 the optimal
combination, the least cost combination of the two inputs occurs at A where the iso-cost line,
P1, is a tangent to the isoquant curve, Q1. After a new technology is adopted, the least cost
combination of the two inputs is attained at B. At A and B the slope of the iso-cost line and
the slope of the isoquant curve are equal, that is, the marginal rate of substitution between the
two inputs equals the ratio of the input prices. Combinations of inputs other than A and B on
the isoquants, Q1 and Q2, result in higher production costs.
The effect of technical change on resource use can be neutral or biased. Figure 2.2 shows the impact of neutral technical change on utilization of two inputs. In the figure the isoquant has moved in a parallel fashion towards the origin. This parallel movement of the isoquant towards the origin implies that for given relative factor prices the ratio of inputs is the same after as before the technical change.

Biased technical change, however, entails change in factor proportions at a given factor price ratio and facilitates relatively greater use of one input. For example, agricultural technologies may favour use of labour or capital. If a technology is biased in favour of capital the technology is said to be capital-biased or labour-saving. On the other hand, if a technology employs more labour than capital it is said to be a labour-biased or labour-intensive technology (Hayami and Ruttan, 1985). Biological technologies, particularly improved varieties and fertilizer, are labour-intensive technologies. Mechanical technologies such as tractors, planters,
harvesters and threshers belong to the capital-intensive technologies. Adoption of mechanical technologies in most cases displace labour. However, some capital-intensive technologies are not necessarily labour-saving since they use more labour. For example, irrigation technology is capital-intensive, but such technology is also labour-intensive since more labour is required for irrigation water management. In addition, irrigation facilitates double or triple cropping and for that more labour will be needed. On the other hand, herbicide is a labour-saving biological technology since it displaces labour otherwise needed for crop weeding.

As noted above, biased technical change leads to a change in factor proportions. Its effect can be expressed by analysing the relation between factor price ratios and relative changes in factor proportions before and after technology adoption. We analyse this relation using Figure 2.3 which represents capital-biased technical change. In the figure, the least cost combination for an old technology is at A. With adoption of capital-biased technology the isoquant moves toward the origin, but becomes steeper; given a constant factor price ratio, this means that the fall in labour is relatively greater than the fall in capital. In the case of extreme bias, the amount of capital used may even increase, as shown in Figure 2.3. With adoption of new technology the optimum levels of labour and capital correspond to point B where the share of capital in the total value of output is more compared to its share at A on isoquant Q1. On the other hand, the share of labour in the total value of output is less at the new optimal input combination than at the old optimal input combination.

An alternative way of expressing the effect of biased technical change is to analyse the changes in relative factor prices needed to maintain the same factor proportion. In Figure 2.3, constant factor proportions (L/K) are shown by the ray 0X. The factor proportions at C are the same as at A, but to maintain the same factor proportion the price of labour would need to fall relative to the price of capital. This relative fall in price results in a new iso-cost line, P3. The difference in the slopes of iso-cost lines P1 and P3 is an alternative measure of the bias
associated with biased technical change. It may also be noted that such biased technical change results in a decline in the income share of labour and rise in the income share of capital.

Among others, Ellis (1993), Rayner and Ingersent (1991) and Hayami and Ruttan (1985) have discussed the impact and policy implications of biased-technical change. In developing countries where labour is assumed to be abundant and capital is scarce, adoption of labour-saving technology creates unemployment and increases income disparities between groups which have differential access to resources and information. On the other hand, adoption of labour-intensive technologies creates employment opportunities and generates income for landless rural labourers.

Figure 2.3. Capital biased technical change.

The discussion above has shown that technical change improves productivity of resource use. In the remaining part of this sub-section we briefly describe the impact of technical change on enterprise choice and its impact at the market level.
In farm production, alternative crops compete for given available resources. Suppose a farmer produces two crops, tef and wheat, then the production possibilities frontier (PPF) shows the maximum output combinations which can be produced, given a set of inputs (Figure 2.4). Technology adoption shifts the production possibilities frontier upwards. The slope of the PPF represents the marginal rate of transformation (MRT), that is, it measures the increase in one enterprise (tef) which results from a decrease in the other (wheat). The economically optimal combination of the two crops is determined by the ratio of output prices and is attained at the point where the iso-revenue line (a line representing combinations that yield a given level of total revenue) is tangential to the PPF. PPF1 in Figure 2.4 represents the output combination before adoption of a new technology. Adoption allows more output of the two crops with the same quantities of other resources, say land and labour. Since the productivity of labour and land increases with adoption of new technology, the production possibilities frontier shifts upwards to PPF2 for a given level of input so more of the two crops can be obtained. The optimal level of production of the two crops is at B where the iso-revenue line, R2, is a tangent to PPF2, assuming constant product prices. Thus, after the new technology is adopted, wheat production increases from W1 to W2 while tef production rises from T1 to T2.
At the market level, adoption of new technology and its effects can also be described using supply and demand curves. Adoption of new technology shifts the supply curve to the right (Figure 2.5). This shift in the supply may have forward or backward (feed-back) links and the effect may differ across farm size groups and regions. As noted in many studies (e.g. Ruttan, 1977; Lipton and Longhurst, 1989) large farmers tend to adopt new technology first, followed by small farmers. This pattern of adoption allows large farmers to capture the excess profits available in the early stages of adoption, since by the time small farmers adopt the technology the output supply shifts to the right and forces the output price downwards, assuming a closed economy. This condition may discourage small farmers from adopting the new technology.

There are ongoing debates about the effects of technical change on welfare. Those who have a positive view about technical change point out that labour-intensive technical change in agriculture improves land and labour productivity, raises employment and incomes of the
poorest households and leads to large incremental improvements in aggregate food production (Kumar, 1994). In addition to this, direct effect labour-intensive technical change generates rapid agricultural growth with linkage effects that stimulate rural investment in the off-farm sector.

However, as noted by Lipton and Longhurst (1989) and Griffin (1979), the impact of technical change may not always be favourable. It may widen income disparities and result in an excessive concentration of wealth in the hands of those who have political power. The income disparity problem is probably most pronounced when a capital-biased technology is introduced and adopted by already privileged groups of farmers. A study by Lingard (1984) in the Philippines suggested that mechanization had little effect on yield; however, the machinery substituted mainly family labour in land preparation operations. Ellis (1993) also pointed out that the net productivity contribution of tractors is low or non-existent in most developing countries while its negative effects on employment and the living standards of a majority of the rural population is great, since small farmers may be compelled to sell their land and become landless.
Note: The effect of technical change is assumed to occur over a period of years. Over this period demand for a product is also likely to increase a little because of rising income and population growth.

The agricultural sectors of developing countries are often characterized by imperfect factor markets. For example, large farmers have more access to information, credit and government subsidies than small farmers. Because of this and their risk-bearing capacity, large farmers tend to adopt technology first, although small farmers may catch up later. Apart from this temporal pattern of adoption, large and small farmers follow different paths of adoption because of differences in the factor prices they confront. Small farmers tend to face a low opportunity cost of labour and high prices for land and capital while large farmers face a higher price for labour combined with low prices for land and for capital (Berry and Cline, 1979; Ellis, 1993). Such distortions arise because large farmers are able to finance land purchases with loans from formal credit institutions at comparatively low rates of interest. On the other hand, because of size of income, risk of default and lack of collateral, small farmers rarely have access to formal credit and instead depend on moneylenders and landlords, who charge higher
interest rates, as their main sources of credit. Therefore, small farmers commit relatively more
labour to production while large farmers commit relatively more capital to production. Because
of these differences in input market prices, large and small farmers may also follow different
adoption paths. Small farmers tend to adopt land and capital-saving technologies; while large
farmers tend to adopt labour-saving (capital-intensive) technologies even in labour abundant
and land- and capital-scarce economies. Figure 2.6 illustrates the adoption paths for small and
large farmers. Initially, both small and large farmers operate on the same isoquant, Q0, but they
use different proportions of labour and capital due to the relative input price ratios they are
facing. On Q0, small farmers use K2 of capital and L3 of labour, while large farmers use K3
of capital and L2 of labour. Assume labour-biased and capital-biased technologies, represented
in Figure 2.6 by isoquants Q1 and Q2 respectively, are introduced at the same time. As noted
above, small farmers tend to adopt labour-biased technology, so after adoption the amount of
capital used by small farmers reduces from K2 to K1, while the amount of labour used rises
from L3 to L4. On the other hand, large farmers tend to adopt capital-biased technology, so
the amount of labour used reduces from L2 to L1, while the amount of capital rises from K3
to K4.
2.3.2. Induced Innovation

In orthodox economic theory technology is viewed as a factor outside the control of the producer and the industry (Colman and Young, 1989). As a result technical change is viewed as a response to the economic opportunities resulting from advances in scientific and technical knowledge that are themselves exogenous to the economic system.

Attempts to treat technical change as an endogenous process focus on differences in key economic variables such as relative factor scarcities and market demand. Models of induced innovation and empirical tests of such models are an attempt to discover the roles played by factor and product prices and other economic variables in determining the rate and direction of technical change. The theory of induced innovation and its policy implications has been discussed by Binswanger (1978), Hayami and Ruttan (1984), Hayami and Ruttan (1985),
Induced innovation theory has developed along two lines. The first focuses on relative factor prices. In competitive markets, relative factor prices reflect the level and change in relative scarcity of factors (Hayami and Ruttan, 1985). Farmers are induced to search for technical alternatives which save the relatively scarce factors. This serves as a signal for research institutions to develop technology which saves scarce factors. For example, suppose the relative scarcity of land increases in an economy. This will induce farmers to search for land-saving technologies such as high yielding varieties and fertilizer. Responding to farmers' needs, a research institution may then allocate more resources to a crop breeding research programme aimed at developing high yielding varieties which have the desired land-saving characteristics. The second development is based on the premise that the availability of new technology for a commodity is a function of, among other things, market demand for the commodity. The relative profitability of inventing and adopting a new technology then depends on the price and market size of the commodity to which that technology is applied (Griliches, 1957).

A model of induced technical innovations for biological technologies based on the first of the above approaches is illustrated in Figure 2.7. In describing the model we have assumed that land is scarce (hence expensive) relative to fertilizer. In the figure IPC1 and IPC2 represent the innovation possibilities curves (IPC) in time 1 and time 2. The IPC is defined by Hayami and Ruttan (1985) as an envelope of unit isoquants corresponding to the alternative technologies that could potentially be developed with existing scientific knowledge. Given relative factor prices in period 1 a composite variety (a variety developed through selection) represented by Q1 is available. On Q1 the efficient optimal combination of land and fertilizer is attained at A. Due to population pressure the scarcity of land increases, and thereby its price relative to the fertilizer price over time. In response to the rise in relative land price, farmers
try to operate at B on Q1. Their need is to substitute fertilizer for land, but the production method at B is not the most efficient technique which could be developed with the existing knowledge along IPC1. Over a period of time, the changes in relative factor prices induces the development of a more fertilizer responsive hybrid variety (a variety developed through crossing) represented by Q2 along a new IPC2. The development of the new hybrid variety enables farmers to produce more from a given area of land and the efficient combination of land- and fertilizer-use moves from B to C. The fertilizer-responsive hybrid variety performs better under adequate water and drainage and land management. This complementarity between hybrid variety and infrastructure is projected using the ray (D, F). Thus, adoption of the variety stimulates adoption of irrigation, drainage technologies and other land-management practices.

Figure 2.7. Induced biological technical change.

Source: Ellis, 1993.
The theory of induced innovation has been tested primarily by reference to historical comparisons between the United States and Japan, and later extended to the UK, Germany, France, and Denmark (Ruttan et al., 1978; Hayami and Ruttan, 1985). Lin (1991c) has suggested that the theory of induced innovation is expected to hold in centrally planned economies where markets are absent for land and labour. He claims that technical change is induced by changes in relative factor scarcities rather than changes in relative factor prices. Lin argues that, as a factor becomes increasingly scarce, its marginal product rises and this will give the same signal as a change in relative factor price in a market economy, inducing farmers to search for technology that saves the scarce factor and uses the abundant factor. However, Fan and Ruttan's (1992) empirical study of technical change for centrally planned economies, including China, did not support Lin's conclusions. They pointed out that the absence of effective markets has distorted the direction of technical change in the centrally planned economies they studied more than might have been expected, given the differences and changes in factor endowments.

In general, there are criticisms concerning the applicability of the theory of induced innovation, which stem from its reliance on the assumption of competitive markets. For example, Beckford (1972) has pointed out that the conditions required for efficient competitive equilibrium are unlikely to be fulfilled in developing countries. Especially when risk is taken into account, subsistence farmers may not be profit maximizers and any divergence between private and social cost may distort the rate and direction of technical change. There are also doubts whether this theory fully explains the forces that drive technical change. As mentioned in Section 2.3.1, in dualistic agriculture small and large farmers confront different factor scarcities and hence different factor prices. The factor prices these groups confront depend upon their economic positions and political power (Grabowski, 1979). This suggests that large farmers with better access to credit may press for labour-saving technologies (like
mechanization) rather than being guided by market forces in resource utilization. Also, as noted by Burmeister (1987), there are cases in which agricultural innovations have been imposed on farmers by the government rather than conforming to the idea of choice between market driven alternatives.

2.4. Theoretical Model for the Analysis of Individual Adoption Process

Economic models of adoption behaviour are based on the assumption that farmers take economic factors into consideration when choosing between alternative technologies. Following Rahm and Huffman (1984), farmers' adoption decisions are assumed to be based upon the objective of utility maximization.

If we represent a technology by, k where \( k = 1 \) for the new technology and \( k = 2 \) for the old technology, the underlying utility function that ranks the \( i^{th} \) farmer's 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 (profitability, riskiness, divisibility) associated with the technology. Thus, the utility derivable from 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 such as farm size, household head's age, education, experience etc. and the technology specific attributes. This relationship may be described as follows:

\[
U_{ki} = \alpha_k F_i (Z_i , N_i ) + e_{ki} \quad k = 1, 2, \quad i = 1, \ldots, n. \tag{2.1}
\]

where \( F \) is a distribution function and \( e_{ki} \) denotes an error term with zero mean.
In equation (2.1) $F$ can assume linear or non-linear relations. Farmers are assumed to choose the technology that will result in the largest utility. The $i^{th}$ farmer will select option $k = 1$ if $U_{i1} > U_{i2}$. 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 (index) random variable $y = U_{i1} - U_{i2} > 0$ when adoption occurs, where, zero is a threshold value. The probability that $y_i$ takes one, i.e. the farmer adopts the new technologies (fertilizer, herbicide, and improved variety), can be expressed as a function of farm and household head's characteristics and attributes of the technology.

$$P_i = Pr(y_i = 1) = Pr(U_{i1} > U_{i2})$$

$$= Pr(\alpha_1 F_i (Z_i, N_i) + \epsilon_{i1} > \alpha_2 F_i (Z_i, N_i) + \epsilon_{i2})$$

$$= Pr(\epsilon_{i1} - \epsilon_{i2} > F_i (Z_i, N_i) (\alpha_{2i} - \alpha_{1i}))$$

Reparameterizing and assuming symmetry

$$= Pr(\mu_i > -F_i(Z_i, N_i) \beta)$$

$$= F_i(\beta x_i)$$

(2.2)

where $x$ is a matrix of explanatory variables including constant, and $\beta$ is a vector of unknown parameters, $Pr(.)$ is a probability function, $\mu_i$ is a random error term, and $F_i(\beta x_i)$ is the cumulative distribution function for the disturbance term ($\mu_i$) evaluated at $\beta x_i$. Thus, the probability of the $i^{th}$ farmer adopting the new technologies is the probability that the utility of the new technologies is greater than the utility of the old technologies. In other words the probability of adopting fertilizer, herbicide, and improved variety is a function of explanatory variables, unknown parameters and the error term. Estimation of equation 2.2 requires the knowledge of form of $F$. The distribution of $F$ is determined by the distribution of the disturbance term $\mu_i$. If $\mu_i$ is normally distributed, $F$ will have a cumulative normal distribution (Amemiya, 1981; Rahm and Huffman, 1984).
2.5. Explanation of the S-shaped Diffusion Curve and Adoption Ceiling

The adoption of technologies, when mapped over time, generally resembles a sigmoid or S-shaped curve (Figure 2.8). 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 (the inflection point for a logistic curve is attained when 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 decelerating rate and at a certain time the technology will be adopted by all the potential adopters. Although the diffusion pattern of most innovations can be derived in terms of a general S-shaped curve, the exact form of each curve, including the slope and asymptote, may differ depending on the theory and models used to describe the diffusion process. For example, the slope may be very steep initially, indicating rapid diffusion or it may be gradual, indicating relatively slow diffusion. Models that generate S-shaped curves include the 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 and diffusion studies.
Sociologists (Rogers, 1962 and 1983; Rogers and Shoemaker, 1971; Mosher, 1979) sought to explain the S-shaped pattern of diffusion in terms of communication channels (i.e. spread of information) and various social characteristics of the potential adopters comprising age, education, attitude to risk etc. They note that the S-shaped curve results from the fact that only a few members of the social system, farmers, adopt a new technology in the early stage of the diffusion process. At the early stage of introduction of a new technology only a few farmers acquire full information about the potential advantages of the technology; hence the adoption speed is slow. Moreover, at the early stage, even if they get full information about the potential advantage of the technology, fear of the possible risks associated with the new technology mean that many farmers may not adopt. However, in each subsequent time period potential adopters acquire full information about the benefits of the technology, and the degree of riskiness associated with it becomes clearer so that adoption becomes rapid. The adoption increases gradually and begins to level off, ultimately reaching an upper ceiling.
Many economists have tried to explain the S-shaped curve in terms of economic variables and social characteristics of potential adopters as well. For example, 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. Mansfield and Griliches argue that the rate of adoption of technology is a function of the economic merits (particularly profitability) of the technology, the amount of investment required to adopt the technology, the degree of uncertainty associated with it and its availability. Sahal (1981) employed a learning perspective when explaining diffusion patterns. Gutkind and Zilberman suggested that the tendency of large firms to adopt the new technology first also explains the S-shape curve.

A number of theoretical and empirical adoption studies have also attempted to identify factors determining the long-run ceilings of the S-shaped diffusion curve. According to Griliches (1957 and 1980), Dixon (1980) and Jansen et al. (1990) the long-run upper limit or ceiling of the diffusion curve is determined by the economic characteristics of the new technology and other economic, social and agro-climatic factors. They argue that differences in profitability of a technology in different regions or districts will result in different adoption ceilings. It was observed that when some members of the target population have not adopted a technology, adoption ceilings are flexible and can shift upward over time in response to "second generation" technical change (Dixon, 1980, Jansen et al., 1990). For instance, in 1957 Griliches estimated an adoption ceiling for hybrid maize less than 100 per cent in 27 of 31 state in the US. The ceilings estimated ranged from 53 per cent to 100 per cent. A study conducted by Dixon (1980) in the same region showed that hybrid maize had entirely replaced the open-pollinated variety, i.e. diffusion had reached its upper ceiling. Similarly the study by Jansen et al. (1990) in India found varying adoption ceilings. They attributed these variations to location specificity of the technology, differences in the agro-climatic, edaphic, economic, and
infrastructural factors. Since these factors have an impact on profitability and the degree of uncertainty across regions, the adoption ceilings may differ across regions.

2.6. The Adoption Process and Adopters' Categories

Rural sociologists view the adoption process as a mental process that passes through different stages. For example, Rogers (1983) and Rogers and Shoemaker (1971) describe the innovation adoption decision process, as the mental process from the first knowledge of an innovation to the decision to adopt or reject. They noted that the innovation-adoption-decision process is different from the diffusion process. The former takes place within the mind of an individual while the latter occurs among the units in a social system or within a region. Based on this theoretical background they identified four stages in the adoption process. These are (1) initial knowledge of the innovation or awareness; (2) persuasion toward the innovation or interest; (3) the decision whether or not to adopt the innovation or evaluation, (4) confirmation sought about the decision made (trial). These stages in the diffusion process imply a time-lag between awareness and adoption. It is usually measured from first knowledge until the decision is made whether to adopt or not. Hence, adoption is not random behaviour, but is the result of a sequence of events passing through these adoption stages (Rogers, 1983).

Rogers (1962), Rogers and Shoemaker (1971) and Mosher (1979) note that all individuals in a social system do not adopt a technology at the same time. Rather they adopt in ordered 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 suggests that the majority of early adopters are expected to be more educated, venturesome, 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. As noted by Runquist (1984), a practical aspect of the classification of adopters into adopter categories has been in the field of deliberate or planned introduction of innovations. Nevertheless, the usefulness of this categorization is restricted as there is evidence indicating possible movement from one category to another, depending on the technology introduced.

2.7. Modes of Adoption of Technologies

Attention has also been given to explaining the mode (or approach) and sequence of agricultural technology adoption. Two approaches seem to appear in agricultural technology adoption literature. The first approach emphasizes the adoption of the whole package and the second one stresses the sequential or step wise adoption of components of a package. The former approach is often advocated by technical scientists while the latter is advanced by field practitioners, specifically by farming system and participatory research groups. There is a great tendency in agricultural extension programmes to promote technologies in a package form whereby farmers are expected to adopt the whole package. Experiences of integrated agricultural development projects such as CADU, in Ethiopia, however, show that this approach has not brought needed technical change because of resource limitations.

Opponents of the whole-package approach argue strongly that farmers do not adopt technologies as a package, but rather adopt a single component or a few suitable technologies. For example, Byerlee and Hesse de Polanco (1986), Leather and Smale (1991) and Nagy and Sander (1990) emphasis that farmers choose to adopt technologies sequentially: adopting initially only one component of the package and subsequently adding components over time.

The principal reasons given for sequential adoption of a package of technologies are profitability, riskiness, uncertainty, lumpiness of investment and institutional constraints. A
farmer first selects the technology that best exhibits these attributes. Ryan and Subrahmanyam (1975) have also suggested that each part of the technological package might be looked upon by farmers as a less risky activity than the complete package in terms of what the farmer could lose if crop failure occurs in the season. They argue that sequential adoption of components of a technological package is a rational choice for farmers with limited cash. As cash is accumulated from previous adoption of a component of a package, farmers will add another component based on the relative advantage and its compatibility under conditions they are operating. This process will continue until the whole package is fully adopted.

Recently Rauniyar and Goode (1996) suggested that the relationship between technologies may be: independent, sequential or simultaneous and the patterns of adoption follow the relationships between the technological components. Based on this premise they conducted an empirical study to assess the patterns of the technology-adoption process. 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 that the probability of adopting a technology is conditional on adopting technologies that precede 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.

They estimated the relationships among technologies already adopted by maize-growing farmers in Swaziland. By using factor analysis they found farmers adopted the technologies investigated in three independent packages: (1) improved maize variety, basal fertilizer, and tractor ploughing, (2) topdressing fertilizer, and chemicals, (3) planting date, and plant population (density). Their empirical findings do not support a sequential adoption process. They reported that farmers in Swaziland tend to adopt a package of technologies and improved agronomic practices rather than individual technologies or practices. Their study,
however, did not investigate the adoption pattern by which each component in the packages were adopted.

Contrary to their findings there are a number of empirical studies supporting sequential adoption patterns (Byerlee and Hesse de Polanco, 1986; Leather and Smale, 1991; Ryan and Sabrahamanym, 1975). It has to be noted that Rauniyar and Goode's assertion of a random adoption pattern is questionable. In my view farmers take into account the environment under which they operate and make rational decisions in deciding which technology to adopt. Therefore, the adoption pattern that follows rational decision is not random. In my opinion, the mode of adoption for resource-poor farmers follows a sequential adoption pattern, where farmers first adopt only one or a few components of a package at a time and gradually build the technological package over time.

2.8. Diffusion Models

Diffusion models generally serve as a basic research tool to quantify and analyze the spread of technologies, among a population or social system, in terms of a mathematical relationship of the time that has elapsed from introduction of the innovation. It estimates the successive adjustment in the number of adopters and permits prediction of continued development of the process over time (Mahajan and Peterson, 1979). Moreover, the diffusion model facilitates a theoretical explanation of the dynamics of the diffusion process in terms of certain characteristics that influence the diffusion rate. Models used in diffusion studies include those based on logistic, Gompertz, cumulative normal and cumulative log-normal distribution functions. All of these functions give rise to the S-shaped curve discussed in Section 2.3.

The logistic distribution function is extensively used in modelling technology diffusion processes because of its simplicity and ease of interpretation. The diffusion process is viewed
as being analogous to the spread of an infectious disease (Feder and Umali, 1993; Davies, 1979). The analogy between diffusion of technology and the spread of infectious disease suggests that potential adopters acquire (i.e. adopt) new technology upon receipt of information relating to its existence. The exposure to information about a new technology is expected to occur through interaction with other adopters. There are a number of assumptions absolutely necessary to obtain logistic solutions. These include fixed rate of diffusion (or constant $\beta$), a constant and homogeneous population, and homogeneous interaction among the population so that the process become imitative. In other words, demonstration effects and learning from the experience of others are crucial in explaining diffusion using the logistic model. The epidemic diffusion model may be expressed by the following differential equation,

$$\frac{dm_t}{dt} = \beta (N-m_t) m_t / N, \quad \beta > 0$$

(2.3)

where $m_t$ denotes the number of individuals who have adopted the technology at time $t$, $N$ represents the total number of potential adopters, and $\beta$ is the coefficient reflecting the likelihood of adopting a technology. As can be seen from equation (2.3), the number of new adopters at time $t$ is the product of three variables: non-adopters, $N-m_t$, the proportion of adopters, $m_t/N$, and the parameter $\beta$ that represents the probability of adoption. The value that $\beta$ is expected to take depends on specific attributes of the technology such as profitability, compatibility, riskiness and on the degree of interaction between those who have already adopted and those who have not. However, under the epidemic model $\beta$ is fixed and the degree of interaction is assumed to be constant and the number of new adopters at any time is a function of the number that have already adopted the technology and therefore the diffusion process becomes imitative. Nevertheless, the absolute increase in the adopters at any point in time is the product of two opposing forces. As the proportion of adopters, $m_t/N$, increases, the number of potential adopters, $N-m_t$, declines. This gives rise to a bell-shaped curve when the frequency of number of adopter is plotted against time. Equation (2.3) has the
following solution:

\[ m_t = N(1 + \exp(-\alpha - \beta t))^{-1} \]  \hspace{1cm} (2.4)

where \( \alpha \) is the constant of integration which positions the curve on the time scale. Equation (2.4) represents the cumulative density function of the logistic frequency distribution (Stoneman, 1980). The logistic diffusion curve is symmetric around the inflection point and a maximum diffusion rate occurs when 50% of the population has adopted the technology (Thirtle and Ruttan, 1987). The rate of diffusion accelerates until it attains its maximum value at the inflection point; thereafter, it increases at a deceasing rate until it approaches the upper ceiling asymptotically. Many empirical studies have applied linear regression analysis by log transforming equation (2.4).

\[ \log(m_t / N-m_t) = \alpha + \beta t \]  \hspace{1cm} (2.5)

The widely cited study by Griliches (1957) employed a logistic function as a tool for investigating diffusion of hybrid maize in US. Griliches used the logistic function to condense a large data set for each state to three parameters: the intercept, \( \alpha \), diffusion rate, \( \beta \), and the adoption ceiling. The parameter of the logistic curve, \( \beta \), was then used as the dependent variable in a linear regression model. He reported that the logistic curve fitted the data well. Mansfield (1961) also investigated inter-firm diffusion of twelve innovations in industry by employing a logistic model in which diffusion was treated as a function of the proportion of firms adopting the innovation and a number of firm-related characteristics. The logistic model fitted the data well and he concluded from the results that temporal diffusion follows a logistic function.

Some of the assumptions on which the logistic model is built, were questioned by Davies (1979), Doessel and Strong (1991), Knudson (1991), Gore and Lavaraj (1987) and others. Davies applied a log normal distribution function to estimate the effect of farm size in a heterogeneous population. The other three studies attempted to improve the relevance of
logistic function by relaxing some of its stringent assumptions. For instance, Doessel and
Strong (1991) relaxed the assumption of fixed population and incorporated population
variability (unknown population) in investigating the diffusion of a new pharmaceutical drug.
In their model they assume that $a$, and $b$ are not affected by the size of population. Doessel
and Strong argue that the modified logistic model produces valid estimates if the members of
any size of population have the same behavioural characteristics. In a study of semi-dwarf
wheat varieties in the US, Knudson (1991) relaxed the assumption of fixed adoption ceilings
of the logistic model, and allowed for the possibility of disadoption and changes in
complementary technology. She then applied the modified logistic model to data on semi-dwarf
wheat varieties. The result from this study showed that the modified logistic model fitted the
data better than the standard logistic model based on the assumption of constant ceilings.
Another study by Gore and Lavaraj (1987) relaxed the assumption of a homogeneous
population. They estimated the standard and modified logistic models for a spatially separated
population to describe diffusion of crossbred goats in villages (within a town and a village
outside of town) in Pune, West India. They found that diffusion within a town follows the
logistic model, while diffusion in a village outside town was a function of information received
from adopters within the village and the town. The modified logistic model resulted in a
marginal improvement over the standard logistic model.

Questions also arise concerning the symmetric nature of the logistic curve as such
symmetry does not always fit observed data and alternative non-symmetric diffusion models
have been developed to fill this gap. These include the Gompertz, the log-normal, and the
flexible logistic\(^1\) (FLOG) model. The cumulative log-normal can reproduce a family of S-
shaped curves since its inflection point is flexible (Thirtle and Ruttan, 1987). The Gompertz

\(^1\) The flexible logistic (FLOG) model was developed by Bewley and Fiebig (1988). Its
point of inflection and degree of symmetry are determined by the observed data instead
of being imposed by the choice of functional forms.
model generates an asymmetric S-shaped curve with an inflection point occurring approximately when 37% the population adopt the technology.

The theory of imitation on which the standard logistic model is based has been questioned in many diffusion studies. In the standard logistic model it is assumed that information is obtained through a social interaction within a homogeneous population. The information obtained through social interaction is said to come from internal sources of information and adoption is thought to be influenced by the number of adopters in the social system. However, adopters are not only influenced by the number of adopters in the social system; they are also influenced by external information (i.e. information emanating from outside the group of potential adopters) sources such as extension agents and mass media. Although some diffusion situations do correspond approximately to the assumptions of either the internal influence or the external influence models, the great majority do not (Freeman, 1988). To allow for such effects, models that account for influences from internal and external sources of information have been developed. Such models classify the population into two categories, namely, innovators and imitators. It is assumed that the innovators adopt the new technology independently of others in the social system (Feder and Umali, 1993). Their adoption decision is influenced by external information sources such as extension agents, technology suppliers, mass media and other agents of change. The adoption decision of imitators, however, is dependent on the number of adopters in the social system. Rogers (1983) noted that adoption of agricultural technologies is influenced by internal and external information sources. The role that agricultural extension services and input suppliers play represents the external information sources while interaction between farmers represents internal information sources.

The diffusion model that disaggregates adopters into innovators and imitators starts with an intuitive function that relates adoption rate to the potential number of adopters at time
t. Hence, the number of new adopters at any time \( t \) is directly proportional to the potential adopters available at that time. In other words, as the total number of adopters, \( m_t \), approaches its ceiling, \( N \), the number of new adopters decreases proportionally. This may be described as follows:

\[
\frac{dm_t}{dt} = n_t = \beta_1 (N - m_t) \quad t = 1, \ldots, n. \tag{2.6}
\]

where \( n_t \) is the number of new adopters at year \( t \), \( \beta_1 \) is a constant relating the number of new adopters and potential adopters. The value of \( \beta_1 \) depends on the specific technology, the social system, the channel and change agents used to diffuse it and on economic factors (Akinola, 1986; Mahajan and Peterson, 1979). The constant \( \beta_1 \) can be expressed as a function of previous adopters \( (m_t) \). If higher order terms are dropped \( \beta_1 \) may be expressed as,

\[
\beta_1 = \alpha + bm_t \tag{2.7}
\]

where \( \alpha \) and \( b \) are constant. Substituting equation (2.7) into (2.6) and rearranging gives,

\[
\frac{dm_t}{dt} = n_t = \alpha (N - m_t) + bm_t (N - m_t) \tag{2.8}
\]

(\text{innovators}) \quad (\text{imitators})

where \( \alpha \) is the "coefficient of innovation," or the rate of adoption of the proportion of the population whose adoption decision is influenced by exogenous information, and \( b \) is the "the coefficient of imitation," or the rate of adoption of the population whose adoption is based on internal interaction (Mahajan and Peterson, 1979). The coefficient of imitation, \( b \), takes into account the interaction between adopters \( m_t \) and non-adopters \( (N - m_t) \). This model is identical to Bass's (1969)\(^2\) new-product growth model and has been developed further by Mahajan and Peterson (1979). When \( \alpha = 0 \), the Bass model reduces to a logistic model.

Akinola (1986a) applied Bass's innovator-imitator model in his study of diffusion of spraying chemicals among Nigerian cocoa farmers. Theoretically, the model he employed is

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\(^2\) The Bass model assumes that the adoption coefficients for imitators, \( b \) and innovators, \( \alpha \) are constant. This assumption is unreasonable as a general rule, since socio-economic, institutional and supply conditions relating to the innovation influence these variables.
appealing. The model incorporates the external and internal information sources which are prevalent in the agricultural technology diffusion process. However, the result he reported shows that the Bass model is only slightly better than the standard logistic model. In another study, Akinola (1986b) relaxed the assumption of a constant adoption coefficient of innovators, $\alpha$, and the coefficient of imitators, $b$. He also relaxed the assumption that equilibrium in the number of potential adopters ($N$) remains constant with time and tested diffusion patterns of cocoa spraying chemicals in Nigeria. His result from this study suggests that the data on the diffusion of cocoa spraying chemicals among Nigerian Cocoa farmers fitted the model fairly well (Akinola, 1986b). Krashenas and Stoneman (1990) also questioned the a priori assumption of the standard logistic and Bass type models which claim endogenous factors play a dominant role in the learning process throughout the diffusion process. They allow $\alpha$ and $b$ to vary over time and respecified the standard epidemic model by disaggregating the innovators into two groups: those who continue to be instrumental in the learning process and those who no longer contribute to the learning process. They further incorporated economic factors (disposable income, the price of a product and credit conditions) as determinants of the speed of diffusion. The model was applied to the diffusion of colour television in the United Kingdom and performed better than other types of epidemic models (including the logistic and Bass models). The influence of the endogenous learning process on colour television ownership was weak compared with the prior assumption of other models (Krashenas and Stoneman, 1990).

2.9. Conclusions

In this chapter, the basic concepts of adoption and diffusion, and models which describe these processes have been reviewed. Adoption and diffusion are two related concepts, where adoption refers to the decision to adopt or not, and diffusion refers to the spread of a
technology among members of a social system. Adoption is a mental process that involves stages such as awareness, interest, evaluation and trial or adoption. Farmers take account of economic and social factors in adopting technologies. In this study, utility maximization is assumed to drive the adoption decisions of farmers. Concerning modes of adoption, two approaches are found in agricultural technology adoption literature. The first approach emphasises the adoption of the whole package and the second one stresses the sequential or step-wise adoption of components of a package. In this study we adopted the step-wise adoption of components of a package in modelling adoption decisions of farmers at a point in time and over time.

The theoretical and empirical literature shows that the diffusion patterns of most technologies can be described by an S-shaped curve. The S-shape diffusion path is determined by the spread of information and economic characteristics (riskiness, profitability, divisibility, cost etc.) of the new technology. These factors speed up or retard the rates at which technologies are diffused. Models that are used to analyze diffusion of technology include the logistic, Gompertz, cumulative log-normal etc. These models are based on a different set of assumptions concerning the nature of the process giving rise to the observed patterns of diffusion. Compared with the other models the logistic distribution function has been extensively used because of its simplicity and ease of interpretation. However, as noted by Davies (1979), some of the assumptions - constant rate of acceptance, homogeneous population and homogeneous interaction among members of the population, on which this model is based, are unrealistic. In general the fit of the models varies from one case to another. While a particular model fits the data for certain new technologies adequately, it performs poorly with respect to others. Models with different properties may fit a particular set of data equally well. Therefore, as emphasized by Sahal (1981), it is hardly possible to discriminate among alternative models on empirical results.
CHAPTER 3

REVIEW OF EMPIRICAL ADOPTION STUDIES OF AGRICULTURAL TECHNOLOGIES IN DEVELOPING COUNTRIES

3.1. Introduction

Technology adoption is a matter of concern in all sectors of the economy because of its importance in increasing productivity and efficiency. In different sectors, numerous factors affect technology adoption decisions: among others, the structure of the industry, market structure and concentration, natural, social, institutional and cultural factors shape technology adoption decisions. Sectors differ from each other in their modes of production, the services they provide, their size, objectives, and in their limitations. The agricultural sector has its own peculiar characteristics, such as seasonality of production and heavy dependence of production on natural phenomena. Because of these peculiar characteristics we can not draw implications for agricultural technology-adoption based on studies for other sectors of the economy so we review the literature dealing with agricultural technology adoption and we do not review empirical adoption studies of other sectors.

There is also a great difference between the agricultural sectors of developing and developed countries. Agriculture in developing countries is heavily dependent on natural phenomena, while the effects of natural factors are, to some extent, mitigated by the application of modern technology and improved weather forecasting systems in developed countries. Moreover, farmers in developing and developed countries do not face the same types of constraints and opportunities. Therefore, conclusions concerning technology adoption can not be drawn for agriculture in developing countries based on experience of the agriculture in developed countries.
Adoption studies in developing countries started two to three decades ago following the Green Revolution in Asian countries. Since then, several studies have been undertaken to assess the rate, intensity and determinants of adoption. Most of these studies focused on the Asian countries where the Green Revolution took place and was successful. In Africa, new agricultural technologies have only been introduced recently. The success story registered in Asia was not duplicated in African countries except for hybrid maize in Kenya (Roy, 1990) and Zimbabwe (Rukuni, 1994) so the literature on technology adoption for Africa is relatively sparse.

The organization of this chapter is as follows: the next section reviews the empirical studies conducted in developing countries. As noted above, many factors influence technology adoptions. Here, selected factors thought to affect adoption and frequently examined in adoption studies are reviewed. The factors are grouped into household head characteristics, farm characteristics, institutional and agro-climatic factors and technology characteristics. The third section surveys literature on technology-adoption in Ethiopia. There is less literature on technology adoption in Ethiopia and the approach followed in this section is different from the section preceding it. Here main findings are summarized for each study. The final section draws conclusions from the review.

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1 This statement does not emphasise isolated use of technologies in export-oriented, commercial plantations. On such farms new technologies were widely used. However, because of colonial policies, and the unrealistic industrialization policies adopted by some developing countries' governments, much emphasis was placed on cash crop cultivation (for export) and the food crops were neglected (Roy, 1990).
3.2. Adoption Studies in Developing countries

Ruttan (1977) reviewed several empirical studies on the adoption of Green Revolution technologies. He made the following generalizations:

1. The new High Yielding Varieties (HYV) of wheat and rice were adopted at a rapid rate in those areas where they were technically and economically superior to local varieties.

2. Neither farm size nor farm tenure has been a serious constraint on the adoption of new high yielding varieties.

3. Neither farm size nor farm tenure has been an important source of differential growth in productivity. This is to say that the productivity of high yielding varieties were approximately the same on small and large farmers' fields.

4. The introduction of the new high yielding wheat and rice technology has resulted in an increase in demand for labour.

5. Land owners have gained relatively to tenants and labourers from the adoption of high yielding varieties of wheat and rice.

Ruttan (1977) accepts that there are many exceptions to the generalizations he put forward. These exceptions arise mainly from the fact that the technologies have been introduced in environments with different economic, social, political, agro-climatic, and institutional settings. Perrin and Winkelman (1976) also summarized adoption studies done by Centro International de Mejoramiento de Maíz Y Trigo (CIMMYT) on wheat and maize in six countries, namely Kenya, Colombia, El-Salvador, Mexico, Tunisia, and Turkey; they concluded that the differences in adoption rates among these countries are explained by differences in information, agro-climatic and physical environments, availability of input, differences in market opportunities for the crops, and differences in farm size and farmers' risk.
aversion characteristics. Feder et al. (1985) and Feder and Umali (1993) also made a comprehensive survey of agricultural technology-adoption studies done in developing countries. In the studies they reviewed, they found that farm size, risk, human capital, labour availability, access to credit and land tenure systems are the most important factors in influencing farmers' technology adoption decision.

The comprehensive reviews made by Feder et al. (1985), Perrin and Winkelman (1976) and Feder and Umali (1993) suggest that there are many variables that affect the adoption behaviour of farmers. Their conclusions are more or less consistent with each other. They agree that many factors affect adoption and the factors that affect adoption vary over time and from area to area. Their effect also varies over time and from area to area. In this section, selected explanatory factors thought to affect adoption decisions of farmers are reviewed. For ease of summarization the variables are grouped into sub-sections: household head characteristics, farm characteristics, institutional agro-climatic factors and attributes related to technology. The economic variables are discussed under different sub-sections.

3.2.1. Household Head Characteristics

*Age:* Age is one of the farmers' characteristics often studied in empirical adoption studies. The direction of impact of this variable can not be predetermined but many empirical studies have revealed a negative relationship between technology adoption and the age of the decision maker. A study by Jha et al. (1990) indicates that the age of a household head is negatively related with the adoption of improved varieties, cultivation method and fertilizer use in the Eastern Province of Zambia. Their result implies that younger farmers are more likely to adopt and to put more land under the new technology. Akinola (1987) also found evidence of a negative relationship between the age of household head and the decision to hire tractor
services. Additional evidence of such findings was reported by Akinola and Young (1985) in their study of cocoa spraying chemicals in Nigeria.

Contrary to these findings, Zegeye (1989) and Mahabub (1988) found evidence of positive associations between age of household head and intensity of fertilizer adoption. Zegeye argued that older farmers have more experience and hence better knowledge of the use of fertilizer than younger farmers. There are studies (Polson and Spancer, 1991; Voh, 1982; Adesina and Zinnah, 1993; Mann, 1989) that report non-significant relationships between the age of household head and the adoption of improved varieties.

It has to be noted that the effect of age may depend on experience and education levels. Older farmers may have experience and resources 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.

Education: A number of empirical adoption studies have examined the relationships between adoption of new agricultural technology and education. For example, Gerhart (1975) in Kenya, Jha et al. (1990) in Zambia, Rosenzweig (1982) in India, Asaduzzaman (1979) in Bangladesh, Strauss et al. (1991) in Brazil and Lin (1991b) in China assessed the role education plays in a farm household's decision whether to adopt and the intensity of adoption of improved varieties. They found that the household head's level of education has positive and statistically significant effects on the probability and intensity of adoption of improved varieties. Studies by Akinola and Young (1985), Igodan (1988) and Voh (1982) in Nigeria provide additional evidence for the existence of a positive association between education and the adoption of new technology. Jha et al. (1990) also investigated the effect of education on the choice of cultivation method (animal traction) in the Eastern Province of Zambia. Their study
showed that the educational level of the household head had an influence on the choice of cultivation method. In a study focused on evaluating the adoption of a tractor hiring service scheme, (Akinola 1987) revealed that farmers' ability to read and write has a positive impact on farmers' decision to hire tractor services. These studies argue that better educated farmers are more likely to adopt new technology than farm household heads with fewer years of schooling.

However, some empirical studies do not support the positive relationship between education and the technology adoption behaviour of farmers. Such studies suggest that education has no effect on the adoption of new agricultural technologies. For instance, in a study by Shakya and Flinn (1987), the education of the household head is not a significant determinant of improved varieties or fertilizer adoption. Schooling is not statistically significant in explaining HYV adoption in the study by Pitt and Sumodiningrat (1991) and similar results were observed by Green and Ng'ong'ola (1993). It might be argued that, in the presence of effective extension services, education might not be an important factor for simple technology such as improved varieties and fertilizer. Adoption of this technology does not depend on the education of farmers but the education of a household can be an important factor for adoption of complex technologies.

3.2.2. Farm Characteristics

*Farm size:* Farm size is one of the key explanatory factors investigated by several empirical adoption studies. Farm size can have positive, negative or neutral effects on the adoption decisions of farmers depending on the type and characteristics of new technology and the institutional settings in which the new technology is introduced. The theoretical literature suggests that large fixed costs reduce the tendency to adopt or slow down the rate of adoption
by smallholder farmers. This theoretical conclusion is supported by Akinola's (1987) and David and Otsuka's (1990) empirical work showing the positive effect of farm size on farmers' decisions to hire services from tractor hiring units. Jha et al. (1990) also revealed a positive and very significant linkage between farm size and adoption of animal traction. Their findings imply that larger farmers are much more likely to use ox-drawn cultivation technology.

In a study of wheat varietal change, Heisey et al. (1993) examined the effect of farm size on adoption of improved wheat varieties in three zones of Pakistan. They found that in two of the three zones, farm size significantly influenced the adoption of new varieties positively. In Nigeria, Polson and Spancer (1991) examined the relationship between explanatory variables, including farm size, and farmers adoption of new cassava varieties. They modeled the effect of large farm size through a dummy variable which was unity if the farm size was greater than the mean farm size, and zero otherwise. They showed that households with farm size above the mean household farm size are significantly different from those households with less than the mean holding. Thus, it is more likely that farmers with a farm size above the mean farm size would adopt the new cassava varieties. It has to be noted that farm size was not significant when they introduced it as a continuous variable. Perrin and Winkelman (1976) also reported significant effects of farm size on rate of adoption in three of the six studies they reviewed.

In a study made by Shields et al. (1993) in Swaziland and Yohannes et al. (1990) in Ethiopia, the impact of farm size on adoption of basal application and topdressing of fertilizer was positive. The positive relationship between large farm size and adoption of basal and topdress fertilizer support the theoretical hypothesis that larger farmers are more likely to increase their use of technology as a result of lower average fixed costs. Although fertilizer is divisible and scale neutral, associated learning and training costs may discourage its adoption on smallholders' farms. The result displayed by Shields et al. (1993) is not in agreement with
previous findings by Low (1982), who reported negative association. Low (1982) argues that application rate of fertilizer increases as farm size decreases. There are also other studies including Mann (1989) in Pakistan, Asaduzzaman (1979), Alauddin and Tisdell (1988), both in Bangladesh, which have found evidence of negative links between improved varieties adoption and farm size. These findings suggest that small farmers devote a higher percentage of their land to improved wheat varieties.

As pointed out by Feder et al. (1985) farm size is a surrogate for a large number of potentially important factors such as capacity to bear risk, access to scarce inputs, wealth etc. Since the influence of these factors is not the same in different areas or at different times, the relationship between farm size and adoption behaviour of farmers would not be expected to follow the same path over space and time. Thus, the effects of these factors may explain the observed relationship between farm size and the adoption behaviour of farmers.

Some recently conducted studies indicate neutral association between farm size and adoption of new technologies, mainly HYV and fertilizer. For instance, studies by Ramasamy et al. (1992), David and Otsuka (1990), Otsuka et al. (1994), Upadhyaya et al. (1992) and Adesina and Zinnah (1993) showed that farm size is not a significant determinant of HYV adoption.

The non-significant effect of farm size on the adoption of HYV may be explained by its scale neutrality (divisibility). Adoption of HYV does not involve high fixed costs so small farmers can adopt it as large farmers do. However, Feder and O'mara (1981) do not support this proposition. They acknowledge that divisible technologies are neutral to scale but argue that the record of adoption and diffusion experiences in a substantial number of regions throughout the world show that adoption rates and the time patterns of adoption are related to farm size. The reasons adoption of divisible technology differs between farm size groups, they argue, may be explained by differences in information acquisition (learning and training)
costs. Information acquisition costs are higher for small farmers than large farmers and this may discourage them from adopting divisible technology. Another possible explanation for the non-significant effect of farm size is that the technology diffusion process has reached its final stage and the technology has been adopted by large and small farmers. As pointed out by Ruttan (1977), farm size plays a significant role at an early stage in the adoption process. Large farmers adopt technology early because of the relative advantage they have. As adoption progresses, the relative advantage for adoption diminishes and smaller farms catch up. Thus, farm size ceases to be significant factor in adoption of divisible technology at a later stage of adoption process. Thus, as the diffusion process progresses, a number of factors underlying the relationship between farm size and adoption behaviour of farmers may have been removed.

**Labour Availability:** Availability of labour is another factor that has been examined in a number of adoption studies. The direction of the impact of labour on adoption decisions depends on the characteristics of the technology and its labour requirements. Some new agricultural technologies are labour saving, while others may demand more labour as compared to the old technology. For example, the application of fertilizer and some soil conservation practices (terracing, tie-ridge, band construction etc.) require additional labour. Labour shortages may hinder the adoption of such types of technology. On the other hand, technologies such as herbicide, tractors, harvesters and oxen drawn implements are labour saving. The adoption of these is more likely to take place faster under conditions where family labour supply is limited, hired labour is scarce and wages for labour are high.

Shields et al. (1993) examined the effect of family labour on the adoption of basal, topdress fertilizers and tractor cultivation practice in Swaziland. They have found a positive impact of increased labour availability on the adoption of basal and topdress fertilizers. In view of peak season labour shortages and the additional labour requirement of the two technologies, these findings appear to be realistic. A study by Akinola and Young (1985), in Nigeria,
revealed a positive association between unpaid regular family labour and adoption of cocoa spraying chemicals. The practice of cocoa spraying increases the demand for labour at labour peak period. As they have shown in their study, the adoption of cocoa spraying chemicals is more attractive to those families who can absorb the additional labour required for spraying activities. Green and Ng'ong'ola (1993) also found similar results for fertilizer adoption on maize in Malawi.

In an adoption study of tractor ploughing (hiring), Shields et al. (1993) found evidence of a positive association between labour availability and adoption of tractor ploughing practice. This finding contradicts the hypothesis that farmers are less likely to adopt labour saving technology as labour availability increases. They suggested two possible explanations for this divergence from the hypothesis. First tractor ploughing may be used as part of a package of technologies, serving to complement more labour-intensive technologies. Second, farmers who experience labour shortages during the peak labour seasons may be less inclined to use any output increasing technology. For instance, a farmer who is unable to mobilize sufficient labour to adequately weed his fields has no reason to spend resources on tractor ploughing because the benefits made possible by the improved land preparation will not be realized (Shields et al., 1993). On the other hand, Akinola (1987) found evidence of a negative relationship between the amount of family labour on the farm and the decision to hire tractor services.

Igodan (1988) examined factors associated with the adoption of recommended farm practices (fertilizer, improved varieties, seed dressing and planting time) in Nigeria. He found evidence of negative relationships between household size and the adoption of recommended practice. In rural areas, subsistence pressure is more on large households as compared to small households. This pressure has a negative implication for the adoption of technologies as large households tend not to take risks associated with new technology.
Ndiaye and Sofranko (1988) examined the availability of labour at the peak period of planting and weeding in Zambia. They found that there was an acute labour shortage during planting and weeding, especially for maize because of its labour-intensive recommended planting and weeding practices. The adoption of new hybrid maize imposes an additional labour burden on the farm household beyond what can be mobilized within the household, as Ndiaye and Sofranko pointed out, and some farmers leave hybrid maize unweeded or weed it late after considerable damage has been caused. They argue that labour shortages keep farmers from adopting labour-intensive innovations such as hybrid maize and fertilizer application. On the other hand, in studies done by Shakya and Flinn (1985), Mahabub (1988), Ramasamy et al. (1992), and Adesina and Zinnah (1993) the availability of family labour has no significant effect on the adoption of high yielding rice varieties and intensity of adoption of fertilizer.

3.2.3. Institutional and Agro-climatic Factors

*Extension*: The impact of agricultural extension on the adoption of technology has also been the subject of a number of empirical adoption studies. A study by Igodan (1988) presents evidence illustrating the positive impact of extension on adoption. He reported a significant and positive correlation between the source of agricultural information and extension contact, on the one hand, and the adoption rate of recommended technology, on the other. These findings imply that farmers who are more exposed to formal extension information have a higher propensity towards adoption than those who have less exposure to formal extension information. In Gerhart's (1975) study, extension visits, attendance at farmers' training centre courses and attendance at demonstrations were found to be positively and significantly related to adoption of hybrid maize. Studies by Shakya and Flinn (1987), Feder and Slade (1984) and Bisrat (1980) also revealed positive associations between frequency of extension contact and
adoption of HYV and intensity of use of fertilizer.

 Strauss et al. (1991), who studied the role extension plays in the adoption of technology, stress that farmers who have access to high quality extension services (they measured quality in terms of level of education attained by farmers and experience of extension practitioners) tend to adopt soil fertility management practices and use HYV of rice and soybean. Birkhaeuser et al. (1991) made a comprehensive review of the impact of agricultural extension on technology adoption and productivity. In six of the ten studies they reviewed, the impact of agricultural extension is positive with varied statistical significance. In four of the ten cases they considered, the relation between extension and adoption was neutral i.e. statistically not significant. The studies cited above showed the importance of extension in technology adoption process. However, there are studies (Adesina and Zinnah, 1993; Green and Ng'ong'o, 1993 and Kimuyu et al., 1991) that report non significant impact of extension on adoption. It should be noted that extension is an important factor in transfer of technologies to farmers. However, its impact could be compromised by ineffectiveness and inefficiency of institutions that provide extension services.

Credit. Most theoretical studies argue that the need to undertake fixed investment and increased working capital may prevent small farms from adopting indivisible and divisible technologies rapidly (Feder et al., 1985). The fixed investment and working capital must be financed through own savings or access to financial markets. Small farmers do not have capacity to finance from own savings as their savings are limited. They usually depend on financial markets and the availability of the financial market determines the adoption of new technologies by small farmers. Thus, where credit is not available, they may not be able to adopt new technologies at the same rate as large farmers do. Thus, as pointed out by Feder and O'mara (1981), the credit constraint is one of the main reasons for differential adoption rates in many regions.
In a study of Indian agriculture, Bhalla (1979) reported that small and large farmers differed in the reasons offered for not using fertilizer. Lack of credit was a major constraint for 48% of small farmers while this is emphasized by only 6% of large farmers. Bhalla (1979) suggests that access to credit may be responsible for the differences in area put under HYV and in income gain from the HYV by small and large farmers. He showed that gains in income and area under HYV were more for large farmers. In studies of HYV and intensity of use of fertilizer by Nepal, Indonesian and Malawian farmers, Shakya and Flinn (1985), Pitt and Sumodiningrat (1991) and Green and Ng'ong'ola (1993) found positive and significant links between access to credit and adoption of HYV and intensity of use of fertilizer. Akinola (1987) also reported evidence of positive links between credit and adoption of tractor hiring services.

Off-farm job opportunities may generate additional income and offset the cash shortage problem that small farmers usually face to adopt new technology. Under such conditions the effect of credit may not be important. Some studies have therefore investigated the relationship between off-farm income and technology adoption. For example, Low (1986) and Parton (1993) found evidence of positive links between off-farm income and the adoption of new technologies.

**Input and output prices:** Theoretical studies suggest that input and output prices have great impact on technology adoption decisions. It is assumed that lower input prices and higher output prices encourage farmers to increase production. Many empirical studies of individual adoption behaviour do not consider the effects of input and output prices on technology adoption, because input and output prices for individuals from the same locality are constant and lack of variability constrains the use of these variables in a study of individual adoption behaviour. However, those studies that have examined the effect of output and input prices on technology adoption support the theoretical hypothesis. For instance, Shields et al. (1993), who analysed the effect of maize price on adoption of basal fertilizer, showed that farmers...
facing low output prices have little incentive to produce a marketable surplus. They argue that low output prices serve as a disincentive and diminish the likelihood of adopting a new technology. A study aimed at identifying determinants of fertilizer adoption on smallholder farms in Kenya by Kimuyu et al. (1991) found evidence of a direct relationship between the prices of coffee and maize and the intensity of application of fertilizer. He also found a negative association between fertilizer price and intensity of fertilizer application. However, in David and Otsuka’s (1990) study, the input and output price ratio was not a significant determinant of HYV adoption. Since the influences of input and output prices on adoption are in opposite directions the effect of one price may cancel out the effect of the other. However, this depends on the magnitudes of the effects of the two prices.

Agro-climatic and infrastructural factors: Adoption patterns of agricultural technologies are not only determined by social and economic factors but are also influenced by a variety of infrastructural, physical and agro-climatic factors. A number of studies (for example, Gerhart (1975) for Western Kenya, Jansen et al. (1990) and Ramasamy et al. (1992) for India, David and Otsuka (1990) for Philippines Alauddin and Tisdell (1988) for Bangladesh and Upadhyaya et al. (1993) for Nepal) have found evidence suggesting that the environmental factors are an important influence on technology adoption. Such environmental factors include infrastructural factors (roads, seed warehouses, irrigation structure etc.) and agro-climatic factors (particularly rainfall) and edaphic factors (soil fertility, salinity, drainage etc). Pitt and Sumodiningrat (1991) also present empirical evidence on the effects of infrastructural and agro-climatic factors on the adoption of HYV of rice in Indonesia. They show that availability of irrigation and the likelihood of flooding have a significantly positive effect on HYV, while drought is negatively associated with adoption of HYV of rice; the availability of irrigation ameliorates the negative effect of environmental risk associated with drought and encourages adoption of HYV of rice.
Risk and Uncertainty. As pointed out by Feder (1980), Feder et al. (1985), Anand (1990) and Ellis (1993) risk and uncertainty are of central importance to the decision making processes in agricultural production. There are two general approaches to the analysis of risk. The first approach is to treat risk as the probability of events occurring which result in incomes above or below the average expected income in a succession of crop seasons. The second approach is to treat risk as the probability that income will take on a value below some critical minimum or disaster level (Roumasset, 1977; Young, 1979; Ellis, 1993).

Farmers, particularly subsistence farmers in the tropics, are prone to risk because of weather and imperfect markets. A bad year or two may force them to sell their land or leave them without sufficient food supply for their families (Lipton, 1968). Because of this, subsistence farmers are considered to be more risk averse than farmers in industrialized countries. A number of empirical studies have been conducted to examine farmers' attitude towards risks, and have generally confirmed that most subsistence farmers in developing countries are risk averse (Wolgin, 1975; Moscardi and de Janvry, 1977; Dillon and Scandizzo, 1978; Walker, 1981).

Small farmers have limited assets and limited access to credit and information. They often have no means of overcoming the consequences of adverse events so they are more vulnerable to risky conditions. Their vulnerability to risk may influence their attitude towards risk. Studies by Moscardi and de Janvry (1977), Dillon and Scandizzo (1978) and Grisley and Kellog (1987) found evidence of a negative association between wealth (as proxied by income and farm size) and farmers' risk preferences. Thus, with a rise in income, the degree of risk aversion exhibited by decision makers declines.

Small farmers may be willing to forgo some income in order to avoid risk. If the yield from a new agricultural technology is uncertain, or the product price is uncertain, and farmers are risk averse, it can be shown that a lower level of output will be produced than under
perfect certainty (Ellis, 1993). In general, the distribution of output and expected profit among firms will vary with the degree of risk aversion (Sandmo, 1971).

The impact of risk on the optimal level of fertilizer use is illustrated in Figure 3.1. The type of risk analysed here is one of uncertainty about the weather in which two possible outcomes - 'good' weather or 'bad' weather can occur. If 'good' weather occurs the best crop yield will be obtained and if 'bad' weather occurs crop yield will be poor. The alternative total value product (TVP) responses to increasing the level of fertilizer for the 'good' and 'bad' events and for the farmer's expected TVP (based on the subjective probability of the weather) are represented by TVP1, TVP2 and E(TVP) respectively. A total factor cost (TFC) line shows total production cost associated with an increase in fertilizer use.

Figure 3.1. Production decisions under risk.

Source: Ellis, 1993.
There are three alternative fertilizer application levels, F2, FE and F1, which are allocatively rational depending on the farmer's risk preferences. A risk averse farmer is assumed to operate on TVP2, while a risk preferring farmer operates on TVP1 and a risk neutral farmer operates on E(TVP). An application rate of F1 is allocatively efficient on TVP1, and provides the largest profit, AB. On the other hand, if F1 is chosen and TVP2 occurs, a farmers incurs a loss, BJ. Application of F2 level of fertilizer is efficient if 'bad' weather occurs (the outcome is TVP2). At this level of application if it turns out to be 'good' weather a profit, CE, is obtained but if it turns out to be 'bad' weather the farmer still makes a profit, though it will be small (DE). A fertilizer application rate of FE represents the optimal level associated with a balanced assessment of the average outcome of 'good' and 'bad' seasons. Given this level of fertilizer application, if it turns out to be a 'good' year, a profit, FH, is obtained but this is not the largest profit possible on TVP1. On the other hand, if 'bad' weather occurs the loss will be HI but this is not the largest possible loss on TVP2. The empirical results of adoption studies dealing with the impact of risk are noted below.

Gerhart (1975) used the presence of a drought resistant crop mix as a proxy variable for risk perception and found evidence of a strong negative relationship between risk and the adoption of hybrid maize in Kenya. However, Feder et al. (1985) questioned the relevance of using a drought resistant crop as an explanatory variable arguing that the decision to plant drought resistant crops is endogenous and, therefore, should not be taken as an explanatory variable.

More recently, Shields et al. (1993) considered the effects of risk and uncertainty on the adoption of topdress fertilizer and tractor ploughing. They used the standard deviation of rainfall as a proxy variable for objective risk and hypothesized that increased deviation in rainfall would reduce the probability of adoption of topdress fertilizer and tractor ploughing. Their findings indicate the existence of a negative association between deviation in rainfall and
adoption of both technologies. This implies that farmers facing uncertainty in expected rainfall may be less likely to adopt the technologies.

Yohannes et al. (1990) also examined the effect of risk aversion on adoption of fertilizer, pesticides and single ox technologies. They argue that the degree of risk aversion exerts a negative influence on the adoption of these production technologies. Their results suggest that the more risk averse a farmer is, the less willing he is to adopt new technologies.

A study of household goals and technology adoption of smallholders by Parton (1993), in eastern Kenya, also revealed similar results. In his study, Parton categorized the technologies he studied into three categories: 1) non-cash using (early land preparation, dry planting, terracing and farmyard manure), 2) low-risk cash using (fodder, crop storage chemicals and ox plough), and 3) high-risk cash using (fertilizer, improved variety, and field pesticides). He found farmers' behaviour to be risk averse. He reported that farmers pursuing a survival goal have not adopted cash using technologies that involve risk. Specifically, the degree of risk aversion constrained the adoption of high-risk cash using technologies (Parton, 1993).

As noted by Feder et al. (1985), farmers' technology choices are based on their subjective probability and this further depends on their exposure to information concerning new technology. As Gafsi and Roe (1979) show for Tunisia, the adoption of a new variety of bread wheat is more sensitive to risk than the domestically developed new durum wheat varieties. The preference for durum varieties arose from lack of, or limited exposure to, information regarding the introduced new varieties. The information does not serve as a barrier for new durum wheat as these varieties are developed from the local materials and farmers know about the characteristics of durum wheat. Jansen (1992), who investigated interregional variations in the speed of adoption of modern cereal cultivars (rice, wheat, sorghum, pearl millet and maize) shows that the adoption speed of HYV of rice and wheat are constrained by the degree of risk factors associated with different regions. However, for sorghum, pearl millet and
maize, production risk fails to explain variation in adoption speed across regions (Jansen, 1992). This is possibly because these crops are relatively drought tolerant and yield uncertainty is lower under moisture stress conditions compared to rice and wheat.

It has to be noted that risk is closely associated with the agro-climatic conditions in which the technology is introduced. Thus, the probable risk situation differs across regions due to variations in agro-climatic factors and the availability of market and extension information. In contrast to the previously cited empirical investigations, Antle and Crissman (1990) reported positive association between risk and nitrogen fertilizer adoption. They argue that nitrogen fertilizer is not risk increasing, rather it is risk reducing when used with modern varieties under favourable conditions. However, many studies indicated that fertilizer is one of the risk increasing technologies. In my view, Antle and Crisman's findings are location specific and do not represent the reactions of most small farmers in adoption of risky technologies.

3.2.4. Characteristics of Technology

Many empirical adoption studies start with the premise that the technology is appropriate. Byerlee and Polanco (1986) stressed that adoption studies have a "pro-innovation" bias and such studies concentrate on characteristics that are not related to attributes of technology. Even those studies that considered characteristics of technology place more weight on profitability and yield. They neglect other technology related characteristics such as compatibility, and its attributes in meeting farmers preferences. Few studies emphasize the impact of technology characteristics in investigating farmers adoption decisions.

In Malawi Smale et al. (1995) conducted a study of improved maize varieties, giving emphasis to the impact of characteristics inherent to the varieties. They found slow adoption rates for those varieties that have attributes that are not preferred by farmers. In Malawi, where
the study was undertaken, farmers prefer white flint grain texture of maize because of its
storability and superior processing quality. The flint maize can be stored longer because of its
tip cover and harder grains which resist attack by weevils. As noted by Smale et al. (1995) and
Smale (1995), until recently, dent maize varieties have been promoted due to the belief that
dent maize varieties have higher yield potentials than flint maize. However, the rate of adoption
of dent maize was slow (Smale, 1995; Smale et al., 1995). They argue that the classical
economic variables such as prices and income are less likely to be significant factors in the
hybrid dent maize adoption decision in Malawi; instead, the superior processing and storage
characteristics of the flint maize play an important role in hybrid maize adoption.

Smale (1995) also presented evidence of the impact of supply side constraints on
adoption rates. She argues that maize research and the seed production and distribution system
did not provide a high-yielding maize type with a grain texture suitable for smallholders who
consume some of their maize and for whom storability and processing quality is therefore
important. Smale emphasizes that if maize is stored for consumption, the yield advantages of
dent hybrids are significantly eroded by processing and storage losses. Heisey et al. (1993) also
found evidence of a strong and positive relationship between farmers' evaluation of varietal
characteristics and their adoption in Pakistan. Grain yield as evaluated by farmers is the most
important factor affecting profitability of improved wheat varieties adoption. Shattering
resistance of new wheat varieties is also another characteristic which they found important in
determining adoption decision of farmers. Gafsi and Roe's (1979) study of high-yielding
varieties of durum and bread wheat varieties showed that the rate of adoption of the high-
yielding bread wheat varieties is slow as compared to the rate of adoption of high-yielding
durum wheat varieties because of consumer taste preferences. Farmers prefer high-yielding
durum wheat varieties derived from domestic genetic materials to high-yielding bread wheat
varieties derived from exotic genetic material. Adesina and Zinnah (1993) also examined
farmers' perceptions of specific traits of the modern rice varieties, such as taste, yield, cooking quality, tillering capacity and threshability. They found that all of the varietal specific traits, except taste, were highly significant in explaining adoption and intensity of use of the modern rice varieties. Their results demonstrate that technology specific characteristics are important factors in conditioning the adoption behaviour of farmers.

Of the technology specific characteristics, profitability has been widely investigated in theoretical as well as empirical works. Lin (1991a) examined adoption of F₁ hybrid rice in China. He found that under the collective system of farming, profitability was not the driving force for adoption of hybrid rice. Instead adoption under the collective system of farming is explained by political pressure on collective farm leaders to implement planned targets (Lin 1991a). However, with institutional change from the collective system to a household responsibility system farmers responded to profitability in adoption of F₁ hybrid rice. This implies that under the household responsibility system profitability is the major factor in explaining the difference in the adoption rate across regions and over time. In India, Jansen (1992) investigated factors that influence interregional variation in the speed of modern cereal cultivars. He showed that interregional variations in adoption speed of modern rice and wheat varieties are partly explained by profitability. A study conducted by Pitt and Sumodiningrat (1991) also showed positive association between higher profitability of HYV and a higher probability of its adoption. Tables 3.1 and 3.2 present summary of selected studies conducted in developing countries.
Table 3.1. Summary of some adoption studies conducted in Africa.

<table>
<thead>
<tr>
<th>Author and year</th>
<th>Model Used</th>
<th>Farm size</th>
<th>Labour</th>
<th>Distance to market</th>
<th>Credit</th>
<th>Education</th>
<th>Agro-climatic and infrastructure</th>
<th>Extension</th>
<th>Age</th>
<th>Income</th>
<th>Risk</th>
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<tbody>
<tr>
<td><strong>Variety</strong></td>
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<tr>
<td>Adesina and Zinnah 1993</td>
<td>Tobit</td>
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<td>NS</td>
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<tr>
<td>Polson and Spencer 1991</td>
<td>Probit</td>
<td>NS</td>
<td>NS</td>
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<td>+*</td>
<td>NS</td>
<td>+*</td>
<td>NS</td>
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<tr>
<td>Jha et al. 1990</td>
<td>Probit</td>
<td>+*</td>
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<td>+*</td>
<td>NS</td>
<td>+*</td>
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<td>NS</td>
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<tr>
<td>Zegeye 1989</td>
<td>Probit</td>
<td>-</td>
<td>NS</td>
<td>+*</td>
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<td>NS</td>
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<tr>
<td>Gerhart 1975</td>
<td>Probit</td>
<td>NS</td>
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<td>+*</td>
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<tr>
<td>Smale et al. 1995</td>
<td>Tobit</td>
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<tr>
<td>Gafsi and Roe 1979</td>
<td>OLS</td>
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<td>NS</td>
<td>NS</td>
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<td>NS</td>
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<td><strong>Fertilizer</strong></td>
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<tr>
<td>Shields et al. 1993</td>
<td>Logit</td>
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<tr>
<td>Green &amp; Ng'ong'o 1993</td>
<td>Logit</td>
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<td>+*</td>
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<td>+*</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
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<td>NS</td>
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<tr>
<td>Akinola and Young 1985</td>
<td>Probit</td>
<td>-</td>
<td>+*</td>
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<td>+*</td>
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<tr>
<td>Jha et al. 1990</td>
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<tr>
<td>Kimuyu et al. 1991</td>
<td>OLS</td>
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<td><strong>Tractor/oxen-traction</strong></td>
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<tr>
<td>Shields et al. 1993</td>
<td>Logit</td>
<td>+*</td>
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<tr>
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<td>Probit</td>
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<tr>
<td>Jha et al. 1990</td>
<td>Probit</td>
<td>+*</td>
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<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>+*</td>
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<tr>
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<td>Probit</td>
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<td>+*</td>
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<td>NS</td>
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<td><strong>Two or more technologies</strong></td>
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<td>Voh</td>
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<td>+*</td>
<td>NS</td>
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<tr>
<td>Rauniyar &amp; Goore 1996</td>
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<td>+*</td>
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<td>NS</td>
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<td>+*</td>
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</tr>
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Note: +* and -* indicate positive and negative impact respectively. NS indicates non-significance. - denotes the variable is not included in the study.
Table 3.2. Summary of some adoption studies conducted in Asia.

<table>
<thead>
<tr>
<th>Asia</th>
<th>Variety</th>
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<th>Labour</th>
<th>Distance to market</th>
<th>Credit</th>
<th>Education</th>
<th>Agro-climatic and infrastructure</th>
<th>Extension</th>
<th>Age</th>
<th>Income</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Author and year</td>
<td>Shakya and Flinn 1985</td>
<td>Probit</td>
<td>NS</td>
<td>NS</td>
<td>-</td>
<td>+*</td>
<td>NS</td>
<td>+*</td>
<td>+*</td>
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<tr>
<td></td>
<td>Mahabub 1988</td>
<td>Probit</td>
<td>NS</td>
<td>NS</td>
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<td>NS</td>
<td>NS</td>
<td>+*</td>
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<td></td>
<td></td>
<td>Tobit</td>
<td>NS</td>
<td>NS</td>
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<td>NS</td>
<td>+*</td>
<td>+*</td>
<td>+*</td>
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<tr>
<td></td>
<td>Alauddin &amp; Tisdell 1988</td>
<td>Logit</td>
<td>+*</td>
<td>+*</td>
<td>-</td>
<td>-</td>
<td>NS</td>
<td>+*</td>
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<td></td>
<td></td>
<td>OLS</td>
<td>+*</td>
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<td></td>
<td>David and Otsuka 1990</td>
<td>Probit</td>
<td>NS</td>
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<td>+*</td>
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<td></td>
<td></td>
<td>Probit</td>
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<td>Probit</td>
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<tr>
<td></td>
<td>Strauss et al. 1991</td>
<td>Probit</td>
<td>NS</td>
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<td>NS</td>
<td>+*</td>
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<td></td>
<td>Upadhyaya et al. 1993</td>
<td>Tobit</td>
<td>NS</td>
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<td></td>
<td>Heisey et al. 1993</td>
<td>M. Logit</td>
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<td>NS</td>
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<tr>
<td></td>
<td>Lin 1991b</td>
<td>Probit</td>
<td>+*</td>
<td>NS</td>
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<td>+*</td>
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<td></td>
<td></td>
<td>Tobit</td>
<td>NS</td>
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<td>NS</td>
<td>+*</td>
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<tr>
<td></td>
<td>Jansen et al. 1990</td>
<td>Logistic</td>
<td>-</td>
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<td>+*</td>
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<tr>
<td></td>
<td>Jansen 1992</td>
<td>Logistic</td>
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<td>+*</td>
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</tbody>
</table>

Note: +* and -* indicate positive and negative impact respectively. NS indicates non-significance. - denotes the variable is not included in the study.

3.3. Adoption Studies in Ethiopia
The preceding sections showed that a wide range of economic, social, agro-climatic and attributes of technology influence the adoption of new agricultural technologies. This section briefly reviews the results of adoption studies done in Ethiopia. The next sub-section briefly shows a historical perspective of adoption studies in Ethiopia. Sub-section 3.3.2 presents major findings of the adoption studies done in Ethiopia. Since only few studies were conducted the structure adopted in the previous section is not used here. In this sub-section each study is summarised in chronological order. This method allows us to see the important variables identified by the study and its limitations, if any.

3.3.1. Historical Perspective

In Ethiopia relatively few adoption studies have been conducted. Most of these studies were carried out in areas where integrated rural development projects had been undertaken. Some of the studies were conducted in mid and late 1970s (Tesfai, 1975; Cohen, 1975; Bisrat 1980; Aragay, 1980) following the introduction of an integrated rural development pilot project and minimum package programme in some parts of the country. These studies focused on evaluating the performance of the pilot projects and on examining the rate of adoption of technologies promoted by the projects. Cohen's (1975) study went beyond determining the rate of adoption and assessed the economic and social impact of new technologies in the CADU area.

In the 1980s, research conducted by economists in rural areas of Ethiopia concentrated on understanding the farming systems and generation of economically, socially and technically compatible agricultural technologies. During this period a number of diagnostic surveys with a farming system perspective were carried out in different parts of the country. These surveys
assessed the status of agricultural technology adoption and found that the rate of adoption of improved varieties, fertilizer, herbicide, and other agronomic practices were low (Aleligne, 1988; Tilahun and Teshome, 1987; Legesse et al., 1987; Raya, 1988; Kassahun et al., 1992). Research conducted during this period also focused on the impact of centrally planned economic policies (state farm formation, collectivization, resettlement, villagization, price control and inter regional trade regulation) on peasant farmers and to some extent on the effects of these policies on the technology adoption process. In the 1990's further adoption studies were carried out by Yohannes et al. (1990), Mulugetta (1996), Getachew et al. (1995) and Chilot et al. (1996).

3.3.2. Main Findings of Adoption Studies

Tesfai (1975), conducted an adoption study in the Arsi zone (CADU area). He showed that the probability of adoption of improved varieties and fertilizer increases with farm size. The availability of cash for down payments, membership in local associations and literacy also increased the likelihood of adoption. However, he suggested that the influence of literacy and participation in local associations on the rate of adoption was not as strong as the influence of farm size and extension services. Tenurial arrangements and extension contact (represented by distance from the extension centre) were negatively related to adoption; in particular tenants were found to be less likely to adopt improved varieties and fertilizer as compared to owner cultivators.

Cohen (1975) examined the rates of adoption and the impact of land tenure on adoption of improved varieties and fertilizer. He reported that 25% of the target population in CADU area had taken up the technology over the three year period, 1968-1970 and found that tenure arrangements were the major bottleneck for technology adoption and the overall
development of the country (see Chapter 4). Cohen also found that mass eviction of tenants was one of the main negative social consequences of the introduction of new technologies in the project area.

Another study by Aragay (1980) investigated the adoption of improved varieties, fertilizer and the mouldboard plough in the CADU area using multiple regression and correlation analysis. He reported that traditionalism and debt avoidance tendencies were significantly and negatively correlated with the adoption of fertilizer. This means that traditionalism and higher farmer adherence to debt avoidance strategy can undermine the adoption decisions of farmers. His study showed that most of the farmers adopted improved wheat varieties and fertilizer. However, they rejected the mouldboard plough and certified seeds on rational economic and technical grounds since the certified seeds were expensive, while the mouldboard plough was found to be technically inappropriate (too heavy to be drawn by small-statured local oxen). The degree of contact farmers had with sources of useful agricultural information was also found to be a key factor influencing the adoption behaviour of farmers. This study has two methodological limitations. First, the study had used a linear regression model to analyze the adoption behaviour of farmers. Application of this model does not allow for inclusion of non-adopters in the analysis and therefore creates sample selection bias. Second, the study drew on correlation analysis to identify factors affecting adoption. Since correlation analysis can not estimate the combined effect and the effect of a variable in the presence of other variables, we are not sure whether the same results can be obtained if an appropriate model is used.

2 In the CADU project area about 150,000 ha was under crop cultivation. Seeing the advantages of fertilizer, improved variety and all round subsidies (low interest rate credit, exemption tractors and machinery from import duties, tax exemption for fuel, land use and income tax relief etc.) land owners and contract farmers engaged in mechanized farming by evicting tenants who had no legal protection. In 1974 about 32,000 ha was under mechanized farming. This accounted for 1/5 of the area covered by the project. About 10,000 tenants were evicted (Cohen, 1975).
Yohannes et al. (1990) investigated the effects of economic, social and physical factors on the adoption of three technologies, namely fertilizer, insecticide and use of single-ox for traction in two districts of northern Shewa zone. They found that farm and off-farm income has a positive effect on the adoption of the production technologies. Farm size had a positive effect on the adoption of the two divisible technologies (fertilizer and pesticides) and a negative effect on the single-ox traction. Their result is in agreement with that of Aragay's (1980) findings. This study also indicated that family size, education, exposure to outside information and experience, as represented by age, have a positive effect on the probability of adoption of fertilizer and pesticide. On the other hand, the degree of risk aversion exerts a negative influence on the adoption of production technologies.

It should be noted that most empirical adoption studies actually examine the relationship between observed explanatory variables and actual decision made by individual decision makers in acceptance of a technology; however, Yohannes et al. used intended (planned) adoption for some of his sample farmers as dependent variable, i.e. they considered as adopters those farmers who expressed their intention to adopt the technology in the following years as adopters. Although it is often valuable to obtain farmer's opinions about the feasibility of using a technology and identifying what its merits and drawbacks might be, this information cannot be used to assess adoption. Statements about what a farmer would like to do, is interested in, or hopes to do, are not substitutes for data on actual technology adoption (CIMMYT, 1993). Those farmers who have a plan to adopt a technology may or may not adopt it. If this is the case, the relationship reported by Yohannes et al. (1990) based on planned adoption decision, may or may not represent the actual decision making process.

A study conducted by Legesse (1992) in Arsi Negele area showed that 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
improved varieties and intensity of use of fertilizer and herbicide. In this study farm size was not found to be an important factor in affecting adoption of improved varieties or intensity of fertilizer use.

A study by Beyene et al. (1991) examined the level of adoption of a recommended maize package comprising improved variety, fertilizer and method of planting in the Bako area using descriptive statistics. They reported that about 42% of farmers adopted the recommended package. They reported that unavailability of seed and lack of extension advice are important factors in affecting the adoption of an improved maize variety. Cash shortages, manuring maize fields, and status of soil fertility were also important in affecting the adoption of fertilizer. Beyene et al. reported that many farmers (65%) adopted the row planting practice. They argue that the suitability of row planting for ox-cultivation (shilshalo) is the main reason for the high acceptance of the row planting practice.

Asmerom and Abler (1994) investigated production technologies in Ethiopian agriculture, with the objective of assessing the characteristics of the technologies and choices among production technologies. They found that farmers with more resources (in terms of livestock and farm size) do enjoy advantages in gaining access to fertilizer. Thus, an increase in farm size increases the probability of use of fertilizer.

In coffee producing areas of Western Welega, Gimbi, Getachew et al. (1995) examined the adoption rate of recommended coffee production technologies. The technologies they considered include land preparation practice (spacing and pit excavation), new Coffee Berry Disease (CBD) resistant varieties, spraying chemicals against CBD, herbicide, fertilizer, pruning and stumping. Of these recommended technologies, only two technologies, CBD resistant varieties (59%) and old coffee stumping (62%) have had reasonably widespread adoption. The remaining technologies have not been adopted or have been adopted by less than 10% of the sampled farmers. The reasons Getachew et al. gave for rejection of these
technologies include financial constraints, lack of awareness of the technologies (especially in the case of herbicide and pruning) and lack of spraying tools and chemicals. They further tested the effect of farmer and farm household characteristics, social environment, and institutional factors using discriminant analysis. They found that labour availability, household asset position, leadership in local associations, the timely availability of the technology, the number of livestock owned, coffee area, and the knowledge and skill\(^3\) of the household head are positively related to adoption of CBD resistant varieties and old coffee stumping techniques. However, age, experience, extension and farmers' perception of farm gate coffee price have no significant influence on adoption.

A recent study by Mulugetta (1996) examined the determinants of adoption and intensity of use of fertilizer on wheat in Arsi zone. He found that access to credit and timely availability of fertilizer positively and significantly influence adoption of fertilizer, while the age of the household head is negatively related to adoption of fertilizer. In the case of herbicide adoption, he showed that the variables measuring access to credit, education, number of oxen owned, and extension contact have positive and significant effect on the rate of adoption. Contrary to expectations, farm size was found to have a negative and significant effect on adoption of herbicide. Mulugetta (1996) also studied the intensity of use of fertilizer on wheat. He found evidence of a positive association between intensity of use of fertilizer and family size, number of oxen owned, extension contact and timely availability of fertilizer. These results suggest that resource endowment plays a critical role in the intensity of adoption.

Another recent study by Chilot et al. (1996) investigated factors influencing adoption of wheat technologies in Welmera and Addis Alem weredas (districts). The findings of this

\(^3\) The variable knowledge and skill of the household head is created by combining variable
study suggest that perceived profitability of the new wheat technologies and timely availability of fertilizer and herbicide (as complementary input for improved variety adoption) have significant effects on farmers' adoption decisions. They also found that the distance of respondents from extension centres negatively influenced the probability of improved variety adoption, as well as intensity of fertilizer and herbicide use. It is important to note that farm size and experience of farmers were not found to have a significant effect on the adoption of improved wheat varieties and intensity of use of fertilizer and herbicide. Thus, Chilot et al. argue that characteristics of the household and household heads had little influence on the adoption decisions of farmers. They suggest that improved production packages have been extensively diffused so that farmers might have full information about the benefits of the new technologies.

3.4. Conclusions

From the above review, it could be inferred that agricultural technology adoption and diffusion patterns are often different from area to area. The differences in adoption patterns were attributed to variations in agro-climatic, information, infrastructural, institutional and social environment factors between areas. Moreover, adoption rates were noted to vary between different groups of farmers due to differences in access to resources (land, labour and capital), credit, and information and differences in farmers' perceptions of risks and profits associated with new technology. The direction and degree of impact of adoption determinants are not uniform; the impact varies depending on type of technology and the conditions of areas where the technology is to be introduced. Thus, extensive diffusion of technology over large areas can not be easily duplicated with the same rate and scale as it was once believed by many agricultural scientists.
Many studies reviewed here assume that the technologies are appropriate to the conditions where they are introduced and they concentrated on investigating the rate and patterns of adoption and the factors that determine the rate and patterns of adoption. A few adoption studies gave emphasis to characteristics of introduced technologies and found farmers' preferences and the technical suitability, profitability and riskiness of the new technology to be important factors in explaining adoption.

Regarding adoption studies conducted in Ethiopia two points are worth mentioning. First, the studies done by Yohannes et al. (1990) and Aragay (1980) have methodological limitations, while Bisrat's (1980) study has a data limitation. Moreover, some of the studies (Cohen, 1975; Tesfai, 1975; Bisrat, 1980; Aragay, 1980) were conducted two decades ago. Since then, a number of changes have taken place in the rural economic structure of the country. For example, the landlord-tenant relationship was abolished and extension strategy and policies related to rural development, rural organizational structure etc. have been changed. This being so, the results of these studies may not reflect factors currently underlying adoption patterns.

Second, prices of input and output are assumed to be the key factors in technology adoption decisions but no study has examined the impact of these variables on adoption decisions in Ethiopia. Moreover, no study has systematically investigated the dynamic aspect (i.e. duration of adoption) of the adoption process. As in the case of other developing countries, time varying variables were not examined in any of the adoption studies conducted in Ethiopia. In view of these limitations and changes, new studies employing more recent data and methodology are warranted. This study attempt to fill these gaps.
ETHIOPIA'S ECONOMY AND AGRICULTURE

4.1. Introduction

The objectives of this chapter are to describe agricultural production systems and government policies that have implications for agricultural technology adoption. Smallholding farmers are the most important in terms of area cultivated and production and are typical of our study area. Therefore, the chapter focuses on describing their production system and policies particularly important to them.

4.2. The Macro Settings

According to the 1994 census, Ethiopia has a population of 53 million and is estimated to be growing at 3% per annum. About 47% of its population is economically active (15-64 years of age). Ethiopia's economy depends on agriculture, the role the manufacturing industry, mining, energy and other sectors play being minimal. The industrial sector, in particular, is small in size and coverage contributing, on average, only about 16% of Gross Domestic product (GDP). Agro-based industries constitute around 70% of large and medium-scale industries (Sisay, 1994). Heavy industries are few, and some of the manufacturing industries are import-dependent for raw materials (Berhanu, 1994) and therefore, exposed to external shocks. The economy suffers from a poorly developed infrastructure, the country having one of the lowest road densities in Africa (World Bank, 1992).
Although productivity in agriculture is low, the economy is heavily dependent on the export of agricultural commodities for foreign currency earnings. The two main export commodities of the country are coffee and skins and hides. These commodities have been the dominant export of the country since the 1950s and sufficient effort has not been made to diversify exports. The economy is poorly integrated and characterized by limited and service-oriented investment. Thus the service sector has been expanding while the productive sectors are stagnant, indicating that there are problems in the economic structure of the country. The contributions of the agriculture, service and manufacturing sectors to GDP since 1970s are shown in Table 4.1.

Table 4.1. Contribution of agricultural, other commodity and service sector to GDP 1974-1993.

<table>
<thead>
<tr>
<th>Year</th>
<th>Percentage contribution by sector</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Agriculture</td>
</tr>
<tr>
<td>1974/75</td>
<td>53</td>
</tr>
<tr>
<td>1979/80</td>
<td>51</td>
</tr>
<tr>
<td>1984/85</td>
<td>41</td>
</tr>
<tr>
<td>1989/90</td>
<td>43</td>
</tr>
<tr>
<td>1993/94</td>
<td>45</td>
</tr>
</tbody>
</table>

Source: Calculated from World Bank (1990); Hansson (1994)

\(^a\) Mining, manufacturing, handicrafts and small-scale industry, building and construction, electricity and water.

Macro-economic figures also exhibit either stagnation or very slow growth in the economic performance of the country over the last two decades. For example, between 1973/74 and 1990/91, GDP grew by an average of less than 2% a year while population rose on average between 2.6% and 3% a year (Mekonin, 1994). This mismatch in the two growth rates shows that the average standard of living of the people of Ethiopia deteriorated over the years. The poor economic performance resulted from a combination of factors including
misguided economic policies, severe fluctuations in weather conditions, little application of modern technologies and the prolonged civil war. The poor performance of the economy is more pronounced in the dominant sector of the economy, agriculture. Agriculture grew at an annual average rate of 0.6% over the period 1973 to 1980 but collapsed by 3.6% over the period 1980 to 1985 (Table 4.2).

Ethiopian economic structures have been subject to repeated and profound changes during the past two decades. The 1974 revolution ended an era of monarchy and feudalism and replaced market mechanisms with a centrally planned economy. Large industries, rural and urban land changed from private, community and church ownership to public ownership. In 1991, the new government adopted a new economic policy which signalled a move away from centralized planning towards a market-oriented system in which private ownership will dominate most sectors. Since then an adjustment and privatization programme has been underway. Agricultural Development-Led Industrialization (ADLI) strategy which aimed at enhancing food self-sufficiency, increasing foreign exchange earnings and supplying raw materials to industry was adopted. The focus of ADLI is on accelerating growth through increased use of new technologies, particularly fertilizer and improved seeds.

Table 4.2. Average annual growth rates of the agriculture, industry and service sectors.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>2.1</td>
<td>0.6</td>
<td>-3.6</td>
<td>3.4</td>
<td>-4.0</td>
<td>5.0</td>
<td>-6.5</td>
</tr>
<tr>
<td>Industry</td>
<td>6.4</td>
<td>1.4</td>
<td>3.8</td>
<td>-2.1</td>
<td>-4.1</td>
<td>11.6</td>
<td>1.7</td>
</tr>
<tr>
<td>Manuf.</td>
<td>8.8</td>
<td>2.6</td>
<td>3.9</td>
<td>-2.2</td>
<td>-10.0</td>
<td>21.9</td>
<td>7.1</td>
</tr>
<tr>
<td>Service</td>
<td>6.5</td>
<td>3.1</td>
<td>3.3</td>
<td>0.4</td>
<td>-12.8</td>
<td>8.8</td>
<td>13.4</td>
</tr>
<tr>
<td>GDP</td>
<td>4.1</td>
<td>2.2</td>
<td>0.5</td>
<td>1.3</td>
<td>-7.7</td>
<td>7.7</td>
<td>2.3</td>
</tr>
</tbody>
</table>

4.3. Role of Agriculture in the Economy

In Ethiopia, agriculture is the mainstay of the economy. The latest figures suggest that agriculture contributes 45% of GDP (Table 4.1) and generates employment for over 85% of the population. If we see this contribution by agricultural sub-sector, crop production accounts for about 65% of Agricultural Gross Domestic Product (AGDP), which is equivalent to nearly 30% of total GDP (Ann., 1995). The livestock sub-sector contributes 30% of AGDP (which is equivalent to 13% of GDP), while forestry, fishery and other sub-sectors of agriculture together contribute 5% of AGDP. Agriculture is the principal source of the country's export commodities and contributes about 90% of the export earnings of the country. Out of the export earnings generated by agriculture, coffee accounts for 62% followed by skins and hides which account for 20%. Pulses, oil crops, live animals and horticultural crops jointly account for the remaining share. Industry contributes only 10% to export earnings. Agro-industrial products such as sugar, molasses, processed meat, oil-cake and beeswax take the largest share of the 10% earned by non-agricultural products.

Agriculture is also an important source of raw materials for the textile, food processing and beverage industries. Apart from providing raw materials, agriculture indirectly generates employment in the industrial and service sectors, as well. In the case of the service sector, for example, transport and trade depend on agriculture as these services primarily deal with agricultural commodities. A further indication of the contribution agriculture makes is that it feeds a population of nearly 53 million and more than 90% of food supply in Ethiopia is derived from domestic production of crop and livestock.
4.4. The Natural Resource Base

Ethiopia has an area of 1.115 million square kilometres and is the ninth largest country in Africa. Oil reserves, natural gas and different types of minerals are thought to exist in Ethiopia. Of these, gold, potash and copper are currently exploited to a limited extent. Hence, the country's principal natural resource is its vast arable land, of which only 15% is cultivated at present (Figure 4.1). About 66% of the land is considered potentially suitable for agricultural production (Teketel, 1996). There is a large labour force and generally adequate rainfall in the highlands and in the humid lowlands, but it has to be noted that rainfall is not adequate in semi-arid and arid parts of the country.

Although Ethiopia lies within the tropic, the country enjoys tropical, sub-tropical, and temperate environments because of the altitudinal variations. Traditionally, three broad agro-climatic zones are known in Ethiopia: *kola*, representing warm climate (less than 1500 meters above sea level (masl)), *weinedeg*, representing moderate climate (1500 to 2500 masl), and *dega*, which represent a cool climate (greater than 2500 masl).

Crops and livestock production are concentrated between 1500 and 3500 masl where the temperature ranges from moderate to cool (*weinedega* and *dega*). The country is endowed with enormous water resources. The water potential of the country comprises 10 big rivers and their tributaries, and 11 lakes with sizes ranging from 20 km² to 3600 km². The irrigation potential of the country is over 3.5 million ha (Teketel, 1996; FAO, 1986). However, there are barriers, at least in the short run, to exploiting this potential. In particular, potentially irrigable lands are located in sparsely populated lowland areas where infrastructure is poorly developed and environmental risks to health are very high, mainly due to mosquitoes.

Ethiopia has a variable rainfall occurring in two seasons. The main rainfall occurs in the months of June to September, while lesser amounts of rain fall from February to mid-May.
Crop production is mainly carried out during the main rainfall season. The major crop production areas receive on average 800 to 1200 mm of rainfall in normal years and produce 95% of crop production (FAO, 1986). In some parts of the highlands, shortages and uneven distribution of rainfall occur approximately once in 3 to 5 years when the amount of rainfall received may fall below 400 mm and be unevenly distributed. In general the reliability of rainfall decreases from South to North and from West to East. The arid and semi-arid part of the country suffers from shortages and from the erratic nature of rainfall. Our study-area falls in the moderate climate area (1500-2500 masl) and receives adequate rainfall in normal years.

Figure 4.1. Land use pattern in Ethiopia - 1995.

![Land use pattern in Ethiopia - 1995](image)

Source: MOA (personal communication).

With regard to its livestock population, Ethiopia stands first in Africa and tenth in the world (Pickett, 1991). According to MOA, Livestock and Fishery Resource Development Department, there are about 28 million cattle, 24 million sheep, 18 million goats, 7 million equine (horses, donkeys and mules), 1 million camels and 52 million poultry (personal communication). This great potential is not well exploited.
4.5. Agricultural Production Systems in Ethiopia

There are three main production systems in Ethiopia: the pastoral-nomadic system, the smallholder mixed farming system, and the modern mechanized system. The pastoral livestock production system dominates the semi arid and arid lowlands, usually below 1500 masl. It covers a vast area of land with a small livestock population. Since this production system has no relevance to our study, its characteristics will not be further discussed. On the basis of their organizational structure, size, and ownership of farms, the agricultural production systems can also be classified into smallholders mixed farming, cooperative farms, state farms, and private commercial farms. Data is not available for the latter production system and its characteristics will not be discussed. The smallholder mixed production system is the single most important system in terms of area, production, and size of population involved. It is also typical of the study area and therefore, our discussion focuses on this system.

4.5.1. Smallholders' Mixed Farming System

Table 4.3 presents the status of the three production systems. As shown in the table, the smallholder's production system accounted for 93% and 98% of cultivated area and production before and after the economic reform of 1990, respectively. The increment in area and production was mainly due to the shift from collective farming to private smallholder farming.

The smallholder production system is characterized by small land holdings, the average being 1-2 ha per household. A typical farmer grows more than one crop on his plots. The types of crop grown are different from one area to the other depending on climate, soil type, and other factors. In addition to crop production smallholder farmers raise livestock on their farms.
The classes of livestock kept on the farm include cattle, sheep, goats, horses, donkeys, mules and poultry. Most of the farmers keep cattle on their farms mainly for draught power, food (milk and meat), manure, and cash income. Old and small ruminants and animal products are sold to generate cash income.

Table 4.3. Crop production in Ethiopia before and after 1990 reform: area and production by category and mode of production

<table>
<thead>
<tr>
<th>Area/category</th>
<th>Small holding</th>
<th>State farms</th>
<th>Cooperatives</th>
<th>All farms</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979/80-1989/90</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area ('000 ha)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cereals</td>
<td>4572.29</td>
<td>133.52</td>
<td>190.82</td>
<td>4896.63(84)</td>
</tr>
<tr>
<td>Pulses</td>
<td>694.09</td>
<td>4.08</td>
<td>29.93</td>
<td>728.10(12)</td>
</tr>
<tr>
<td>Oil crops</td>
<td>209.85</td>
<td>14.68</td>
<td>14.17</td>
<td>238.70(4)</td>
</tr>
<tr>
<td>Total</td>
<td>5476.23(93)</td>
<td>152.28(3)</td>
<td>234.92(4)</td>
<td>5863.43(100)</td>
</tr>
<tr>
<td>Production ('000qt)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cereals</td>
<td>49696.45</td>
<td>2517.74</td>
<td>1696.55</td>
<td>53910.74</td>
</tr>
<tr>
<td>Pulses</td>
<td>6682.37</td>
<td>19.19</td>
<td>170.45</td>
<td>6872.01</td>
</tr>
<tr>
<td>Oil crops</td>
<td>862.68</td>
<td>52.44</td>
<td>39.89</td>
<td>955.01</td>
</tr>
<tr>
<td>Total</td>
<td>57241.50(93)</td>
<td>2589.37(4)</td>
<td>1906.89(3)</td>
<td>61737.76</td>
</tr>
<tr>
<td>1989/90-1994/95</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area ('000 ha)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cereals</td>
<td>4877.55</td>
<td>64.52</td>
<td>0</td>
<td>4941.59</td>
</tr>
<tr>
<td>Pulses</td>
<td>938.83</td>
<td>2.22</td>
<td>0</td>
<td>941.05</td>
</tr>
<tr>
<td>Oil crops</td>
<td>248.96</td>
<td>2.64</td>
<td>0</td>
<td>251.60</td>
</tr>
<tr>
<td>Total</td>
<td>6065.33(99)</td>
<td>68.28(1)</td>
<td>0</td>
<td>6134.23</td>
</tr>
<tr>
<td>Production ('000qt)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cereals</td>
<td>51933.87</td>
<td>1087.46</td>
<td>0</td>
<td>53021.33</td>
</tr>
<tr>
<td>Pulses</td>
<td>6884.28</td>
<td>15.71</td>
<td>0</td>
<td>6899.99</td>
</tr>
<tr>
<td>Oil crops</td>
<td>1348.98</td>
<td>17.62</td>
<td>0</td>
<td>1366.60</td>
</tr>
<tr>
<td>Total</td>
<td>60167.13(98)</td>
<td>1120.79(2)</td>
<td>0</td>
<td>61287.92</td>
</tr>
</tbody>
</table>

Source: Estimated from CSA data, statistical bulletin for various years.

( ) Figures in parentheses are percentages.

On smallholdings, a large proportion of cultivated land is allocated to cereal production: tef, barley, maize, wheat, sorghum, finger millet and oats. The area covered by
pulses, oil crops, coffee (where conditions permit), and horticultural crops is relatively small. As shown in Table 4.3, cereals account for 84%, pulses around 12% and oil crops around 4%.

There are a variety of factors that determine crop-mix and land allocation to a crop at farm level. The major factors that influence a farmer's land allocation decision to a given crop or crops are climate, soil type and fertility status, labour availability and the priority or value farmers attach to a given crop. The crop mixes for major crops in different parts of the country are shown in Table 4.4. There are differences in land allocation for different cereals as depicted in the table. The land allocation and the consequent cropping pattern stem from values farmers attach to different crops. In the study area farmers give priority to tef in land allocation and technology adoption.

The central objectives of production of smallholder farmers are to secure a food supply for home consumption and to generate cash in order to meet needs for household expenditure, clothing, farm inputs, taxes etc. The farming systems studies made by Hailu and Chilot (1992), Legesse et al. (1992) and Tilahun et al. (1992) revealed that smallholding farmers give priority to staple food-crop production in resources allocation. It has to be noted that for smallholding farmers food crops generally serve a dual purpose: as food crop and cash crop. Some food crops are mainly grown for market; examples include tef in maize growing areas, and white tef in tef producing areas. The degree to which the subsistence objective dominates the market objective varies with location. From common knowledge and logic, we expect the market objective to play a more important role in resource allocation in areas which are closer to and have better interaction with big urban markets. The subsistence as well as the market objectives have implications for technology adoption. Subsistence pressure may discourage adoption of risky technologies.

With the exception of fertilizer, and to some extent herbicide in Shewa and Arsi zones, the use of modern agricultural technologies on smallholder production system is minimal. Improved varieties of crops and upgraded animals are used by few farmers in very limited
areas. These technologies are not available in sufficient amounts or on time. In the case of improved varieties, there is also reluctance on the farmers' side to use it. Most of the farmers feel that seeds of improved varieties are expensive, and hence hesitate to purchase the limited amount made available. Some farmers also have doubts about the colour and performance of some of the improved wheat varieties such as Bulk and Enkoy. These varieties have brown coloured grain which is not preferred by consumers for bread making.

Farmers use age-old traditional tools and implements to perform different farm activities. For example, land preparation is done by oxen-drawn plough, maresha. Planting is, in general, done by manual broadcasting even for maize in most parts of the maize growing areas. Weeding and harvesting are performed manually with or without the help of hoe or

<table>
<thead>
<tr>
<th>Area</th>
<th>Ploughing method</th>
<th>Major crops</th>
<th>Area cultivated (ha)</th>
<th>Time of Planting</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Western</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bako</td>
<td>oxen</td>
<td>maize tef <em>nong</em></td>
<td>1.60</td>
<td>April-May</td>
</tr>
<tr>
<td>Man &amp; Goma</td>
<td>oxen</td>
<td>coffee maize <em>enset</em></td>
<td>0.70</td>
<td>March-April</td>
</tr>
<tr>
<td>Asendabo</td>
<td>oxen</td>
<td>maize sorghum tef</td>
<td>2.50</td>
<td>March-July</td>
</tr>
<tr>
<td><strong>Central</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nazret (rift valley)</td>
<td>oxen</td>
<td>maize tef haricot-beans</td>
<td>2.50</td>
<td>April-July</td>
</tr>
<tr>
<td>Sendafa-Aleltu</td>
<td>oxen</td>
<td>tef wheat faba-beans</td>
<td>3.00</td>
<td>May-September</td>
</tr>
<tr>
<td>Inewari</td>
<td>oxen</td>
<td>wheat tef faba-beans</td>
<td>1.80</td>
<td>June-October</td>
</tr>
<tr>
<td>Ada</td>
<td>oxen</td>
<td>tef wheat chickpea</td>
<td>2.30</td>
<td>June-October</td>
</tr>
<tr>
<td><strong>South-Western</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kulumsa</td>
<td>oxen</td>
<td>barley wheat faba-beans</td>
<td>2.5</td>
<td>July-August</td>
</tr>
<tr>
<td>Sidama lowland</td>
<td>oxen</td>
<td>maize <em>enset</em> haricot-beans</td>
<td>1.18</td>
<td>-</td>
</tr>
<tr>
<td>Sidama highland</td>
<td>hoe</td>
<td><em>enset</em> maize coffee</td>
<td>0.78</td>
<td>-</td>
</tr>
<tr>
<td>Sinana</td>
<td>oxen</td>
<td>barley wheat</td>
<td>-</td>
<td>June-July</td>
</tr>
<tr>
<td><strong>North-Western</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adet</td>
<td>oxen</td>
<td>tef barley maize</td>
<td>1.74</td>
<td>April-September</td>
</tr>
<tr>
<td>Bahr-Dar Zuria</td>
<td>oxen</td>
<td>Finger-millet tef maize</td>
<td>3.50</td>
<td>-</td>
</tr>
</tbody>
</table>

Source: Summarized from various diagnostic survey reports, Institute of Agricultural Research.
sickle, respectively. Thus, because of little or no modern agricultural technologies, the productivity of crops and livestock on smallholder farms is low.

Agricultural production calendars and production patterns on smallholdings depend on rainfall. Land preparation for most crops commences in February-March after a shower of rainfall is received and the soil is moist. Planting times range from April to September depending on agro-ecological zone, rainfall and type of crops grown. Generally, irrigation is not practised by smallholder farmers, with only a few farmers growing horticultural crops under irrigation; thus the area under irrigated crops in any one year is no more than 2% of cropped land.

4.5.2. Producer Cooperatives (PCs)

The past socialist government viewed PCs as a means of hastening the use of modern agricultural technologies and as a means of overcoming problems associated with fragmentation of land holdings. It was with this understanding and political and ideological motivation that producer cooperatives were formed hurriedly during 1970s and 1980s. However, despite government support for PCs their progress was very slow, because PCs did not offer better services or higher income to their members. Therefore, there was resistance from smallholder farmers to join PCs. By 1989 there were only 3741 PCs with a membership of 321,324 households or 4% of all rural households (Stroud and Mulugetta, 1992). More than two-thirds of these cooperatives were not registered and had no legal status so were not eligible for institutional credit. The number of PCs dropped drastically after the 1990 economic reform. Data on currently existing PCs is not available. Our brief discussion, therefore, depends on figures recorded before most PCs were dissolved. As shown in Table 4.3 the PCs cultivated 4% of cultivated area and accounted for 3% of total production. The PCs mainly
produced for consumption and to a minor extent for market. They were producing mainly food crops such as tef, maize, wheat, barley, sorghum, pulses and oil crops. They were not specialized in production of specific commodities. As in the case of smallholder farmers, the types of crops they grew were dictated by natural factors; use of irrigation water was also minimal.

<table>
<thead>
<tr>
<th>Category</th>
<th>Private Smallholder</th>
<th>Cooperatives</th>
<th>State farms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereals</td>
<td>11.50</td>
<td>8.60</td>
<td>18.05</td>
</tr>
<tr>
<td>Pulses</td>
<td>9.10</td>
<td>5.66</td>
<td>5.76</td>
</tr>
<tr>
<td>Oil crops</td>
<td>4.84</td>
<td>2.97</td>
<td>4.54</td>
</tr>
<tr>
<td>Weighted average</td>
<td>10.89</td>
<td>7.89</td>
<td>16.54</td>
</tr>
</tbody>
</table>

Source: Estimated from CSA data, statistical bulletin for various years.

With regard to application of technologies, the PCs tended to use more modern technologies such as fertilizer, improved varieties and insecticides as compared to private smallholder farmers. Some PCs had their own tractor or had access to tractors owned by Service Cooperatives (SC). However, productivity on these farms were even worse than on smallholder farms. The average yield on PCs farm is much less than the yield obtained on smallholder farms (Table 4.5). For example, cereals yield per hectare on PC farms was less by about 25% than the yield obtained on smallholder farms.

4.5.3. State Farms

State farms were set up in 1975 to manage 70,000 hectares of nationalized commercial farms. Since then the government has expanded the size and number of state farms by clearing forest and taking farmers' grazing lands. In 1979 the government formed two ministries
namely, the Ministry of State Farm Development (MSFD) and the Ministry of Coffee and Tea Development (MCTD) to manage state-owned farms. State farms range in size from 500 ha to 15,200 ha. The total area cultivated by state farms ranged from 214,000 to 240,000 ha in 1980s. As shown in Table 4.3, state farms cultivated only 3% of total cultivated land and accounted for 4% of total production. The area cultivated and the amount of production produced by state farms dropped to 1% and 2% in 1995, respectively.

The state farms are generally specialized in production of particular cash and food crops. The main commodities produced by state farms include cotton, coffee, sugar cane, banana, fruit, vegetables, tea, wheat and maize. Some have also specialized in the production of milk, beef, eggs and poultry. Production on state farms has been for both the local market and export market. The cropping system on state farms is mono cropping and crop production on approximately 75% of farms is rainfed. The remaining state farms make use of supplementary irrigation or are totally dependent on irrigation water.

The state farms are highly mechanized. They use tractors for seed bed preparation, for planting and inter-row cultivation (where applicable). They employ tractor-mounted sprayers and aeroplanes to spray herbicides for weed control and they use combine-harvesters for harvesting. Moreover, they are high users of fertilizer, improved varieties and hybrids, herbicides, insecticides and rodenticide. Those state farms which are involved in livestock production use either cross-bred or pure exotic animal breeds. They also apply modern animal husbandry practices.

In spite of the application of these modern technologies, the productivity on state farms, as measured by yield per hectare, is not different from the other two production systems (Table 4.5). Most of the state farms run at a loss (Stroud and Mulugetta, 1992), due mainly to their highly centralized control systems, excessively large size and insufficient utilization of machinery and inputs.
4.6. Performance of Agriculture

Farmers as well as government allocate more resources to the crop production sub-sector than other sub-sectors of agriculture. Therefore, we concentrate on the crop production sub-sector to assess how the agricultural sector is performing. The data needed to analyze the performance of other sub-sectors of agriculture are not available, but we suspect that the performance of the non-crop sector of agriculture is no better than that of the crop sub-sector.

4.6.1. Production and Productivity

Table 4.6 shows the area, production and yield of cereals, pulses, and oil crops for the period 1979/80 to 1994/95. Over this period, the total area cultivated fluctuated between a maximum figure of 7.79 million ha in 1994/95 and a minimum of 4.94 million ha in 1992/93. Two factors were responsible for the variation in area cultivated. First, in the 1992/93 crop season, there was a localized drought in the Northern and Eastern part of the country. The rainfall came late and the amount received was insufficient. As a result a large area of crop land was left uncultivated. Second, the method employed to estimate area cultivated, production and yield, in 1993/94 and 1994/95, was different from the method used in the preceding years. From 1980 to 1993 the Central Statistical Authority (CSA) used a sample survey method to estimate area, production and yield. In 1993/94 and 1994/95, however, this method was not applied and CSA adopted a subjective estimation method usually used by MOA. MOA estimates area cultivated, production and yield subjectively through its extension agents stationed at extension centres. Often the data from these two sources are not consistent. Data generated by CSA seem to under-estimate the area cultivated, while data generated by MOA show higher figures.
Although the figures obtained through the two methods are different, since we are interested in trend rather than precision, it is justifiable to use them to examine the general performance of agriculture. As can be seen from Table 4.6 changes in area cultivated in normal years (from 1979/80 to 1991/92) were not very large. Therefore, changes in total production caused by changes in cultivated areas are expected to have been small. Over the period 1979/80 to 1994/95, crop production increased from 75 million to 78 million qt with an annual average growth rate of 0.3%. Total production ranged from a low of 49 million qt in 1984/85 to a high of 78 million qt in 1982/83 and 1994/95. The low production in 1984/85 was caused by the devastating drought, which claimed the lives of thousands of people. The high production years were because of good weather, a concerted effort by the public and different institutions through different support services, and a slight increase in area cultivated.

Table 4.6. Total area, production, and yield of major crops (cereals, pulses and oil crops) in Ethiopia, 1979/80-1994/95.

<table>
<thead>
<tr>
<th>Year</th>
<th>Area ('000 ha)</th>
<th>Production ('000 qt)</th>
<th>Yield (qt/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979/80</td>
<td>6056.89</td>
<td>74955.80</td>
<td>12.38</td>
</tr>
<tr>
<td>1980/81</td>
<td>5678.17</td>
<td>65605.23</td>
<td>11.55</td>
</tr>
<tr>
<td>1981/82</td>
<td>5652.56</td>
<td>62962.17</td>
<td>11.14</td>
</tr>
<tr>
<td>1982/83</td>
<td>6087.91</td>
<td>78053.70</td>
<td>12.82</td>
</tr>
<tr>
<td>1983/84</td>
<td>5733.25</td>
<td>63366.04</td>
<td>11.05</td>
</tr>
<tr>
<td>1984/85</td>
<td>5864.58</td>
<td>48553.31</td>
<td>8.28</td>
</tr>
<tr>
<td>1985/86</td>
<td>5984.87</td>
<td>54036.57</td>
<td>9.03</td>
</tr>
<tr>
<td>1986/87</td>
<td>5777.92</td>
<td>63378.91</td>
<td>10.97</td>
</tr>
<tr>
<td>1987/88</td>
<td>6005.78</td>
<td>67908.03</td>
<td>11.31</td>
</tr>
<tr>
<td>1988/89</td>
<td>5790.15</td>
<td>64098.20</td>
<td>11.07</td>
</tr>
<tr>
<td>1989/90</td>
<td>5865.57</td>
<td>69162.55</td>
<td>11.79</td>
</tr>
<tr>
<td>1990/91</td>
<td>5400.40</td>
<td>71092.23</td>
<td>13.16</td>
</tr>
<tr>
<td>1991/92</td>
<td>5295.25</td>
<td>57602.00</td>
<td>10.88</td>
</tr>
<tr>
<td>1992/93</td>
<td>4935.17</td>
<td>58399.67</td>
<td>11.83</td>
</tr>
<tr>
<td>1993/94</td>
<td>7247.39</td>
<td>58228.71</td>
<td>7.34</td>
</tr>
<tr>
<td>1994/95</td>
<td>7792.93</td>
<td>78069.25</td>
<td>9.14</td>
</tr>
</tbody>
</table>

Source: CSA
The productivity of the agricultural sector as measured by yield per ha is very low, even by African standards and productivity for the smallholder farmers who dominate agricultural production appears to have been stagnant over the years. The situation is worse when climatic conditions are unfavourable, as evidenced by 1984/85 drought and other localized droughts. The observed low productivity and stagnation can be attributed to traditional crop management practices. With the exception of fertilizer, modern agricultural technologies are not widely used.

4.6.2. Food Supply Performance

Domestic food production and supply have been consistently below food needs over the last three decades. Official government data and other data sources (FAO, UNDP and World Bank) agree in depicting a deteriorating trend in food supply and an emerging scenario of increasing food imports and aid to fill the gap.
Table 4.7. Status of domestic food production and per capita availability in Ethiopia, (Production indices, 1979-1980=100).

<table>
<thead>
<tr>
<th>Year</th>
<th>Crop production</th>
<th>Livestock product</th>
<th>Agri. Production per capita</th>
<th>Food production per capita</th>
<th>Consumption per capita (cal. per day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>106.93</td>
<td>103.00</td>
<td>102.52</td>
<td>102.52</td>
<td>1566.6</td>
</tr>
<tr>
<td>1983</td>
<td>101.20</td>
<td>104.77</td>
<td>93.55</td>
<td>95.12</td>
<td>1837.2</td>
</tr>
<tr>
<td>1984</td>
<td>91.60</td>
<td>101.10</td>
<td>83.27</td>
<td>84.27</td>
<td>1533.7</td>
</tr>
<tr>
<td>1985</td>
<td>97.02</td>
<td>105.29</td>
<td>86.07</td>
<td>87.17</td>
<td>1236.1</td>
</tr>
<tr>
<td>1986</td>
<td>112.17</td>
<td>121.43</td>
<td>96.74</td>
<td>96.16</td>
<td>1349.6</td>
</tr>
<tr>
<td>1987</td>
<td>103.47</td>
<td>104.09</td>
<td>87.41</td>
<td>88.02</td>
<td>1589.8</td>
</tr>
<tr>
<td>1988</td>
<td>106.08</td>
<td>105.97</td>
<td>86.92</td>
<td>87.59</td>
<td>1537.6</td>
</tr>
<tr>
<td>1989</td>
<td>109.14</td>
<td>111.96</td>
<td>86.75</td>
<td>87.41</td>
<td>1624.0</td>
</tr>
<tr>
<td>1990</td>
<td>112.60</td>
<td>114.0</td>
<td>86.68</td>
<td>87.46</td>
<td>-</td>
</tr>
<tr>
<td>1991</td>
<td>112.56</td>
<td>114.53</td>
<td>84.60</td>
<td>84.80</td>
<td>-</td>
</tr>
<tr>
<td>1992</td>
<td>117.12</td>
<td>115.17</td>
<td>84.57</td>
<td>85.56</td>
<td>-</td>
</tr>
</tbody>
</table>

a. World Bank, 1990 Trends in developing Economies

Table 4.7 shows trends in food production per capita over the years 1982 to 1992. Over these years, indices of total agricultural production of crops and livestock have shown an increase. However, per capita food production exhibited a declining trend, falling below the per capita food production in the base year (1979-80). The decline is caused by fast growing population (the current population growth rate is estimated to be around 3% per annum) and stagnant or very slow growth in food production and productivity.

Figure 4.2 shows food imports and aid over the period 1981 to 1990. Over this period, food imports grew an average of 12% per annum. The amount of food aid to the country fluctuated over the years with an average annual growth rate of 14% over the period 1981-1982 to 1989-1990. There is also spatial variation in the food-supply gap and per capita consumption in the country. Areas known to have rainfall shortages experience chronic food insecurity. Moreover, transitory (i.e. two to three months before harvest) food insecurity is
common in most rural areas.

Figure 4.2. Trends in food import and aid in Ethiopia, 1981-1990.

Source: Import data - FAO, 1981-1990 Trade Yearbook,
Food aid data - Tesfaye (1991), Table 13.2 column 1.

4.6.3. Export Performance

As pointed out in section 4.3, agricultural commodities account for 90% of the value of export earnings and serve as a basic source of financing for import of capital goods for the development of other sectors of the economy as well as agriculture. However, if we look at export performance the prevailing trend is not encouraging. From 1973 to 1994 the capacity of export earnings to finance imports declined (Figure 4.3). The capacity dropped from 93% in 1973 to 21% in 1992. In 1986 and 1989 export performance showed an improvement but failed to sustain this improvement in subsequent years. A number of reasons can be put forward for the poor performance of agricultural export earnings but two factors in particular, unfavourable international trade and government policies are mainly responsible. Historically,
grain was moved from surplus areas to coffee producing regions by private traders. With the adoption of a fixed-price policy and regulation of grain trade the function of private traders was curtailed. On the other hand, the Agricultural Marketing Corporation (AMC), which took responsibility for supplying food in 1976, failed to move grain from surplus areas to grain deficit regions. As a result, prices of food crops increased and coffee farmers shifted away from coffee production in favour of food grain production (Kassahun et al., 1992).

Figure 4.3. Trends in import financing capacity of export, 1973 - 1994.


Another policy-driven effect was unbalanced support for different modes of production. In Ethiopia more than 97% of coffee production is produced by smallholder farmers. In spite of this fact, government policies favoured cooperatives and state farms. Up until the mid 1980s, newly released Coffee Berry Disease (CBD) resistant varieties and other inputs were not provided to smallholder coffee producers (Kassahun et al., 1992).
With regard to unfavourable international trade, it is known that prices of primary commodities are low, as compared to prices of industrial goods. Owing to this and other factors, the capacity of export earnings to finance imports collapsed.

4.7. Policies and Their Impact on Technology Adoption

4.7.1. Imperial Period (1950 - 1973)

Development policies formulated during the imperial period neglected the agricultural sector. For instance, agriculture received only 6% of total investment during the Second Five Year Plan (Cohen and Weintraub 1975). Moreover, policies were biased toward developing commercial farms by disregarding subsistence farmers. During this period land became concentrated in the hands of the church\(^1\), royal families, landlords, governors, and powerful civil and military officials. Peasants were victims of tenure insecurity, exploitation and a corrupt administrative and unjust judicial system. Before 1975, about 50% of farmers were share tenants (Cohen, 1975). These tenants had to pay landlords, as land rent, about 50% of their total production. In addition, they had to provide free labour for the landlord or his local agent. There was no legal protection for the tenant, and they often had to bribe the landlord's agent in order to stay on the land.

It has been argued by many economists that sharecropping causes inefficient allocation of resources because the sharecropper will not apply the optimal level of variable inputs, since he will equate the full marginal cost of such inputs with his share of their marginal product, not with the total marginal product. For a review of the historical debate, see Johnson (1950),

\(^1\) The Ethiopian Orthodox church was an extensive land holder. But the size of land held by the church is not known. Cohen and Weintraub (1975) estimated that up to 20% of the country's agricultural land belonged to the church. Dessalegn (1984) estimated a figure of 10% to 12% for the period before 1975.
Griffin (1979) and Ellis (1993). It has to be noted that sharecropping is not currently a common form of land tenure in Ethiopia’s agriculture, having been abolished in 1975 by the radical land reform (see Section 4.7.2.1).

Figure 4.4 illustrates the effect of 50% sharecropping with respect to intensity of fertilizer use. The tenant maximizes at point A where his share of marginal value product (MVP) equals marginal factor cost. At this point the total MVP of fertilizer is higher than the MFC indicating that sharecropping is inefficient. One might expect a rational tenant to operate at point B where MVP = MFC (the efficient point). However at this point, the tenant’s share of MVP falls to C, which is far below the MFC. If the tenant operates at B he incurs costs in the area of ABC while the land owner’s gain is ADB. In Ethiopia, before 1975 when sharecropping was a common form of land tenure, land owners did not generally share the cost of new technologies such as fertilizer and improved seed so there was no economic incentive for tenant farmers to operate at the economically efficient point.

Figure 4.4. Effect of sharecropping on intensity of application of fertilizer.
Economic policies during this period were implemented under three five-year development plans. The First Five Year Plan (1957-1962) focused on infrastructural development (roads and communications) to lay a base for industrialization, while the Second Five Year Plan (1963-1968) gave emphasis to the development of manufacturing, power and improved infrastructure. With regard to agriculture, the First Five Year Plan aimed to accelerate agricultural development by promoting large-scale commercial farms. The Second Five Year Plan aimed at changing the predominant agricultural economy to an agro-based economy (Sisay, 1994). In particular, it emphasized diversification through commercial farming and the introduction of modern processing methods. As pointed out by Cohen and Weintraub (1975), only 1% of total investment expenditure was earmarked for the peasant sector during the Second Five Year Plan. Over the First and Second Five Year Plan period of 1957 to 1968, the country trained fewer than 120 extension workers (Robinson and Yamazaki, 1980), and these extension agents provided extension services to commercial farms only.

During the Third Five Year Plan (1968-1973), an agricultural policy aimed at improving and expanding commercial farming on the one hand and supporting agriculture on the other hand was adopted. However, policy makers still viewed large commercial farms as the key to agricultural progress. This bias had implications for technology development and its adoption on smallholder farms.

4.7.2. Period of Centrally Planned Economy (1974-1990)

As stated above, little attention was given to agriculture during the imperial period. The 1974 Ethiopian revolution was expected to bring changes in the rural economy and the lives of farmers and, following the revolution, the economy was restructured. The restructuring of the rural economy attempted by government was, in theory, expected to create a more
efficient, modern basis for agriculture and increased output. However, as will be made clear below, the restructuring process did not change the lives of subsistence farmers very much.

After the 1974 revolution, attention was given, at least on paper, to agriculture development. Government expenditure on agriculture increased compared with the previous regime and a number of policies were formulated to bring changes in the agricultural sector. However, most of these policies were ideologically and politically driven and were not able to bring the hoped for changes. Most of the policies formulated were mis-guided and distorted resource allocation. The policies which contributed toward the distortion and had adverse negative effects on agricultural development included recurrent land redistribution, cooperativization, villagization and resettlement, state farm development, price control and interregional trade regulation. Since smallholder farming is so dominant, we examine the impact of post revolution policies on smallholder farmers. It is obvious that the impact of policies on this group of farmers will be reflected in the overall agricultural performance.

4.7.2.1. Land Reform Policy

Of all the policies formulated during the post-revolution period, the 1975 land reform was the most popular and far-reaching. It abolished all previous land tenure systems, the landlord-tenant relationship and private ownership of land. The policy granted user-rights up to 10 ha of land to any individual who wanted to cultivate land (Dessalegn, 1984). This increased freedom of decision for individual farmers; particularly for tenants and farm

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2 The land tenure system during the imperial period included kinship (communal) tenures, village tenures, private tenures, church tenures, and state tenures (see Cohen and Weintraub, 1975; Dessalegn, 1984).
labourers. The land reform policy was implemented through Peasant Associations (PAs), which were responsible for the redistribution of land according to the new land reform principles.

It is not known to what extent land reform policy increased production. From the overall agricultural sector performance and food shortage crisis in Ethiopia, however, we may infer that its effect was marginal. At least three factors are responsible for the failure of land reform in increasing agricultural production. First, in a given economic setting different sectors' and sub-sectors' policies interact with each other and in Ethiopian conditions, there were many policies which operated against the interests of smallholders. Smallholder farmers, in spite of being the most important economic force in the country, were not given the incentives necessary to expand production. They received less than adequate support and some 85%, 50%, and 79% of total agricultural credit, fertilizer and improved seeds respectively was allocated directly to state farms and PCs. Such policies reduced incentives for small farmers to increase production and may have undermined the effect of land reform. Second, with increased population pressure, land redistribution created a new types of land tenure insecurity in rural areas. In areas where PCs were organized, fertile fields were given to cooperative members. This may have affected farmers interested in investing in land and in increasing use of modern technology. Third, one argument for land reform was that tenants and farmers with insufficient land showed greater interest in innovations for the purpose of improving their production but new technology was not made available in sufficient quantity at reasonable prices. A study conducted by Dessalegn (1984) indicates that the price of fertilizer increased

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3 PAs were organized on an average of 800 ha each. In addition to their responsibilities in land distribution, they served and still serve as grass root level organizations through which government involves the rural population in political, social and economic affairs. PAs greatly facilitate technology transfer and on-farm research activities.

4 Land was to be allocated according to family size for individuals living in the PAs.
considerably in the early 1980s. Thus, the increment in price and unavailability of input may have affected the productivity of land and compromised the effect of land reform.

4.7.2.2. Cooperatives and State Farm Expansion Policy

In the Ten Year Perspective Plan issued in 1984/85, the intention was to put 50% of total cultivated land under PCs by the end of the plan period (1994). However, the transformation of individual farms to PCs was much slower than envisaged in the plan. The PCs received preferential treatment in terms of access to formal credit (provided they were registered with MOA), and to modern agricultural technology. They paid 10 birr less per 100 kg of fertilizer and the amount of tax PCs members paid was also less by 10 birr per hectare as compared to taxes paid by smallholders. PCs had access to free labour as individual farmers were obliged to work on PC farms for 0-2 days per week during agricultural peak periods (personal observation and Kassahun et al., 1992). They also received preferential treatment in extension services; a Development Agent (DA) was assigned to a PC to provide extension services. Because of this support, the rate of technology adoption on PCs' farms was higher than on individual smallholdings. For example, a study made by Legesse and Asfaw (1988), in Bako area western Ethiopia, showed that all the cooperative farms used fertilizer and improved maize varieties in 1988, while during the same period only 34% and 50% of smallholder farmers adopted the improved maize variety and fertilizer respectively.

The most pressing impact of cooperativization policy was its negative effect on incentives and production conditions in the smallholder sector. As noted, individual farmers were obliged to provide free labour for PCs. Moreover, when a PC was formed in a peasant association or when the number of members in a PC increased, the members of the PC had priority in allocation of the best land as well as in access to irrigation. This implies that fertile
land was transferred from private smallholder farmers to members of PCs. The individual farmers concerned were allocated land of poor quality. Thus, 'eviction' due to formation of PCs had intensified the land insecurity problem for private smallholder farmers. This may have hampered conservation and other forms of land improvement measure.

4.7.2.3. Marketing and Price Policies

Marketing policies adopted during the post-revolution period have also had a great effect on overall agricultural development and the adoption of new technology. In 1976, the government established the Agricultural Marketing Corporation (AMC) to purchase and distribute agricultural products. Quotas for grain to be delivered to AMC were set for different administrative regions and weredas and for individual farmers. In line with this, interregional trade regulation was introduced. Prices of grains were pan territorially fixed by government and kept constant. In most surplus-producing areas the activities of licensed grain traders were totally or partially taken over by AMC. The policy allowed grain traders to participate in grain marketing as long as they sold 50% of their purchase to AMC. The traders were expected to deliver to AMC at a price margin of 15% to 20% over the prices paid to farmers. In practice, the market prices were substantially higher than the fixed prices and the 15% to 20% margin was not adequate to serve as an incentive for traders, in the light of foregone opportunities in the parallel market. Thus, many traders tended not to participate in legal (licensed and paying tax) marketing activities.

The implications of marketing and price policies for the production and income of farmers and thereby for farmers technology-adoption decisions were negative. It is assumed that an increase in the agricultural product price raises the incentive for technology adoption which, in turn, leads in higher production per unit area of land or labour. Information on the
impact of different grain prices on new technology use (adoption) is limited. Few studies have been done, but the findings from these studies converge to the same conclusion. Cohen and Isaksson (1988) argue that the marketing policy had a negative impact on smallholder farmers' production and income. Franzel et al. (1992) examined the impact of fixed AMC price and average annual market prices of output using data from on-farm fertilizer experiments. The trial results showed, on average 63% (ranging from 21% to 140%) and 72% (ranging from 0% to 172%) responses to fertilizer use on maize and wheat, respectively. At AMC fixed prices, application of fertilizer was not profitable at 82% of the trial sites (Table 4.8). This was due to the fact that the fixed AMC price was so low that the marginal value of production did not cover the marginal cost of fertilizer. At annual average market prices of maize and wheat, application of fertilizer became profitable at 78% of the sites. Franzel et al. (1992) found that the fixed low prices reduced farmers' incomes and incentives to use new technologies. A study done by the World Bank (1987) based on rough estimates of fertilizer response indicated that the benefit-cost ratio for fertilizer use, assuming AMC fixed price, was too low to provide adequate incentives for the farmer, except for maize and wheat in some areas.

Table 4.8. Impact of AMC and market prices of output on profitability of fertilizer in Ethiopia, 1984-1987.

<table>
<thead>
<tr>
<th>Crop</th>
<th>No. of trial sites</th>
<th>Sites at which fertilizer is not profitable to farmers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>At AMC fixed Price</td>
</tr>
<tr>
<td>Maize</td>
<td>35</td>
<td>34 (97%)</td>
</tr>
<tr>
<td>Wheat</td>
<td>28</td>
<td>16 (57%)</td>
</tr>
<tr>
<td>Tef</td>
<td>9</td>
<td>9 (100%)</td>
</tr>
<tr>
<td>Total</td>
<td>72</td>
<td>59 (82%)</td>
</tr>
</tbody>
</table>

Source: Adapted from Franzel et al. (1992), in Research with Farmers: Experience from Ethiopia.
In the mid 1980s, a strategy was developed to make the country self-sufficient in food production. The strategy was to concentrate resources and technology on grain-surplus-producing weredas (areas). More than 100 surplus producing weredas were selected to implement the strategy. Technologies such as fertilizer and improved varieties were made available to surplus producing weredas and extension activities were strengthened. The responses to these concerted efforts were encouraging since production and yield increased in the selected weredas. At the aggregate level, total production was also increased in the years 1986 and 1987. The marketing policy in place during that time, however, compromised the gain from these efforts. Restrictions on grain trade resulted in lower prices in surplus-producing areas as surpluses could not be moved out. It is obvious from this analysis that the policy had a negative effect on use of modern technologies in grain-surplus-producing areas of the country as the benefit from a technology declines with a decline in output price.

4.7.2.4. Villagization and Resettlement Policies

In Ethiopia, villagization and resettlement programmes were undertaken in the 1980s. The villagization and resettlement programmes moved peasants from their old settlements to new sites and regions. Between 35 and 40% of farmers were forced to move to a new village site (Hansson, 1994) by the villagization programme. The extension workers, who were responsible for transfer of technology, were assigned to implement this programme. Since the programme was undertaken without consulting farmers, an unhealthy relationship was created between farmers and technology promoters, DAs and other extension workers.

The resettlement programme moved rural people, farmers, from drought-prone areas to the Western, South-Western and Southern part of the country. In 1984-85 an estimated half a million people were resettled (Sisay, 1994). The resettlement programme was not based on
detailed studies and failed. At least four factors were responsible for the failure of the programme. First, farmers were moved and resettled against their will. Because of the forceful nature of these measures, they were not interested in the resettlement scheme. Second, the implementation of the programme involved many resettlers and high costs, and the government failed to provide adequate support. Third, the government had the intention of developing the resettlers farms into PCs farms, but the resettlers had no interest in collective farming. Fourth, resettlers had limited participation in decisions concerning their farms.

On resettlers' farms, technologies such as fertilizer, improved variety, and tractors were used. It has to be noted that the degree of participation by resettler farmers in decision making, particularly in decisions concerning what to produce and the type and level of input to be used, was minimal. Such decisions were mainly made by the authorities responsible for the implementation of the programme. Hence, we do not consider the application of modern agricultural technologies as an adoption decision made by resettler farmers. It is not known whether they would have continued to use the technology in the absence of the authorities responsible and financial support.

4.7.3. Post Economic Reform Period (1990-1995)

A number of reform measures have been undertaken since the 1990 economic reforms. In particular the abolition of the compulsory grain quota and fixed price and the lifting of inter-regional regulation were of great importance for the private smallholder farmers. Recurrent land redistribution was stopped and indefinite user right and the rights to transfer to legal heirs was given to farmers (Hansson, 1994). Guidelines were developed for cooperative and state farm restructuring to make them viable economic units. Above all, discrimination against peasant farmers was terminated. Economic reform was enforced by the new government in 1991.
Data required to make an evaluation of the impact of the economic reform programme on technology adoption is not available. Well focused and detailed studies are required to examine the impact of the economic reform, not only at a macro level but also at a micro level. To highlight the possible impact, we refer to some preliminary studies and use secondary data from CSA to compare the situation in area cultivated, production, and availability of input before and after the reform. The effect of the policies is expected to be positive. According to Hansson (1994), one year after the 1990 reform, peasant farmers increased the cultivated area by 12% to 20% and agricultural production was estimated to have increased by 6%. As shown in Table 4.3, the area cultivated by smallholder farmers increased, on average, from 93% in the pre-reform period to 99% of the total cultivated land after the reform. Similarly, crop production increased, on average, from 93% to 98% after the reform. As noted above, the increment in area was mainly due to the shift from cooperative farms to private smallholder farms. Besides, the performance of agriculture was greatly influenced by the weather. As pointed out by Eshetu (1994) the country had two consecutive years of good rain and this may account for the considerable improvement in performance of the agricultural sector after the reform.

Table 4.9 compares fertilizer and improved seed availability before and after the reform. After the reform the availability of fertilizer improved considerably. It increased from 109,301 tons in 1989 to 210,420 tons 1995 with an average annual growth rate of 11%. As observed during the survey, problems relating to the timely availability of fertilizer were reduced. At the

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5 The figures reported by Hansson (1994) do not look realistic in face of the national data reported by CSA. Using CSA data average growth rate of cultivated land over the period 1991 to 1994 was 9%. As noted in section 4.5.1, the techniques employed in cultivated area estimation was also different in 1991 and 1994.

6 This statement may not necessarily reflect conditions in remote areas of the country. It only represents the condition in the study area relatively where infrastructure is better. Public as well as private input dealers do give emphasis to the two zones in which this study was done. Approximately 40% to 50% of total fertilizer supply goes to these zones.
time this survey was undertaken, sufficient amounts of fertilizer had reached final distribution centres in the study area. At the national level, the availability of fertilizer doubled over the period 1989 to 1994 (Table 4.9).

As compared to the pre-reform period, the amount of improved seeds made available to farmers rose from 9,273 tons in 1989 to 12,456 tons in 1995 with an average annual growth rate of 5%. The quantity of improved seed supplied to peasant farmers rose from around 15% in 1982 to more than 70% in 1995. It has to be noted that much of the seed distributed during the post-reform period, particularly after 1991, was done through safety-net and rehabilitation programmes and projects. Thus, improved seed was distributed to farmers either free of charge or on loan through a revolving fund scheme with a recovery period of 3 to 5 years (MOA, Personal communication).

Table 4.9. Availability of fertilizer and improved seeds to smallholder farmers before and after the 1990 economic reform.

<table>
<thead>
<tr>
<th>Selected year</th>
<th>Fertilizer ('000 ton)</th>
<th>Improved Seed ('000 ton)</th>
<th>Proportion of improved seed by sub-sector</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>State farm</td>
</tr>
<tr>
<td>1975</td>
<td>13979</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>1980</td>
<td>43287</td>
<td>1922</td>
<td>NA</td>
</tr>
<tr>
<td>1984</td>
<td>46884</td>
<td>3193</td>
<td>80</td>
</tr>
<tr>
<td>1989</td>
<td>109301</td>
<td>9273</td>
<td>51</td>
</tr>
<tr>
<td>1993</td>
<td>135146</td>
<td>15586</td>
<td>22</td>
</tr>
<tr>
<td>1994</td>
<td>202325</td>
<td>17191</td>
<td>20</td>
</tr>
<tr>
<td>1995</td>
<td>210420</td>
<td>12456</td>
<td>23</td>
</tr>
</tbody>
</table>

Source: Agricultural Input Supply Enterprise (AISE) and Ethiopian Seed Enterprise (ESE). Note: NA, Data not available.

After the economic reform, extension activities were decentralized and devolution of power took place. Approximately 3,000 to 5,000 assistant development agents, who can speak the local language were trained and deployed over three years (MOA, Personal
communication). This is a big achievement when compared to the number of DAs deployed in the pre-reform period. However, as noted during the field survey, the quality of Assistant Development Agents (ADA), who were newly recruited, was poor. This was mainly because of the greater emphasis placed on the political outlook\(^7\) of an individual than his potential technical capability in recruiting individuals for the job.

4.8. Conclusions

In Ethiopia, agriculture is the mainstay of the economy and the contribution of industry is minimal. Over the last two decades, the economic performance of the country has been poor and the standard of living has deteriorated. The country has agricultural potential but the potential is not well exploited. Three agricultural production systems: pastoral, smallholders mixed farming and modern mechanized systems exist in Ethiopia. The smallholder mixed farming is the single most important system accounting for more than 95% of cultivated land and total production. This system is also typical of the study area. The objectives of production on the smallholders' farms are for subsistence and to generate cash. Application of modern agricultural technologies on smallholder farms is minimal and because of this, productivity is low. Despite the application of modern technology the productivity on the state farm and PCs farms is low, too.

Emphasis has not been given to smallholder subsistence farmers by the imperial government and its successor, the socialist government. The imperial regime totally neglected the subsistence farmers and promoted commercial farms. The socialist government advocated

\(^7\) These ADAs were trained for 6-9 months. The assistant development agents were recruited by wereda administrators (elected politicians) with very little and passive participation of the responsible agricultural office. As extension experts reported during the survey period, most of those who were selected were members or supporters of the ruling political party.
the development of PCs and state farms. It also implemented policies that discriminated against the smallholder farmers. For example, the marketing policy, with its distinct character of fixed low output price and inter-regional trade regulation, had a negative effect on the profitability of fertilizers and other technology. This eroded incentives to use the new technology. Extension agents were assigned to implement the villagization programme in which farmers had no interest. This had a negative impact on the technology transfer process because of the unhealthy relationship created between extension workers and farmers.
CHAPTER 5

AGRICULTURAL RESEARCH AND EXTENSION IN ETHIOPIA: AN OVERVIEW

5.1. Introduction

Research and extension systems have the potential to generate and disseminate technologies that increase productivity at every step of the production and distribution process. This chapter describes the status of agricultural research and extension systems in Ethiopia and the technologies which have been generated and disseminated amongst farmers. The chapter also discusses the problems involved in developing and disseminating technologies suitable for smallholder farming conditions. It also describes the links between the research-extension systems. This chapter also explains why this study has focused on fertilizer, herbicide, and improved varieties.

5.2. Status of Agricultural Research

The history of public agricultural research in Ethiopia dates back to the initiation and establishment of Ambo and Jima Technical Schools and Alamaya College of Agriculture in the late 1940s and early 1950s. These institutions had triple mandates: training, research and extension; they were the major publicly funded institutions conducting agricultural research until 1966. However, the research they conducted covered very few topics. Technologies were tested in sites close to the agricultural college and therefore had limited adaptability. They also focused on testing introduced technologies. To overcome these shortcomings, the Institute of Agricultural Research (IAR) was established in 1966 as a semi-autonomous public institution
with the following objectives:

(i) To coordinate national agricultural research,

(ii) To formulate national agricultural research guidelines, and

(iii) To conduct agricultural research.

And in 1975, the Ethiopian Science and Technology Commission (ESTC) was set up to guide and formulate science and technology policies and development. Since 1975 the IAR has been responsible for conducting and coordinating agricultural research in the country.

Currently the IAR, Alamaya University of Agriculture and Addis Ababa University and Awasa, Ambo and Jima agricultural colleges, MOA, and the Coffee and Tea Development Authority are engaged in different categories of agricultural research. Of these, only the IAR is devoted entirely to research; the other institutions which are engaged in agricultural research have other objectives as well so research is only a secondary activity for them. The MSFD also used to undertake adaptive research to fit its own needs. In addition to these indigenous research institutions, one international agricultural research institute, the International Livestock Research Institute (ILRI), is based in Ethiopia and conducts agricultural research there. There are some international agricultural research institutes (for example, CIMMYT and the International Agricultural Research Institute for Semi-Arid Tropics (ICRISAT)) which technically and materially support the national research institutions as well. The IAR conducts research in different fields of agricultural disciplines and agro-ecological zones of the country. Therefore, in the discussions to follow we give much emphasis to the activities undertaken by IAR and, when necessary, discuss the research carried out by other institutions, as well.
5.2.1. Organization and Coordination of Research Programmes

The IAR research programmes are organized into discipline-based departments which are further organized into divisions and teams. These departments focus on field crops, coffee, horticulture, soil science, animal sciences, agricultural engineering and food science, and agricultural economics, each with a department head to coordinate the programme. With the exception of the engineering and food science departments, each department has a division in the main research centres. The academic institutions engaged in agricultural research have organized their research programmes along the same lines.

The IAR has 8 main research centres and 18 sub-centres located in different parts of the country. Under the academic institutions there are a further 6 research centres or sub-centres (Goshu, 1994). Following the re-organization of extension services on the basis of agro-ecological zones, two research streams were adopted and the research programmes were reorganized after 1986 on a national commodity and zonal research programme basis. The national commodity programme is designed to tackle the production problems of the selected crops and livestock which were accorded top priority by the government in pursuing the national goal of achieving food self-sufficiency, supplying raw materials for the industry, and earning foreign exchange. Twenty three commodity programmes were identified (Mulugetta, 1994) and those for wheat, maize, sorghum, cotton, coffee, highland and lowland pulses and oil crops are operating. The dairy, sheep, beef, and animal nutrition and feeds programmes are also operating. Most of the commodity programmes deal with breeding of crops and livestock (mainly cattle and sheep).

The zonal programmes are organized on the basis of agro-ecological zones and are responsible for tackling the priority problems of a particular agro-ecological zone. There are eight zonal research programmes with one or more research centre in each zone. The zonal
programmes deal mainly with agronomic research and collaborate with the national commodity research programmes in variety testing. The commodity and zonal programmes are based in the same research centres. The zonal programme collaborates with the commodity programme in varieties testing, provided that the research on varieties is relevant for that specific zone. Following the decentralization of power and demarcation of new political boundaries in 1992, the zonal research centres were transferred to the regional states, while the commodity research programmes were left under the control of the federal government. The zonal programmes are funded by the regional state and became accountable to the regional agricultural Bureaux. Both the national commodity and zonal research centres coordinate their programmes in a series of annual research planning and evaluation meetings. The other institutions that are engaged in research have their own research planning mechanisms and procedures. In general there is little inter-institutional interaction in research problem identification and priority settings. Farmers are not involved in the formulation of research priority settings and strategies. With the exception of the limited research conducted by IAR on farmers fields, farmers are not usually involved in the planning, implementation and evaluation of research programmes.

5.2.2. Research Outputs

Since its inception, the agricultural research system has emphasised the development of new varieties. Over the last 30 years the National Agricultural Research System (NARS) developed, tested or released 250 technologies, mainly new varieties of wheat, maize, sorghum, pulses and oil crops (Getinet et al., 1996) (Table 5.1). It is worth noting that the applicability of some of these varieties has been limited due to the widely varied agro-ecological conditions and a very wide indigenous genetic base. If we look at the released
varieties, nearly half of the cereal group varieties released are no longer available for production. The reason is that many of them have been out-yielded by newly released varieties and replaced, others have gone out of production because of disease susceptibility and deterioration in their yielding capacity. Seed of some of the released varieties has never been produced for commercial use. The ESE mainly produces seeds of improved varieties of maize, wheat, sorghum, barley and, to a limited extent, tef seeds. The Ethiopian Hybrid Pioneer, a multinational company, produces only maize. There are no public or private organizations that produce seeds (planting materials) of released varieties of fruits, vegetables, roots and tubers, fibre and forage crops or agricultural implements. In the case of livestock, a few ranches have been established to produce upgraded animals, mainly for cattle and sheep but the capacities of these ranches are very limited and their activities were discontinued in 1991 because of civil unrest. At the time this study was undertaken, some ranches had resumed their activities. Only a very limited amount of cereal seeds (see Chapter 4) are produced by the ESE and research centres.

In addition to variety development, many agronomic recommendations (i.e., plant population and spacing, fertilizer types, rates and application methods, physical and chemical crop protection practices and water and soil conservation techniques) have been made by the different research centres. However, there appears to have been little uptake of the improved agronomic practices by smallholder farmers. Some of the research recommendations have not taken into account the problems and resource limitations facing farmers. Thus, the technologies listed in Table 5.1 and associated agronomic recommendations have contributed very little to raising agricultural productivity on smallholder farms. The major beneficiaries of NARS's research outputs were the state farms and to some extent the producer cooperatives. There are a number of reasons, including unavailability of input and poor support services, for the limited uptake of research findings. In the 1980s, the research system gave greater emphasis to
technologies suitable for state farms and producer cooperatives. The inability of the NARS to generate technologies appropriate for the smallholder farmers is one of the reasons for the limited uptake of the technology. Sufficient efforts have not been made to incorporate smallholder farmers' demands and their local knowledge in the technology generation process.

Table 5.1. Summary of technologies generated by the national agricultural research systems.

<table>
<thead>
<tr>
<th>Technology group</th>
<th>Total (number)</th>
<th>Technologies (number)</th>
<th>Released&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Available from research&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereals</td>
<td>6</td>
<td>83</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td>2</td>
<td>20</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Tef</td>
<td>1</td>
<td>8</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Pulses</td>
<td>3</td>
<td>16</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Oil crops</td>
<td>7</td>
<td>32</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>Fibre crops</td>
<td>2</td>
<td>17</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Coffee</td>
<td>1</td>
<td>16</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Spices</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Roots and tubers</td>
<td>2</td>
<td>8</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Fruits</td>
<td>14</td>
<td>25</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Vegetables</td>
<td>3</td>
<td>12</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Forage crops</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Livestock</td>
<td>3</td>
<td>14</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Agri. implements</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>66</td>
<td>250</td>
<td>182</td>
<td></td>
</tr>
</tbody>
</table>

Source: IAR, Getinet et al. 1996.

<sup>a</sup> indicates total number of improved varieties released by the Variety Release Committee.

<sup>b</sup> indicates the number of improved varieties released that can be put for commercial use. This figure was obtained by deducting the varieties that lost their yielding potential and disease resistance and varieties out yielded by new improved varieties from the total number of the released varieties.
Thus, most of the technologies developed by IAR are not produced for commercial use and therefore not made available to farmers. It is because of the unavailability problem that we focused on fertilizer, herbicide, and improved varieties of tef and wheat in this study. With the exception of improved varieties of wheat and tef, fertilizer and herbicide are imported. They are being distributed to farmers by public and private input distributors and made available to farmers.

5.3. Agricultural Extension Services

In Ethiopia, agricultural extension to smallholder farmers was started in the early 1950s by the Alamaya College of Agriculture and the Ambo and Jima Technical Schools. During the initial period much emphasis was placed on the livestock sector, and exotic livestock and poultry breeds were imported to assist extension efforts. The extension personnel were very few and were stationed at the College or in big towns. There was no coherent programme of work, and there were no tested technologies, formal credit, and distribution channels for inputs. Because of these problems the extension service was not effective. As discussed in Chapter 4, much emphasis was placed on commercial farms during the 1950s and 1960s. In the late 1960s, fertilizer trials were started in the central highlands with external support. These trials programmes included complementary supervised credit schemes. In 1968 three credit centres were established and 72 farmers received 19 tons of fertilizer on credit (MOA, 1976).

During the same period, a comprehensive package programme that targeted smallholder farmers was introduced. The comprehensive package programme was started as a pilot project in Arsi, Chilalo, in 1967, and was financed by the Swedish International Development Association (SIDA). The pilot project provided research, extension, credit, seed multiplication and marketing services to smallholder farmers. It also focused on developing
rural infrastructure, mainly rural roads. Two more pilot projects, the Ada Agricultural Development Project (AADP) and the Walayita Agricultural Development Unit, were launched during this period, financed by a grant from United State Department of Agriculture (USAID) and loan from the World Bank. These projects introduced fertilizer, improved varieties and improved agronomic and crop protection practices. Compared to the total number of farmers and area cultivated in the country, the coverage of the pilot projects was small, and they were not replicated over larger areas as they were found to be very expensive and the government had neither the capacity nor willingness to finance such projects1.

A Minimum Package Programme (MPP) was introduced in 1971 (MOA, 1974). The MPP was based on experience gained from a number of comprehensive pilot projects and implemented by the Extension and Project Implementation Department (EPID). In its first phase (1970/71-1975/76), the MPP area typically contained 10,000 families and extended 5 km on either side of a 50 to 75 km stretch of all-weather road (MOA 1976). In the second phase (1977/78-1979/80), the wereda development area approach was adopted as the basic unit for extension services. The wereda extension area coincides exactly with local administration boundaries and MOA wereda offices were established throughout the country.

Until 1970/71, the extension services of the MOA consisted of around 120 trained extension personnel (MOA, 1976). Funds were inadequate, research information was limited and there were inadequate credit facilities for the smallholder farmers. The MPP had addressed the financial and manpower shortages and credit unavailability problems (MOA, 1994). The extension service area coverage had been expanded to cover most of the areas accessible by all-weather roads in the highlands. The MPP provided technologies, mainly fertilizer and improved seeds, and extension and credit services to smallholder farmers. Other technologies, such as improved land preparation, small farm implements, organic fertilizer, improved storage

1 This is discussed further in Section 4.6.2.
methods and water and soil conservation, were not implemented by MPP projects because their relevance to local conditions and acceptability by farmers had not been verified by research. Because of this, the package was mainly confined to fertilizer and improved varieties. In the second phase of MPP more emphasis was given to organizing farmers into producer and service cooperatives and manpower was thinly spread over the weredas so the programme was not as effective as in the first phase.

In the mid 1980s the MPP was terminated and another type of extension management system was introduced. For the purposes of agricultural development, extension administration and planning, the country was divided into eight major zones, known as Peasant Agricultural Development zones. Comprehensive extension projects, the Peasant Agricultural Development Projects (PADEP), were implemented in four of the eight agro-ecological zones. The PADEP used a Training and Visits (T and V) extension management system to improve the effectiveness of the services provided to farmers. These projects were funded by the World Bank, European Economic Community, African Development Bank and the Ethiopian government. The MMP programmes had been criticised for not including livestock development components or soil and water conservation activities. The PADEPs were comprehensive in nature and directly contributed to the development in infrastructure, including small-scale irrigation, rural roads, animal health clinics and input warehouses. They were also involved in the distribution of agricultural input, livestock development, soil and water conservation activities and in regular technology-promotion activities, particularly improved varieties and fertilizer.

Despite all these efforts, the national extension services have not met the extension needs of farmers. The MOA is responsible for the provision of extension services to small farmers. The MOA has been subjected to frequent reorganization because of changes in the political structure of the country and changes in extension management approaches. Among
many reasons, the frequent reorganizations have contributed to the ineffectiveness of the extension services. These reorganizations resulted in discontinuity of extension programmes and frequent reshuffling of staff. Moreover, lack of in-service training for development agents, lack of incentives, and inadequate transport facilities for agents have resulted in a generally poorly motivated staff (Stroud and Mulugetta, 1992). Because of this, the extension system has not been effective in promoting available technologies. In 1992 another fundamental change in the country's political and economic structure took place. The country's political and economic management system changed from a unitary form of government to a federal type of government. In response to this the MOA was restructured again and the mandate for providing agricultural extension services to farmers was transferred to the regional agricultural bureaux. The regional agricultural bureaux are accountable to the regional states and the MOA lost control of extension activities. Since their establishment in 1993, the regional bureaux have been restructured and most of the problems noted above carried over to them so that the extension services remained ineffective.

5.4. Research and Extension Links

Agricultural research and extension are dependent on one another for their successful functioning. Extension services cannot be fully effective without the backing of appropriate research programmes, while sound research efforts depend on close links with extension and feedback from farmers. In the absence of a continuous flow of new technologies suited to farmers' needs, the extension service has nothing to extend to farmers. There is no justification for spending resources on agricultural research, if the technologies are not extended to farmers.
The links between extension and research in Ethiopia are weak (Tackele, 1986; Mulugetta, 1994; Goshu, 1994; Aberra and Beyene 1996). One reason for this is that research and extension are the responsibility of separate organizations. At field level, research and extension function independently and forums for interaction are few or absent. There was a time when researchers viewed technology transfer as a peripheral responsibility. On the other hand, the extension services have not appreciated the need to give feedback to researchers and to understand those areas in which available research findings are applicable. There have been occasions when researchers blamed extensionists for failure to disseminate technologies already generated while extensionists blamed researchers for their failure to provide appropriate technologies worthy of dissemination. Extensionists have not been formally involved in on-farm research activities and the number of fora or publications where research findings could be passed to extension workers have been limited. Similarly, there have been few attempts to collect farmers' feedback concerning newly introduced technologies.

From the early days this problem has been recognized by the research and extension systems and efforts have been made to narrow the gap. Annual conferences, information exchange through publications, and joint IAR/MOA implementation of out-reach programmes have been tried to strengthen the links between research and extension. These types of linkage arrangements were found to be successful at the national level. However, they have not led to the creation of strong links at the field level. In 1986 an attempt was made to improve the weak research and extension links at national, zonal and field levels. A Research and Extension Liaison Committee (RELC) drawn from the IAR and MOA was formed. At the national level RELC was chaired by the Minister of Agriculture and by zonal agricultural heads at zonal levels. The function of the national RELC was mainly to provide overall policy directions concerning research extension links. The primary function of the zonal RELC was to review and approve research proposals and extension recommendations, identify training needs for
MOA's subject matter specialists and oversee the operation of research and extension links in the zone.

However, the establishment of the RELC has not effectively bridged the linkage gap between the research and extension systems. In Ethiopia, the organizations involved in research and extension are autonomous and neither has authority over the other. Each organization makes an effort to achieve its own objectives so common objectives and responsibilities tend to be neglected.

This being an important factor influencing the ineffectiveness of the RELC, there are also other factors that have contributed to the weak performance of the RELC in forming links between research and extension. First, the MOA was subjected to frequent reorganization because of changes in the political structure of the country and changes in extension approaches. These changes have resulted in frequent reshuffling of manpower and RELC members. This reshuffling of RELC members resulted in discontinuity of the linkage arrangements for some time. Consequently, the resolutions and recommendations made at RELC meetings were either lost or not carefully handled by incoming committee members.

Second, the linkage activities were considered to be part-time work. There were no rewards or penalties and, therefore, the functioning of the linkage committee has been largely dependent on individual commitment and personal good will. Third, effective technology generation and transfer involve full participation of researchers, extension workers, farmers representatives, technology producers and distributors, and credit providers. The RELC included only the first two and ignored the others, particularly at zonal levels. Fourth, the finance required for improving linkage was lacking and, because of this, joint field monitoring and evaluation have not been conducted as planned.
5.5. Conclusions

In Ethiopia, some form of agricultural research has been carried out for the last three decades, and some technologies have been extended to farmers through the extension services. However, on the whole, smallholder farming production practices have remained unchanged and new technologies have not been widely adopted which means that the impact of research and extension on productivity has been marginal.

Although a number of factors contributed to the low level of productivity, the failure of research to generate technology suitable for smallholder farmers and the failure of extension to disseminate available technology was largely responsible for the low level of productivity. Research findings have not been disseminated and used on smallholder farms. Instability in organizational structure of MOA contributed to the reshuffling of staff and discontinuity of programmes which undermined the effectiveness of the extension service in promoting new technologies. The research and extension links remained weak and efforts made to strengthen links have not fully achieved their objectives. The involvement of farmers in research and extension programme formulation was absent, contributing to the ineffectiveness of research and extension in generating and extending technologies that are suitable to the conditions in which farmers have to operate.

This chapter has suggested that fertilizer, improved varieties and to some extent herbicide have been the main components of the technological package promoted by the extension services in Ethiopia. Compared to other agricultural technologies, fertilizer has been widely adopted by farmers. With the exception of a few improved varieties, most of the technologies developed by research have not been widely adopted by farmers. It was with this background that fertilizer, herbicide and improved varieties of wheat and tef have been chosen for empirical analysis in the later chapters.
CHAPTER 6

METHOD OF DATA COLLECTION, VARIABLES AND THEIR EXPECTED EFFECTS ON TECHNOLOGY ADOPTION

6.1. Introduction

Data collection involves a range of activities, such as library research, experimentation, observation, census, case study, sample survey etc. The choice of one of these methods depends on the problem to be addressed, availability of resources and time allocated to the study. The sample survey method of data collection is widely used for primary data generation in economic studies. This method applies sampling theory and it is the development of sampling theory that expanded the wider application of the sample survey method of data collection (Casley and Lury, 1987). The collection of data through census and experimental methods is time consuming and expensive. The survey method of data collection deals with a representative sample from a population and, therefore, saves time and resources i.e. it is less costly. As compared to the census method, many topics can be covered by the survey method and the quality of data can be better because of better supervision.

Considering the specific problem to be addressed, and the time and resources available, the sample survey method was used in collecting data for this study. A single visit survey was carried out from May 1996 to August 1996. This chapter explains the method used in conducting the survey. Data on a number of factors affecting technology adoption were collected. Based on theoretical and empirical studies, factors believed to affect technology adoption have been selected for discussion in this chapter. Hypotheses to be tested in the later chapters are formulated.
The organization of this chapter is as follows. Section 6.2 explains how the field work was organized and managed. It also illustrates the sampling techniques employed and describes how the enumerators were selected and interviews conducted. Section 6.3 and 6.4 pinpoint the units of measurement used and the limitations of the data, respectively. This is followed by section 6.5 which defines variables that we later included in the econometric analysis. It also discusses the reasons why the different variables were included in the analysis and indicates the direction of effects of each individual variable on technology adoption. The final section gives concluding remarks on data collection methods and variables included in the later chapters.

6.2. Survey and Sampling Methods

6.2.1. Organization and Management of the Field Work

The field work was conducted in the West and East Shewa zones of Oromia Regional State, Ethiopia. It covers four weredas (districts), namely Dandi, Ejere in West Shewa zone, Ada and Lume in East Shewa zone. Emphasis was placed on two crops, tef and wheat for the following reasons. First, tef and wheat are widely grown in the study area, especially in the highlands of West and East Shewa zones. Table 2 reveals the importance of tef and wheat in the weredas sampled and in the two zones. As shown in the table, cultivated areas allocated to tef and wheat range from 28% to 76% and from 15% to 27% of total cultivated land, respectively. Thus, these crops are the major crops cultivated by farmers in the study area. Second, improved varieties of wheat and tef have been released and demonstrated to farmers in the study area. Some preliminary studies indicate that a large proportion of fertilizer is used on tef (24%) and wheat (17%) (Asnekew et al., 1991). Third, tef and wheat are priority food crops that are being given attention by government to increase production to meet the objective of national food self-sufficiency.
Table 6.1. Cultivated area allocated to tef and wheat in weredas sampled, as a percentage of total cultivated land.

<table>
<thead>
<tr>
<th>Crops</th>
<th>Dandi Wereda</th>
<th>Ejere Wereda</th>
<th>W. Shewa Zone</th>
<th>Ada Wereda</th>
<th>Lume Wereda</th>
<th>E. Shewa Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tef</td>
<td>28.2</td>
<td>28.7</td>
<td>30.0</td>
<td>58.0</td>
<td>76.0</td>
<td>28.0</td>
</tr>
<tr>
<td>Wheat</td>
<td>21.7</td>
<td>27.3</td>
<td>17.4</td>
<td>22.2</td>
<td>15.0</td>
<td>17.0</td>
</tr>
<tr>
<td>Barley</td>
<td>25.6</td>
<td>31.9</td>
<td>17.7</td>
<td>2.0</td>
<td>1.5</td>
<td>3.7</td>
</tr>
<tr>
<td>Maize</td>
<td>4.6</td>
<td>1.3</td>
<td>8.3</td>
<td>1.5</td>
<td>1.5</td>
<td>34.2</td>
</tr>
<tr>
<td>Sorghum</td>
<td>4.3</td>
<td>0.4</td>
<td>6.8</td>
<td>0.1</td>
<td>0</td>
<td>3.0</td>
</tr>
<tr>
<td>Pulses(^a)</td>
<td>9.8</td>
<td>7.9</td>
<td>11.4</td>
<td>16.2</td>
<td>6.0</td>
<td>14.0</td>
</tr>
<tr>
<td>Oilcrops(^b)</td>
<td>5.8</td>
<td>2.5</td>
<td>8.4</td>
<td>-</td>
<td>-</td>
<td>0.1</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

\(^a\) include Faba-beans, Pea, Chickpea, Lentils, Vetch, Haricot-beans, and fenugreek. 
\(^b\) include Noug, Flax and Rapeseed.

Adoption of three technologies, (namely, fertilizers, improved varieties and herbicides) which are promoted by the extension service were examined by the study. As compared to other types of agricultural technologies these three technologies are made available to farmers, with some degree of variation between them in availability. The current extension and research programmes place great emphasis on promoting these technologies, especially fertilizer and improved varieties.

The field work was started by seeking support and gathering background information from the Oromia Regional Agricultural Development Bureau. This bureau is responsible for provision of extension services and technology transfer in the regional state. Basic information needed to identify the study area was gathered through discussion with the extension experts and cooperative development and promotion experts at the regional level. The discussions focused on the farming system and the status of technology transfer and use in the central highlands of Oromia. As a result of these discussions and previous knowledge of the different zones of the regional state, East and West Shewa zones were selected. The main criteria used...
in the selection process were accessibility, amount of fertilizer distributed over the last ten years and importance of tef and wheat in the farming system.

Because of limited resources and the inconvenience of supervision, the field work in the two zones was carried out one after the other. At the time the field work started, the Ethiopian rainy season was about to begin. During the rainy season, dry weather feeder roads are affected and communication can be disrupted. Therefore, it was decided to start the survey in West Shewa zone, where the feeder roads are in relatively poor condition compared to the East Shewa zone. Following this decision, the respective zonal agricultural departments were contacted and information about weredas was collected through discussion with zonal agronomists and extension experts. Moreover, records and annual reports from the two zonal agricultural departments were consulted to identify weredas for the study. Then lists of potential weredas to be included in the sample were assembled. The weredas were selected on the basis of accessibility and the importance of tef and wheat in the crop mixes.

Once the weredas to be included in the study were identified, the agricultural offices responsible for extension activities were contacted. Information about accessibility of Peasant Associations (PAs)\(^1\), crop mix, extent of technology transfer and input distribution were gathered through discussions and reference to records kept by the weredas' agricultural offices. In addition, information required for the multistage sampling procedure were collected. These include PA lists for sample frame selection and farmers' lists. In the mean time, the staff of wereda agricultural offices were asked to inform potential enumerators with secondary school leaving certificates. Respective wereda agricultural offices also cooperated in announcing enumerator vacancies on their notice boards.

\[^1\] Following the 1975 Rural Land Reform (Nationalization), PAs were organized in the rural areas with the aim of implementing the land reform. The PAs are responsible for the management of the distribution of land. They were established on an average of 800 ha. of land with an average membership of 350 family heads. The PAs also serve as the smallest administrative unit of local government.
At wereda level, wereda administrators (or their deputies) were contacted as a formality and to avoid any problems that might arise during the field work. Meetings were organized and the researcher explained the purpose and the importance of the study to the administrators at their respective weredas. During the meetings with wereda administrators, the researcher was accompanied by the head of the wereda agricultural office, who was acquainted with the officials. Under the current bureaucratic system, support letters are essential for securing data and information required in the sample selection process. Thus, from the regional agricultural bureau level down to PA levels, support letters were obtained from the next higher level.

Once the link was created at wereda level, selected PA's leaders were contacted in advance of the commencement of the interviews. The first meeting and discussion with PA leaders was in the presence of the DA or extension supervisor stationed at the extension centre in which the selected PA falls. Extension supervisors are posted at wereda level, but frequently travel to extension centres and have good acquaintance with farmers. The main purpose of meeting with PAs leaders was to create awareness of the research activities to be carried out in their area. It was also aimed at publicising the research activities, securing PA leaders' approval and minimizing any suspicion about the study. Therefore, the discussions with PA leaders were somewhat detailed and lengthy. The discussions focused on the purpose and procedure of the survey and how their PA and sample farmers were selected. To increase PA leaders' motivation to cooperate, an overview of the questionnaire and the importance of the research, in term of problem identification, were emphasized. The researcher also explained why the survey is being done and how the information will be used. PA leaders were encouraged to give their opinion. This was done to assess their reaction, i.e. to what extent they understood the purpose of the study and to what extent they were willing to cooperate in informing others about the study.
After explaining how sample farmers were selected, a list of sampled farmers was submitted to PA leaders to verify whether the selected farmers were still residing in their peasant associations or not. This was done for the 12 PAs we have sampled. Through this process, two sampled farmers who died were replaced by farmers selected as reserves. PA leaders were also asked to inform sample farmers and the community as a whole about the survey and its importance. The enumerators were also instructed and trained to create a harmonious environment and to win farmers' confidence during interviews. In sample survey methods of data collection, the detection of errors in the field, where it is not too late to make corrections, is very important. The researcher supervised the interview period closely. At the period when the interviews were conducted, the researcher stayed in the village (PA). The completed questionnaires were edited by the researcher each day to identify gaps or inconsistencies and recording errors. In some cases, checking of the questionnaire was done between two interviews.

6.2.2. Sampling Procedure to Select Sample Units

In this study, the farm household head, who actually makes the day-to-day decisions on farm activities, technology adoption, and inputs use, was taken as the basic sample unit. The Peasant Associations were taken as a sample frame to select sample household heads. In the study area, as elsewhere in Ethiopia, household heads are organized into PAs. The PA encompasses all family heads who live within the boundary of the PA and make a living from farming. Lists of PA members are available, and the PA members' lists include the target population to be surveyed for this study. The availability of this information on PAs and its completeness makes PAs a favored sampling frame for such sample surveys. It is for this reason that the PA was used as a sample frame to select the sample farmers.
A three-stage sampling method was applied to select the required number of sample farmers. The first stage in the sampling procedure was to identify weredas (districts) to be covered by this study. There are 24 and 17 weredas in West and East Shewa zones respectively. Because of the objectives of the study, limited time and resources, not all the weredas in each zone were covered by the survey. It was decided to conduct the study in four weredas. Potential weredas to be sampled were selected based on types of crops grown and accessibility. Specifically, weredas in which tef and wheat are produced as major crops were identified in consultation with zonal extension specialists. Inaccessible weredas and weredas in which tef and wheat are not produced as major crops were excluded from the list. Then two weredas were chosen from the lists of major tef and wheat growing weredas from each zones using the "lottery method" of random selection.

The second stage was to identify accessible PAs from the selected weredas. This was done by referring to information kept by wereda agricultural offices regarding PAs, and SCs. Thus, using these records and in consultation with wereda extension team leaders and supervisors who have good knowledge of the PAs, all accessible PAs were identified. Once the complete lists of accessible PAs were identified and assembled, three sample PAs were randomly selected from each wereda. In total, therefore, twelve PAs, six from each zone, were randomly sampled using the "lottery method" of random selection.

The third stage of the sampling procedure was randomly to choose farm household heads from each of the randomly selected PAs. Lists of farmers are held at the PA, SC, and wereda administration offices and the finance and revenue collection office. However, some of these lists are not updated and therefore are not complete. For instance, at the time this study was undertaken, two to three PAs were being amalgamated to form a relatively big PA. Since the amalgamation process had not been completed at the time the survey was conducted, complete members lists were not available for the amalgamated PAs. Lists of farmers kept by
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some dissolved PAs were not available either, as their offices had already ceased functioning. In the cases where these lists were available, they were not updated, and therefore, incomplete. Hence, we opted to use lists recently prepared for collection of rural land-use tax and agricultural-income tax. Rural land-use tax and agricultural-income tax are collected from the household heads who have use-rights and gain income from the land. These lists are relevant for our study since the target population of this study coincides with the population of agricultural land-use and agricultural income tax payers. But compared to the farmer lists available from PAs and Service Cooperatives, the lists prepared for tax collection purposes are more recent and accurate. The lists available at SCs included PA members who were dead or had changed domicile.

A systematic sampling technique was applied to select farm household heads using relatively up-to-date rural tax (land-use and agricultural income tax) payers lists\(^2\). A total of 200 sample farmers was selected. Sample farmers were equally distributed between the two zones; thus, 100 farmers were sampled from each zone. From each selected PA about 16 to 17 farm household heads were chosen randomly. After the survey was completed, it was found that four of the sampled farmers leased out their land. Those farmers who leased out their land do not make decisions on the types of crops to be grown, the type and amount of inputs to be used and technology to be adopted. Such decisions are usually made by the farmers who rent the land. Therefore, those sampled farmers who leased out all their land were excluded from the analysis and the sample reduced to 196 farmers. Furthermore, 7 and 35 farmers did not grow tef and wheat in 1995 crop season, respectively. The reason why these farmers did not grow in that specific year was not investigated. However, the probable reason for not growing these crops could be related to a specific rotation, shortage of land or of seed. Therefore, the

\(^2\) Land use and agricultural income tax payers lists are compiled by PAs. Although these lists are prepared for tax collection purpose and kept in finance and revenue collection offices, the lists include all members of PAs and can be considered PA membership lists.
6.2.3. Recruiting and Training of Enumerators

Initially, the questionnaire for this study was prepared in the English language. Because of this, it was decided to use enumerators who could read, write and understand the English language. Thus, persons with secondary school leaving certificates were selected to serve as enumerators. An interview was conducted to screen and select enumerators. The criteria used in selection of enumerators included:

1. Fluency in local language, Oromiffa,
2. Knowledge of agricultural activities and locality,
3. Education level, Secondary School Leaving Certificate,
4. Experience in data collection, and
5. Honesty.

All the selected enumerators were either resident in a rural area or had recently moved to a town to search for a job. Therefore, they all had an agricultural background and knowledge of the study area. Apart from two enumerators who completed secondary school in 1996, all the enumerators served as enumerators during the 1994 Houses and Population Census and therefore had previous experience of data collection.

The enumerators were trained in class as well as in the field for three days. The training programme was carried out at different times in the two zones. During the training sessions, the enumerators were given class-room instruction on the purpose of the study, definition of concepts and terms used, interviewing procedures, explanation of local measurement units and how to record responses on the questionnaire. The class-room sessions also included training
in how to approach farmers (introductory procedure), how to ask questions, and how to apply other field interviewing techniques. Each question was thoroughly discussed in the class. The enumerators practised by interviewing each other in the class to ensure that they correctly understood each question. Moreover, examples of how to record responses on the questionnaire were demonstrated. The enumerators were advised not to work out conversions from the local unit into metric units at the time of an interview, because the process of making the conversion from one unit to the other takes time and attention and thereby affects proper noting down of responses. The class-room instruction was supplemented by a one day field exercise. This was undertaken on the second day of the training programme. On the final day of the training programme, the experiences gained and problems encountered during the field exercise were discussed.

6.2.4. The Interview

The chief instrument of data collection for the study was a structured questionnaire. The questionnaire was prepared by the researcher using his knowledge of agricultural practices in the study area. It also draws on the experiences of similar interviews in Ethiopia and other developing countries. The questionnaire is generally focused on the use of new agricultural technology for wheat and tef. It also includes farm and household head's characteristics such as age, education, experience, farmers' knowledge of the recommended technologies, communication channels used, farmers' perceptions of prices of inputs and outputs, and risk. The questions were arranged in a logical order. Questions of a general nature were arranged to serve as the introductory question in each section of the questionnaire. These were followed by more specific questions about the use of technologies, credit, yield and income. Some questions were also included for identification and cross-checking purposes.
The questionnaire was pretested to evaluate the appropriateness of questions and revised according to the feedback from pretesting. It was then translated into the local language, Oromiffa. Finally, the enumerators interviewed farmers using the questionnaire under the close supervision of the researcher. Each enumerator was assigned to interview a specified sample of farmers. The enumerators were deployed singly and each one of them was responsible for questioning and recording. The answers were checked by the researcher to identify inconsistencies and to address any problems. In cases where incomplete questionnaires were returned to the researcher and gaps identified, the enumerators were sent back to clarify the points with the sample farmers.

In addition to the formal interview, secondary data were collected to supplement the primary survey data. The secondary data were collected from institutions involved in technology generation, multiplication, and transfer and from institutions promoting formal rural credit. Short guidelines were prepared to collect secondary data. Using the guidelines, information on fertilizer procurement, supply, and marketing was collected from AISE, MOA, and Ethiopian Fertilizer Agency. Information on the status of improved variety generation, production and distribution was obtained from the IAR, ESE and Ethiopian Seed Industry Agency. Data on crop area, production, yield and prices were extracted from different bulletins of the Central Statistical Authority (CSA). Information regarding rural credit supply was obtained from the Commercial Bank of Ethiopia (CBE), rural credit promotion division, and the Development Bank of Ethiopia (DBE), research division.
6.3. Measurement Units

In the study areas, local units are used to measure area, weight and volume. Standard metric units are rarely used. It is known that the measurement methods and conversion factors used may introduce some measurement errors in the data. In spite of this problem, data for this study were collected using local measurement units. This alternative was chosen because most farmers are more comfortable giving responses in the local units than standard metric units. However, in cases where farmers responded in metric units, both units of measurement were recorded to avoid confusion. For certain local units, e.g. *Kuna*, which vary from locality to locality, farmers were encouraged to indicate the equivalent in metric units, if they knew. In addition, information regarding units of measurement and their conversion factors were gathered from non-sampled farmers, extension agents and rural-based input and grain traders. Rural-based grain traders (grain assemblers) use local units when they purchase grain from farmers and metric units when they are selling to consumers or wholesalers so they are knowledgeable about the local measurement units and their conversion factors. Hence, the conversion factors used drew on the information obtained from this group. In the case of land area measurement, the conversion factor commonly used by the agricultural department for reporting cultivated area was used. It has to be noted that areas of land under fertilizer, herbicide and improved varieties were not measured. The crop-cut method was not used for yield measurement, either. The data were obtained by the recall memory method.

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3 *Kuna* is a local unit used to measure grain. One *kuna* weighs 8 to 10 kg.
6.4. Limitations of the Data

In any survey, there are many potential sources of non-sampling errors. These include the possibility of non-response, observation or measurement mistakes, errors in recording or coding the information and others. Some of these are accidental and may tend to cancel each other out. However, if the errors tend to be in one direction, the final estimates can be biased and the interpretation might be misleading. In some cases respondents may tend to under-report due to suspicion regarding the survey. In rural areas of Ethiopia, questions focusing on yield, income and number of livestock are sensitive and there is a tendency to under-reporting.

This study witnessed the tendency of under reporting and unwillingness to report yield and income information. At the time the field work was undertaken, rural taxation policy was being replaced by a new rural taxation policy. Under the old taxation policy, two types of taxes were collected from peasant households: a land-use fee and an agricultural income tax. The land-use fee is a fixed rate levied on agricultural holdings irrespective of size. Household heads are required to pay 10 birr. The old agricultural income tax was progressive in principle but not in practice. Household heads having an income of up to 600 birr per year were required to pay a fixed amount of 10 birr per year. Those who earned more than 600 birr were supposed to pay according to a tax rate fixed for the income range in which their income fell. However, in practice it is very difficult to determine the level of income, and very few farmers report their income to be above 600 birr. Thus, under the old rural taxation policy, nearly all farmers paid a flat tax of 20 birr, irrespective of their land size and income. The new policy introduced a progressive rural taxation system based on the size of farm and amount of income earned from farming. A mechanism that involves the local community (a committee drawn from the PA) was devised to estimate agricultural income. After this new system was put in place, in the 1995/96 crop season, the amount of tax farmers have to pay was considerably increased. For
example, in the 1995/96 Ethiopian fiscal year the amount of tax farmers paid ranged from 20 to 280 birr per family head.

This had an implication for the data collected for the study. At the time when data for this study was collected the issue of tax increment was a major point of discussion in rural areas. Farmers were openly complaining about the increment and although efforts were made to clarify the objective of the study, some farmers remained sceptical. They suspected that the information they gave might be used against them to raise their agricultural income tax rate. As a result, about 11% of sampled farmers declined to report information on yield and income. It is also difficult to believe that all the figures reported on yields were realistic. When data on production is compared with information on consumption, the amount consumed turns out to be very different from that produced, taking into account purchases made in the year. Under such conditions, it is more likely that data concerning yield and income are under-reported. It was also observed that some farmers were hesitant to disclose the amount of yield they obtained and amount of income from non-farm sources (if any). This problem was realized when the questionnaire was tested and a means was devised to collect a proxy variable for income. It was thought that agricultural income tax could serve as a proxy variable for income. Hence, information on agricultural income tax paid by each sample farmer was collected from respective wereda's finance and revenue collection offices. However, in the 2 of the 12 sampled PAs the amount of agricultural income tax paid by sample farmers was found to be uniform, i.e. there was no variability in agricultural income tax paid. This implies that either the variable

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4 The Ethiopian 1995/96 fiscal year ranges from July 7, 1995 to July 7, 1996.

5 In Ethiopia non-farm rural job opportunities are rare. Non-farm activities available include, weaving, pottery, gold smith, hand crafts, trading, brewing etc. During the survey only 5% of sampled farmers reported having non-farm income. Trading and brewing were reported by only 3% of farmers. The amount of income reported from this source ranges from 20 to 100 birr per year. Such low figures suggest there is tendency not to report or under-report.
should be dropped from the analysis or the sample size should be reduced by 2 PAs. The first option was selected and the information on agricultural income tax paid by sample farmers was excluded from the analysis in the econometric models. This limitation of the data explains why income and profitability variables are not included in the analysis presented in the later chapters.

6.5. Variables Definition, Measurement and Its Expected Effects

Adoption decisions of farmers can be influenced by a number of economic, social, and agro-ecological factors (as shown in Chapter 3). Some of the factors that influence adoption vary from area to area and their effects on adoption are often not uniform over space and time. Because of this, the reaction of farmers to new technology is often not precisely the same. In the remaining part of this section, the variables hypothesized to affect farmers' adoption decisions and intensity of use of fertilizer and herbicide are discussed.

6.5.1. Economic variables

*Farm Size* (FRSZ): The relationship between farm size and rate of adoption has been investigated in many theoretical and empirical adoption studies. Since these studies are done under different economic, social, agro-ecological, etc. conditions for technologies having different characteristics, their outcomes vary across space and over time. This is to say that the effect of farm size may vary from place to place and from time to time. To illustrate this idea, let us consider the effects of farm size on adoption over time; at early stage of technology adoption, farmers with large farm size may adopt the technology first because of their risk-bearing capacity. At later stages, all farmers may get sufficient information about the
technology and farm size might not be as important as it was at the initial stage of technology introduction. Similarly, conditions may vary across regions and this may lead to difference in the effects of farm size among regions.

In general, large farms will be more likely to adopt a technology, especially if the technology requires an extra cash investment. The early adoption by large farms can be explained by their better access to credit, inputs, and information. Large farms also mean more resources and a greater capacity to bear risk involved in the adoption of new agricultural technologies.

In the study area, farm size is an indicator of the available economic farm resources. Relatively large farm size entails more resources and a greater ability to invest in improved varieties, fertilizer and herbicide. Hence, a positive relationship is expected between farm size and decision to adopt improved varieties, fertilizer and herbicide at a given point of time and over time, as well.

Labour (FMLB): In Ethiopia, seasonal labour shortage is one of the important constraints affecting crop production. Peak season labour shortage affects timeliness of farm operations and this, in turn, affects productivity at farm level. Labour availability is often mentioned in theoretical and empirical studies as one of the determinant factors affecting farmer’s adoption decision. The effect of labour on adoption decisions actually depends on the nature of the technology under investigation. Some agricultural technologies require more labour than old technologies. For instance, fertilizer requires additional labour for its application and for weeding. In the study area, hired labour during peak time is scarce, and timely operation of farm activities depends on the availability of family labour. Hence, a technology that requires additional labour may be less attractive for those families with limited family size. Therefore, an increase in the availability of family labour is hypothesized to positively affect adoption decision on fertilizer and improved varieties. On the other hand,
technologies such as herbicide, tractors, and threshers are labour saving. Application of herbicide, for example, relieves a labour shortage problem and makes it possible for more timely weed control, allowing increased production. Thus, other factors being constant, families with a limited labour supply are more likely to use herbicides, and a negative relationship is expected between family size and the adoption of herbicide.

*Number of oxen (OXEN):* In the study area, oxen are almost the only source of draught power for land preparation and threshing. Using a pair of oxen, tef and wheat fields are ploughed on average 5 and 4 times, respectively. Land preparation is a prerequisite for any crop production activity. Tef requires fine seed bed preparation because of its small grain size. Wheat production also requires good land preparation. Under rainfed agriculture, the timing of land preparation determines the type of crop to be grown in the season and activities to be undertaken once a crop is chosen. If land preparation is delayed due to shortage of oxen, a farmer may drop the idea of planting an improved varieties and/or drop the idea of applying fertilizer to minimize the risk that may arise because of late planting. In the study area, the quality and timeliness of land preparation and timely planting of tef and wheat depends on the number of oxen owned. Farmers need at least one pair of oxen to be able to prepare their land well and on time. Therefore, the number of oxen owned by a farmer is hypothesized to be positively related to the decision of farmers to adopt the improved varieties of wheat and intensity of use of fertilizer and herbicide.

*Price of Output (PINDEX(t)):* In theory the price of output is expected to have an impact on profitability of a technology and thereby on individual adoption behaviour. In practice, limited cross-sectional variability in output prices constrains the use of this variable in a study of individual adoption behaviour. Thus, the impact of output price on farmer's adoption decisions is not widely investigated in empirical adoption studies. This stems from the nature of data and the way data are collected. For data collected through surveys,
output prices received by farmers in a certain locality at a given period are similar. As a result, the variable that represents output price is usually dropped from the analysis or replaced by a proxy variable. However, the proxy variable may represent a variety of effects the market has on technology adoption and may not single out the effect of output price on new technology adoption. In this study, we overcome this problem by including the price index in the analysis. This is possible in duration analysis, as duration analysis can predict the effect of time-varying and time-invariant variables on adoption of technology over time. The method for combining time-varying and time-invariant variables is illustrated in LIMDEP version 7 manual (Greene, 1996). The rationale in using price as explanatory variable is that high output prices generally serve as an incentive to increase production.

In Ethiopia, different price policies have been implemented over the last two and half decades. Until the mid 1970s agricultural output prices were determined by market forces. From the late 1970s to the end of the 1980s, however, the role of the market was distorted because of government interventions through price control (price fixing) and inter regional trade regulation. During this period, licensed grain traders' grain trade activities were restricted their role was partly taken over by a government agency called the AMC. On the other hand, unlicensed\(^6\) small grain traders flourished in areas closer to big urban centres and in areas where transport facilities are well developed. Thus, a parallel market was operational alongside the controlled marketing system. In March 1990 price control policy and inter-regional trade regulation were lifted and the grain trade was liberalized. Since then, the interaction between demand and supply has been allowed to determine grain prices. In the study area, output price might have served as an incentive for technology adoption on tef and wheat even during price control periods for the following reasons: 1) Many unlicensed grain traders

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\(^6\) Unlicensed grain traders are traders who are not registered with the authority that issues licences. These traders do not pay income tax and they handle small quantities of grain usually 2-3 qt per market day. They visit more than two markets a week.
operated in the area. This group handles only small quantities at any one time, but they serve a number of market days each week. Urban consumers prefer to consume tef produced in the study area because of its quality. As a result, grain prices in the area are relatively high compared to prices of grains produced in other regions of the country. It is, therefore, hypothesized that output price is positively related to the rate of adoption of fertilizer and herbicide over the year.

*Access to Credit* (CRDT): Small farmers are often faced with cash shortages. On the other hand, new technology adoption requires an initial cash outlay (investment) which may account for a considerable proportion of a farmer's annual income. Thus, a shortage of cash may discourage small farmers from adopting new technology and differential access to capital often leads to different adoption behaviour.

In Ethiopia, fertilizer is sold to farmers on credit and for cash. In the case where fertilizer is sold on credit, farmers are obliged to pay a 25 percent down-payment. Thus, farmers access to credit is determined by their ability to pay the 25 per cent down-payment. Furthermore, farmers who have not settled overdue credit will be denied access to more credit. Thus, it is expected that access to credit positively influences adoption of improved wheat varieties and intensity of adoption of fertilizer and herbicide on tef and wheat. Here credit is represented by dummy variables (*one* if obtained from official or informal markets, otherwise *zero*).

*Farmers' perceptions of input prices* (FPIP): Theoretical and empirical studies suggest that innovations that require high initial investment are less likely to be adopted by farmers than innovations that require smaller initial investment. In the case of divisible technology such as

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7 There are traditional open markets held on different days of the week. The government attempted to reschedule the traditional market days from working days to Saturday and Sunday. However, the attempt was not fully implemented because of resistance from market participants (traders, farmers and consumers).
fertilizer, the level of its price determines the level of cash outlay that farmers have to commit. A relatively high fertilizer price means an increase in investment (cash outlay) on fertilizer. Many farmers feel that the price of fertilizer and improved varieties are getting beyond their purchasing power. It is assumed that the high price of fertilizer, herbicide and improved varieties as perceived by farmers constitutes a disincentive for farmers to invest or adopt these new technologies. Thus, negative relationships are expected between farmers’ perceptions of the expensiveness of the various technologies and their adoption behaviour. In this study, the effect of input prices on adoption is assessed by analysing farmers’ perceptions of input prices. Farmers’ perceptions were measured using dummy variables. Thus, we assigned value one if a farmer considers the price of input very expensive, zero otherwise.

**Farmers’ perception of risk and uncertainty (PRKT):** It is a well-known fact that agricultural production in developing economies is characterized by uncertainties arising from unpredictable climate and unstable markets. Furthermore, small farmers are more prone than large farmers to uncertainties arising from erratic rainfall and unpredictable price-fluctuations. The consequence of uncertain events on small farmers is more severe since they do not have means to mitigate them. Technologies may entail a subjective risk and objective risks. Subjective risk arises with the introduction of unfamiliar technology (technique) which may lead to uncertain yield expectations, while objective risks arise due to weather variations, pest occurrences, and market price fluctuations. Subsistence farmers follow risk-aversion behaviour in crop production and they may want to avoid the risk of their return (yield) falling below a certain minimum (subsistence) level. Thus, subsistence farmers may not adopt a technology until they get sufficient information that reduces technical (subjective) uncertainty. In general, uncertainty about climate, lack of market information and lack of information about the likely outcome of the new technology may lead to sub-optimal economic decision making and may lead to rejection or slowness to adopt new technology.
Farmers' perceptions of risk and uncertainty may determine the course of action they have to take to cope with the incidence of unpredictable climate, price variations and uncertain yield expectation. Here, farmers' perceptions are defined through their evaluation of the circumstances under which they make decision. Uneven distribution of rainfall, late on-set, early finishing and shortage of rainfall in mid-season are sources of risk and uncertainties in the study area. Unpredictable grain prices are also another sources of risk and uncertainty. Thus farmers' perception of these uncertainties is expected to affect their adoption decision on fertilizers, improved varieties and herbicides. Farmers' risk-aversion behaviour is measured using dummy variables. A farmer is considered as risk-averse if he responded "yes" to the question "Would you use improved varieties and fertilizer if you expected rainfall to be insufficient?" and value one was assigned. If the response was "no", we assumed he was not risk-averse and the dummy variable takes the value zero.

Distance to Market (DMKT): In Ethiopia rural infrastructure is under-developed, and the existing infrastructure is concentrated in rural towns. Most traditional open markets are held in towns and farmers visit these markets for disposal of their produce and purchase of industrial goods and inputs. Farmers closer to markets have an advantage in having easy access to information and credit. They face lower transport costs for marketing their produce and purchased inputs. For those farmers who are far away from the output and input markets, transport costs may be prohibitive, leaving no incentive to use new technologies since they have to pay high transport costs for inputs and marketable output. Distance from the market may capture variations in access to credit, off-farm job opportunities, transport costs, access to information (from urban-based input suppliers and extension messages) and access to market outlets for produce. This implies that the further the farmer is located from a market, the more likely he will be to incur increased transport costs and the less likely to have access to credit and information. Increased transport costs for input and output reduce the effective
price a farmer receives for output and increases the effective price he pays for acquisition of inputs. Therefore, it is hypothesized that distance to market is inversely related to the adoption of improved wheat varieties and intensity of adoption of fertilizer and herbicide.

6.5.2. Non-Economic Variables

Age (AGE and AGE): Past adoption studies have shown that the age of the household head, (i.e. the decision maker) influences adoption decisions. The relationship between age and technology-adoption could be negative or positive. Empirical findings suggest two possible reasons for this relationship. First, younger farmers have been found to be more flexible in their decisions than older farmers. They may be more willing to bear risk due to their longer planning horizons and because they have more schooling than the older generation. The second line of argument is that older farmers may have more experience and resources which allow them more possibilities for trying a new technology. Here we hypothesize that the age of a farmer will influence the rate of adoption of improved varieties of wheat and intensity of adoption of fertilizer and herbicide on tef and wheat. Under this hypothesis, the direction of effect of age on technology-adoption could be negative or positive and it is left open to be determined by data. AGE, a is time-varying variable indicating the cumulative age of a farmer. Cumulative age is measured by taking a base age of a farmer at the year technology is first introduced or the year a farmer started farming and adding one each year until the year the adoption decision is made.

Education (EDUC): Evidence from empirical studies indicates that education plays a significant role in the technology adoption process. Education improves a decision maker's managerial skill. Education may also make a farmer more receptive to advice from an external source such as an extension agent or technology supplier. It equips farmers with the necessary
skills to deal with technical recommendations that require a certain level of literacy and numeracy. Farmers who can read and write are more efficient in grasping new ideas brought to their attention by extension agents. They are also more efficient in allocation of their limited resources. This implies that the educated farmer is more likely to be aware of and willing to adopt new technologies. Thus, in this study, education is hypothesized to influence positively the adoption of improved varieties of wheat and use of fertilizer and herbicide on tef and wheat. Furthermore, a positive association is expected between the duration of adoption of fertilizer and herbicide and education.

*Extension* (INFO): Access to information about new technologies leads to knowledge about how the technologies can optimally be used and may reduce subjective (technical) uncertainty. This, in turn, may have an impact on the adoption behaviour of farmers. In Ethiopia, information about new technology is transferred to farmers through regular extension services by MOA, radio broadcasts and through outreach programmes by various research centres. The extension agents convey extension messages through different methods. The agents directly visit selected contact farmers and give advice about when and how new technologies are used. The extension agents also demonstrate the advantage of new technology over the old ones, by laying down demonstration plots on permanent demonstration sites and on the contact farmers' fields. Field days are usually organized by extension workers to enable other farmers to visit demonstrations, on-farm trials and research centres. It is expected that direct contacts between farmers and extension agents, visits to practical demonstration sites and visits to on-farm trials and research centres increase farmers' awareness of the new technologies and their performance. It is thought that farmers' awareness of the technologies develops through the combined effect of extension activities (direct visits, training, demonstrations etc.) used in conveying information to farmers. Therefore, an information index that may reflect the combined effect was created as follows. $INFO = (extension\ contact/month$
+ visit demonstration or trial + participation in training) divided by three. The extension and farmers' interaction, as represented by the information index (INFO) is expected to have a positive effect on farmers' technology adoption decision.

**Gender (GNDR):** In Ethiopia, most rural households are headed by males. Female-headed households are few. The latter group depend on male members of their family or on hired labour for major farm operations such as land cultivation and planting. In spite of this, it is the responsibility of the household head to decide which types of crops and varieties to grow and which technology to use. Female-headed households are often forgotten in agricultural extension and so have limited access to credit and extension information about new technologies. It is hypothesized that female-headed households are therefore less likely to adopt improved wheat varieties and apply a small amount of fertilizer and herbicide on tef and wheat.

### 6.6. Conclusions

Data for empirical studies can be obtained using different methods. Application of one of the methods depends on the problem to be addressed and on availability of resources and time. For this study, the sample survey method was employed to collect data required to assess technology adoption process. This method saves time and resources and is an appropriate method to generate primary economic data. A survey of 200 sample farmers was conducted in four weredas located in West and East Shewa zones of Ethiopia. Sampling is crucial to the survey method of data collection. Hence, a three-stage sampling procedure was applied to select weredas, Peasant Associations and sample farmers randomly. A set of data that includes personal, household and farm characteristics, use of inputs and technologies were collected using a structured questionnaire.
Adoption of technologies can be influenced by many factors. Based on theoretical and past empirical findings, variables which affect technology-adoption were identified. The variables thought to affect adoption of improved varieties, fertilizer, and herbicide include farm size, credit, prices of outputs, number of oxen owned, education, extension, age and price of inputs. The latter two variables may have negative impact on the adoption of technologies. The remaining other variables are expected to have a positive impact on the adoption of the three technologies. The effect of labour on adoption could be negative or positive depending on the type of technology considered. For instance, availability of labour may not encourage adoption of herbicide and other labour saving technologies. Profitability is another important variable known to influence technology adoption. As issues related to yield and income are sensitive and it was not possible to secure reliable information on expected profitability or return, this variable will not be included in empirical models.
7.1. Introduction

One of the objectives of this study is to determine the rate and intensity of technology adoption by farmers in the study area. This chapter describes the rate and intensity of adoption of improved varieties, fertilizer and herbicides for tef and wheat. The analytical methods applied in this chapter are simple descriptive statistics including percentages, contingency tables with chi-square and mean comparisons. The two-way (bivariate) analysis depicts the impact of an individual factor on adoption and helps to identify variables that should be included in the econometric models.

The chapter continues in Section 7.2 with a description of personal and household characteristics. Section 7.3 follows with a general description of farm characteristics. Section 7.4 examines whether and to what extent the technologies have been adopted. The adoption patterns of the technologies and reasons for non-adoption are discussed in the same section. This is followed by an analysis of the links between household, farm characteristics and adoption in Section 7.5. The effect of some selected institutional variables on the rate and intensity of adoption are assessed in Section 7.6. The final section summarises the main findings and indicates how they influenced the choice of variables to be included in the analysis reported in the later chapters. There are some variables which are included in this chapter but not in the later chapters.
7.2. Description of Household and Personal Characteristics

The sample households have a total of 1356 members with an average family size of 6.9 persons and standard deviation of 2.7 persons. From the total household members, 52% are male and 48% are female. The average family size in the study area is greater than the national average of 5 persons. This implies the existence of potential labour for various farming activities. On average, 3.6 persons per household are potentially active agricultural workers (i.e. between 15 and 60 years of age). However, the number of family members permanently engaged in on-farm work is about 2.6 persons (Table 7.1). About 0.44 persons work on-farm part time. Children less than 15 years of age accounted for 42% of the family. This indicates that there is a high number of dependents per household. Labour hiring seems to be common in the study area. In the survey year, about 55% of sample farmers used hired labour either for weeding or harvesting of tef and wheat. Moreover, traditional means of labour mobilization, such as debo (raising labour by preparing food and drinks), and wenfel (exchanging labour between individual farmers) were practised by farmers. About 85% of the households are headed by a male while the remaining 15% are headed by a female.

The average age of farmers in the sample is 51 years with a coefficient of variation of 0.29. The average length of farming experience is 27 years with CV of 0.56. Farming experience was counted from the time the farmer started his or her own farm. Thus, the farmers have long farming experience. Concerning the education of the sample household heads, about 38% of them can read and write (Table 7.2). However, the number of years of schooling for most of those farmers who reported they could read and write is less than 6. Nearly 45% of them took advantage of the literacy campaign undertaken in the early 1980s but can only sign their name since there was no follow up programme and library.
Table 7.1. Family size, gender and age distribution of sample household.

<table>
<thead>
<tr>
<th>Family size/age distribution</th>
<th>Average Number (persons)</th>
<th>Coefficient of Variation (CV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average family size</td>
<td>6.92</td>
<td>0.38</td>
</tr>
<tr>
<td>Active agri. workers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male 15-60 years of age</td>
<td>2.09</td>
<td>0.66</td>
</tr>
<tr>
<td>Female 15-60 years of age</td>
<td>1.54</td>
<td>0.64</td>
</tr>
<tr>
<td>Persons above 60 years of age</td>
<td>0.36</td>
<td>1.47</td>
</tr>
<tr>
<td>Children 10-14 years of age</td>
<td>1.21</td>
<td>0.94</td>
</tr>
<tr>
<td>Children below 10 years of age</td>
<td>1.70</td>
<td>0.85</td>
</tr>
<tr>
<td>Permanently working on farm</td>
<td>2.55</td>
<td>0.67</td>
</tr>
<tr>
<td>Working off-farm</td>
<td>0.07</td>
<td>3.47</td>
</tr>
<tr>
<td>Working part time on-farm</td>
<td>0.44</td>
<td>2.09</td>
</tr>
</tbody>
</table>

Source: Survey data.

Table 7.2. Education level of sample household heads.

<table>
<thead>
<tr>
<th>Education Level</th>
<th>Number</th>
<th>Per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illiterate</td>
<td>122</td>
<td>62.24</td>
</tr>
<tr>
<td>Read and write</td>
<td>74</td>
<td>37.76</td>
</tr>
<tr>
<td>Attended literacy campaign classes</td>
<td>33</td>
<td>16.84</td>
</tr>
<tr>
<td>1-3 years</td>
<td>16</td>
<td>8.17</td>
</tr>
<tr>
<td>4-6 years</td>
<td>17</td>
<td>8.67</td>
</tr>
<tr>
<td>7-8 years</td>
<td>6</td>
<td>3.06</td>
</tr>
<tr>
<td>Above 8 years</td>
<td>2</td>
<td>1.02</td>
</tr>
</tbody>
</table>

Source: Survey data.

In the study area, farming is the main occupation and off-farm job opportunities are rarely available. About 95% of farmers indicated farming as their full-time occupation, a secondary occupation being reported by only 5%. The type of off-farm work reported includes trading, weaving, handcrafts, brewing, leather making and pottery.
7.3. Description of Farm Characteristics

Table 7.3 presents information on the sample farm size, distribution and land use patterns. The average farm size is 2.49 ha with standard deviation of 1.72 ha. Because of population pressure, the average holding is small and most of the farmers (66%) have 2.5 ha or less. Farmers used more than 82% of their land for crop cultivation. The principal crops grown are tef, wheat and chickpeas. Minor crops include barley, sorghum, vetch, lentils and faba-beans. Tef, the most important food and cash crop, accounts for 60% of the cultivated area (Table 7.4). Farmers grew three types of tef in 1995. The proportion of farmers growing red, mixed and white tef were 74%, 48% and 32% respectively. About 91% of white tef growers planted white tef mainly for sale. Wheat is the second most important crop accounting for 24% of the cultivated area. Only 17% of the land was allocated for grazing so there is a shortage of grazing land. The land left fallow was negligible, reflecting the population pressure on land.

In addition to cultivating annual crops, the farmers keep livestock on their farms for various economic and social reasons. Farmers keep livestock, mainly cattle, primarily as a source of draught power, food and cash income. They also keep livestock as a means of accumulating wealth and for security (i.e. to sell when their crops fail). Table 7.5 shows the average number of livestock kept on farm by type for the total sample of farmers and for the livestock owners sub-sample. Farmers keep, on average, 4.66 Livestock Units (LU) per household.
**Table 7.3.** Household land use pattern and farm size distribution.

<table>
<thead>
<tr>
<th>Land use</th>
<th>Area (ha)</th>
<th>Farm size groups</th>
<th>Proportion of farmers in each groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average farm size</td>
<td>2.49</td>
<td>≤ 1.50 ha</td>
<td>24</td>
</tr>
<tr>
<td>Cultivated land</td>
<td>2.05</td>
<td>1.50-2.50 ha</td>
<td>42</td>
</tr>
<tr>
<td>Grazing land</td>
<td>0.41</td>
<td>2.51-3.50 ha</td>
<td>18</td>
</tr>
<tr>
<td>Fallow land</td>
<td>0.02</td>
<td>&gt; 3.50 ha</td>
<td>16</td>
</tr>
<tr>
<td>Homestead</td>
<td>0.01</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Survey data.

**Table 7.4.** Crops grown and area allocated to each crop by sample household.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Area (ha)</th>
<th>CV</th>
<th>Growers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Number</td>
</tr>
<tr>
<td>Tef</td>
<td>1.23</td>
<td>0.73</td>
<td>189</td>
</tr>
<tr>
<td>Wheat</td>
<td>0.50</td>
<td>1.00</td>
<td>151</td>
</tr>
<tr>
<td>Barley</td>
<td>0.06</td>
<td>2.14</td>
<td>49</td>
</tr>
<tr>
<td>Sorghum</td>
<td>0.10</td>
<td>2.00</td>
<td>49</td>
</tr>
<tr>
<td>Chickpea</td>
<td>0.10</td>
<td>1.64</td>
<td>68</td>
</tr>
<tr>
<td>Vetch</td>
<td>0.05</td>
<td>2.13</td>
<td>49</td>
</tr>
<tr>
<td>Others</td>
<td>0.01</td>
<td>-</td>
<td>11</td>
</tr>
</tbody>
</table>

Source: Survey data.
Bivariate Analysis

Table 7.5. Average number of livestock kept on farm by type of livestock.

<table>
<thead>
<tr>
<th>Type and class</th>
<th>Sample</th>
<th>Owners</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>LU</td>
</tr>
<tr>
<td>Oxen</td>
<td>2.03</td>
<td>2.03</td>
</tr>
<tr>
<td>Cows</td>
<td>1.19</td>
<td>0.86</td>
</tr>
<tr>
<td>Heifers</td>
<td>0.64</td>
<td>0.35</td>
</tr>
<tr>
<td>Bulls</td>
<td>0.59</td>
<td>0.59</td>
</tr>
<tr>
<td>Calf</td>
<td>0.68</td>
<td>0.23</td>
</tr>
<tr>
<td>Sheep</td>
<td>0.46</td>
<td>0.09</td>
</tr>
<tr>
<td>Goats</td>
<td>0.59</td>
<td>0.12</td>
</tr>
<tr>
<td>Donkeys</td>
<td>0.84</td>
<td>0.61</td>
</tr>
<tr>
<td>Horses</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Total</td>
<td>-</td>
<td>4.66</td>
</tr>
</tbody>
</table>

Source: Survey data.

( ) figures in the parentheses indicate the number of cases considered.

As noted above, the main aim of rearing cattle, in smallholder mixed farming, is to generate draught power for crop cultivation. At least one pair of oxen is required for land preparation. The sample farmers owned, on average, 2.03 oxen with standard deviation of 1.51 oxen. Therefore, from the average value, it looks as though farmers have sufficient oxen for land preparation. However, if we categorize sample farmers by the number of oxen owned, about 33% of farmers do not have a sufficient number of oxen, while 17% have more than one pair.

7.4. Adoption of Technology for Tef and Wheat

This section describes the rate of adoption of improved varieties, fertilizer, herbicide, broad-bed maker and tractors. It also presents the intensity of use of the first three types of technology on tef and wheat. The sequences of adoption of this technology was also discussed.
7.4.1. Rate and Intensity of Fertilizer Adoption

Fertilizer was introduced to the study area in early 1970s through a minimum package programme and FAO's fertilizer demonstrations. Since then MOA has been promoting the use of fertilizer through its regular extension programmes. Due to these extension activities, farmers have a general awareness of fertilizer and its importance in increasing productivity. Table 7.6 provides a broad picture of fertilizer adoption rates on tef and wheat. From the sample households, 92% and 61% of farmers used fertilizer in tef and wheat production in 1995, respectively. The proportion of farmers who have ever used any fertilizer on tef is 93% while the proportion still using fertilizer on tef is 92%. This, suggests that use of fertilizer is well established and farmers do continue using fertilizer once they have adopted it.

<table>
<thead>
<tr>
<th>Adoption</th>
<th>Tef</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Percent</td>
</tr>
<tr>
<td>Ever used</td>
<td>183</td>
<td>93</td>
</tr>
<tr>
<td>Applied in 1995</td>
<td>180</td>
<td>92</td>
</tr>
</tbody>
</table>

Source: Survey data.

A great variation was noticed in the adoption of fertilizer on tef and wheat. This variation may be explained by the priorities farmers attach to tef and wheat and by economic factors attributed to these crops. In the study area, tef is a high value crop; it fetches a higher price than wheat or any other cereals. Because of this it receives high priority in fertilizer allocation. Figure 7.1 shows the rate of adoption of fertilizer over the period 1971-1995. A significant proportion of farmers adopted fertilizer in 1976. The rate of adoption was also high for tef in 1986. The high rate of adoption that occurred in 1976 can be attributed to extension
activities carried out during that time. The minimum package extension programme, implemented in early 1970s, promoted fertilizer and improved varieties as a core technological package in the study area. The programme reached many farmers by mid 1976 and probably contributed to the high acceptance of fertilizer. The two periods of peak adoption of fertilizer were also associated with post famine periods. Following the famine years, concerted efforts were made to overcome food supply shortages in the country. A national food self-sufficiency objective was set by the government and extension activities strengthened in surplus producing areas. To meet the food self-sufficiency objective, new technologies were promoted to increase production. Fertilizer and credit were made available to farmers and this has increased the adoption rate.

Figure 7.1. Rate of fertilizer adoption over time in East and West Shewa zones.

In general, there was a steady but slow rate of adoption of fertilizer on both crops. About half of the sample farmers had adopted fertilizer on tef by 1980. A close look at Figure 7.1 shows that the remaining 40% of adopters adopted fertilizer over the following 15 years.
period. Thus, it took 25 years to reach the current fertilizer adoption rate of 92% on tef. In the case of wheat, only 61% of the sample farmers have adopted fertilizer over the past two and half decades. As can be seen from Figure 7.1, the cumulative fertilizer adoption curve for wheat inclines more toward the horizontal axis than the cumulative fertilizer adoption curve for tef. This suggests that the rate of adoption of fertilizer on wheat is slower than the rate of fertilizer adoption on tef.

The factors that contributed to the slow rate of adoption on both crops may take two forms: supply-side and demand-side problems. In Ethiopia fertilizer is not domestically produced; it is imported using foreign currency obtained from export, long-term credits and donations. In most years, the quantity of fertilizer required has not been available because of shortages of foreign currency, high freight costs, and the ineffectiveness and inefficiency of the organizations involved in procuring and marketing fertilizer. Moreover, poor infrastructure, especially limited all-weather and feeder roads, shortages of transport facilities and lack of adequate storage facilities have contributed to lack of availability at the right time.

The demand-side constraints are discussed in Chapter 8 and 9. Here we briefly highlight the effect of fertilizer prices on adoption. Fertilizer prices increased greatly over the study period. Although prices of outputs also increased, widespread poverty and limited purchasing power makes fertilizer too expensive in the eyes of farmers. Thus, according to the survey, about 79% of sample farmers feel that fertilizer is very expensive. This perception was shared even by those farmers who adopted fertilizer.

The intensity of use of fertilizer is shown in Table 7.7 for both crops. The intensity of fertilizer adoption is measured in terms of crop area fertilized and the ratio of fertilizer applied by farmers (amount applied as a percent of the recommendation). About 93% and 84% of tef and wheat fields were fertilized in 1995 with an application rate of 122 and 93 kg/ha (Table
These rates are higher than the national average of 34 kg/ha\(^1\) in 1995 and lower than the agronomic recommendation of 150 kg/ha (100 kg DAP and 50 kg Urea). For adopters, the observed application rates were a little lower than the agronomic recommendation of 150 kg/ha for tef and about the same in the case of wheat. In East Shewa zone, fertilizer rate applied by some farmers was greater than the agronomic recommendation. Recently, another agronomic recommendation of 200 kg/ha (100 kg DAP and 100 kg Urea) was introduced and being demonstrated through Sasakawa-Global 2000 project and through an intensification programme run by the regional states' agricultural bureaux. When we compare farmers' average application rates with the new blanket recommendation, it is lower than the recommended rate.

Table 7.7. Intensity of fertilizer adoption on tef and wheat.

<table>
<thead>
<tr>
<th>Adoption</th>
<th>Tef</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sample</td>
<td>Growers</td>
</tr>
<tr>
<td>Total area (ha)</td>
<td>1.23</td>
<td>1.30</td>
</tr>
<tr>
<td>Fertilized area (ha)</td>
<td>1.15(93)</td>
<td>1.24</td>
</tr>
<tr>
<td>Appl. rate (kg/ha)</td>
<td>112</td>
<td>133</td>
</tr>
</tbody>
</table>

Source: Survey data; Figures in parentheses indicate percentages.

The recommended types of fertilizers were not used in combination by some farmers. For instance, researchers recommended the application of DAP and Urea in combination. In 1995, only 59% and 36% of farmers used the two types of fertilizer in combination on tef and wheat, respectively. Most of the farmers who applied the two types of fertilizer in combination did not stick to the recommended rate. About 88% and 59% of sample farmers applied only DAP on tef and wheat, respectively. These results are consistent with the finding of Beyene

\(^1\) This rate is higher than the commonly reported national average of 10 kg/ha. Since nearly all fertilizer is applied on cereals, the national average reported here is estimated by dividing total fertilizer consumption by cereal area.
et al. (1991), Legesse et al. (1992), and Hailu et al. (1992). With regard to application method, nearly all farmers applied at the planting time using the broadcasting method. About 44% of the sample farmers did not follow the recommended split-application\(^2\) of Urea on tef. No single farmer applied Urea on wheat using a split-application method.

The observed rate and intensity of fertilizer adoption on both crops showed that most farmers apply fertilizer. The use of fertilizer has become a well established practice in the study area. However, some farmers did not apply fertilizer and most farmers did not use the recommended fertilizer rate. Therefore, one needs to examine why these farmers did not apply fertilizer and what factors caused the low level of fertilizer application. Those farmers who did not apply fertilizer in 1995 were asked why they did not. About 86% of them reported that the fertilizer was too expensive to use. The remaining farmers mentioned the risk associated with fertilizer application. Farmers were also asked whether they had purchased the amount they needed. Fifty nine per cent of the sample farmers responded that they bought the amount they needed in 1995. About 9%, 58%, 15%, and 44% of the remaining farmers reported they did not buy the required amount because of unavailability, cash shortage, untimely availability, and expensiveness of fertilizer, respectively (the percentages given do not add up to 100% because of multiple responses).

\(^2\) Split application is an application where the amount fertilizer recommended is divided into two or three and applied at different times.
7.4.2. Rate and Intensity of Improved Varieties Adoption

Research programmes on tef and wheat have produced improved varieties that have the potential to increase productivity. As evidenced by a number of verification trials and demonstrations, improved varieties of tef and wheat are more productive than the local varieties, respectively (Table 7.8). To narrow the yield gap, improved varieties were introduced as a package with fertilizer. Nevertheless, the rate of adoption of improved varieties was low and lagged behind the rate of adoption of fertilizer. This is more pronounced in the case of improved tef variety. As indicated in Table 7.9, only 20% and 43% of the sample farmers planted the improved varieties of tef and wheat in 1995, respectively. The rate of adoption of improved varieties was very slow over the years, as well.

Table 7.8. Potential impact of improved varieties on productivity.

<table>
<thead>
<tr>
<th>Crop/variety</th>
<th>Adaptation zone</th>
<th>Seed rate (kg/ha)</th>
<th>Yield potential (qt/ha)</th>
<th>Demn. yield* (qt/ha)</th>
<th>Farmers’ yield (qt/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Altitude (masl)</td>
<td>Rainfall (mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tef</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cross-37</td>
<td>1800-2200</td>
<td>134-500</td>
<td>25-30</td>
<td>14-16</td>
<td>15</td>
</tr>
<tr>
<td>DZ-01-196</td>
<td>1800-2400</td>
<td>300-700</td>
<td>25-30</td>
<td>14-16</td>
<td>14</td>
</tr>
<tr>
<td>DZ-01-354</td>
<td>1600-2400</td>
<td>300-700</td>
<td>25-30</td>
<td>17-22</td>
<td></td>
</tr>
<tr>
<td>DZ-01-787</td>
<td>1880-2000</td>
<td>400-700</td>
<td>25-30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Durum wheat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buhea</td>
<td>1850-2400</td>
<td>500-900</td>
<td>125-150</td>
<td>25-45</td>
<td></td>
</tr>
<tr>
<td>Foka</td>
<td>1800-2600</td>
<td>500-900</td>
<td>125-150</td>
<td>25-45</td>
<td>26</td>
</tr>
<tr>
<td>Bread wheat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enkoy</td>
<td>1850-2800</td>
<td>500-800</td>
<td>125-150</td>
<td>40-60</td>
<td></td>
</tr>
<tr>
<td>Deresclign</td>
<td>1850-2800</td>
<td>400-600</td>
<td>125-150</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Ke-629.4A</td>
<td>1850-2750</td>
<td>&gt; 600</td>
<td>125-150</td>
<td>40-60</td>
<td></td>
</tr>
<tr>
<td>Ke-6290 Bulk</td>
<td>1850-2150</td>
<td>500-600</td>
<td>125-150</td>
<td>40-60</td>
<td></td>
</tr>
<tr>
<td>ET-13</td>
<td>1800-2900</td>
<td>&gt; 600</td>
<td>125-150</td>
<td>40-60</td>
<td></td>
</tr>
</tbody>
</table>

Source: IAR. * indicates average yield on demonstration plots.
Table 7.9. Rate of adoption of improved varieties, in East and West Shewa, 1995.

<table>
<thead>
<tr>
<th>Adoption</th>
<th>Tef</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Percent</td>
</tr>
<tr>
<td>Rate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Awareness</td>
<td>100</td>
<td>51</td>
</tr>
<tr>
<td>Ever planted</td>
<td>41</td>
<td>21</td>
</tr>
<tr>
<td>Planted in 1995</td>
<td>39</td>
<td>20</td>
</tr>
</tbody>
</table>

Source: Survey data.

Table 7.10. Intensity of adoption of improved varieties.

<table>
<thead>
<tr>
<th>Adoption</th>
<th>Tef</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sample Growers</td>
<td>Sample Growers</td>
</tr>
<tr>
<td>Total area (ha)</td>
<td>1.23</td>
<td>0.50</td>
</tr>
<tr>
<td>Area under improved variety area (ha)</td>
<td>0.20(16)</td>
<td>0.24(48)</td>
</tr>
<tr>
<td>Seed rate (kg/ha)</td>
<td>49</td>
<td>135</td>
</tr>
</tbody>
</table>

Source: Survey data.

The proportions of the areas allocated to improved varieties were 16% for tef and 48% for wheat, when the total sample is taken. The figures rise to 64% and 88% for tef and wheat respectively, when only adopters are considered. The area planted with improved varieties (Table 7.10) was quite small compared to the area allocated to fertilizer (Table 7.7). Thus, the intensity of adoption of varieties was lower than the intensity of use of fertilizer. Although, demand-side constraints contributed to delayed adoption, supply-side problems might be of great importance for the delayed adoption of improved tef and wheat varieties.

In Ethiopia, crop breeding research programmes have emphasised breeding and release of widely adaptable varieties. Since the country has very diversified agro-ecological zones, it is very hard and time consuming to find the varieties that perform best in each zone. The number of variety-testing sites currently used by breeders are few and they are not adequately distributed within or among different agro-ecological zones. As a result, some of the varieties
that were released failed to perform better than local varieties in many areas and those varieties were rejected by farmers.

The other supply-side problem that contributed to the low rate of variety adoption was the unavailability of improved seed. In general the amount of seed produced per year is very small. Over the period 1980 to 1994, the average amount of seed produced each year was about 23000 tons. This amount only covers approximately 5-8% of the total cereal area. Moreover, seed distribution is less developed than fertilizer distribution. As observed during the survey, public and private business companies and retailers involved in fertilizer distribution have no interest in distributing improved varieties because of fear of loss. For example, the AISE distributed seed to farmers in the past but stopped this activity after 1992. The reason given by the sales and distribution head of AISE was that they were not able to sell seed because of its high price and the consequent lack of demand. It has to be noted that seed was not made available to farmers in small packages to enable them to buy the amount they wanted. Moreover, beyond MOA’s regular extension activities, sound seed extension activities were lacking. Since 1993, regional agricultural offices have been involved in distribution of seed to farmers.

During the survey, the reasons why farmers did not grow improved varieties were investigated. The reasons given are presented in Table 7.11. It appears that expensiveness, unavailability, and lack of awareness were found important in determining the decision not to adopt varieties. However, the importance of these factors varied between the improved varieties of tef and wheat. Lack of awareness (34%) was more important for non-adoption of tef varieties, where expensiveness of seed (44%) was more responsible for rejection of improved wheat varieties. About 36% of wheat variety adopters obtained new seed from MOA, while 45% of adopters used improved varieties from previous harvests or obtained them from neighbours through exchange or purchase. The latter figure suggests that quite a large
proportion of farmers depend on the improved seed from the previous harvest to cope with the unavailability problem and high cost of purchased seed.

Table 7.11. Reasons given by farmers for not adopting improved varieties of tef and wheat (%).

<table>
<thead>
<tr>
<th>Reasons</th>
<th>Tef (N=139)</th>
<th>Wheat (N=94)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed expensive</td>
<td>25</td>
<td>44</td>
</tr>
<tr>
<td>Seed not available</td>
<td>27</td>
<td>19</td>
</tr>
<tr>
<td>Do not have information</td>
<td>34</td>
<td>14</td>
</tr>
<tr>
<td>Not convinced of its benefits</td>
<td>8</td>
<td>13</td>
</tr>
<tr>
<td>Drainage problem (no suitable land)</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Shortage of cash</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Shortage of draught power</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

Source: Survey data; Note: The percentages do not add up to 100 because of multiple responses.

7.4.3. Rate and Intensity of Herbicide Adoption

Herbicide was first introduced in the early 1970s. However, much emphasis has not been given to expanding the use of herbicide. This is mainly because policy makers have assumed that surplus labour exists in rural area and have therefore not supported the use of herbicide for weed control. As shown in a number of surveys (Aleligne, 1988; Legesse et al., 1987; Tilahun and Teshome, 1987; Kassahun et al., 1992) this assumption is not well founded in the Ethiopian context where labour shortages exist during the peak season. In the study area, labour shortages occur during planting and weeding time. Since farmers grow more than one crop, the planting activity of one crop overlaps with the weeding activity of the other and creates a high demand for labour for a short period of time. This encourages farmers to use labour-saving technologies.
Table 7.12. Rate of herbicide adoption on tef and wheat.

<table>
<thead>
<tr>
<th>Adoption</th>
<th>Tef</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Percent</td>
</tr>
<tr>
<td>Ever used</td>
<td>150</td>
<td>77</td>
</tr>
<tr>
<td>Used in 1995</td>
<td>144</td>
<td>74</td>
</tr>
</tbody>
</table>

Source: Survey data.

Table 7.13. Intensity of herbicide adoption on tef and wheat.

<table>
<thead>
<tr>
<th>Adoption</th>
<th>Tef</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sample</td>
<td>Growers</td>
</tr>
<tr>
<td>Total area (ha)</td>
<td>1.23</td>
<td>1.37</td>
</tr>
<tr>
<td>Area sprayed (ha)</td>
<td>0.86(70)</td>
<td>1.20(88)</td>
</tr>
<tr>
<td>Rate (lt/ha)</td>
<td>0.38</td>
<td>0.51</td>
</tr>
</tbody>
</table>

Source: Survey data; Figures in parentheses are in percentages.

In the study area, post-emergence herbicides are widely used for weed control in tef and wheat. Pre-emergence herbicides are unknown and no farmer adopted them. As shown in Table 7.12, 75% and 44% of farmers used post-emergence herbicides such as 2.4-D and U-46 for weed control in tef and wheat, respectively. About 53% of herbicide users applied 2.4-D and 2% of adopters applied U-46. The remaining farmers (45%) do not know the commercial name of the herbicide they applied. As depicted in Figure 7.2 herbicide application has been practised by some farmers since the early 1970s. Two points can be noted from the figure. In general, the rate of adoption of herbicide was slow specially on wheat. There was a tendency to apply herbicide on tef rather than on wheat. There was a substantial gap between rates of adoption on tef and on wheat in a given year. Figure 7.2 also suggests the existence of a widening gap between rates of herbicide adoption on the two crops over the years.
Non-adopters were asked why they did not apply herbicide. Two factors emerged from their responses: expensiveness (63%) and ineffectiveness (25%) of herbicides were the main reasons given for rejection of herbicide. In contrast to improved varieties, unavailability of herbicide was emphasized by only a few farmers (Table 7.14). Although policy makers do not encourage the use of herbicide, the distribution channels for herbicide are better developed in the Shewa and Arsi zones than those for seeds. Importation and distribution of herbicide is mainly done by national and multinational private companies. Most farmers (57%) purchased all their herbicide from traders, while 36% bought from MOA. The remaining farmers obtained herbicide from both sources.
Table 7.14. Reasons for rejecting herbicide technologies

<table>
<thead>
<tr>
<th>Reasons</th>
<th>Number</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Too expensive</td>
<td>33</td>
<td>63</td>
</tr>
<tr>
<td>Herbicide not effective</td>
<td>13</td>
<td>25</td>
</tr>
<tr>
<td>Have sufficient labour</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Not available</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Lack of information</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Source: Survey data.
Note: The percentages do not add up to 100 because of multiple responses.

As presented in Table 7.13, herbicide was sprayed on 70% and 48% of tef and wheat fields, respectively. If we consider only adopter farmers, the areas sprayed rise to 88% and 92% for tef and wheat. This indicates that herbicide was applied on a large area of crop fields once the adoption decision had been made. However, the rate of application was about half the recommended level\(^3\) for both crops. The low application rate might be explained by the expensiveness of herbicide. About 78% sample farmers feel that herbicide is expensive, and 42% of them did not purchase the amount they needed for the same reason.

7.4.4. Rate of Adoption BBM and Tractor and Harvester Hiring Services

In the study area, most farmers depend on animal traction for land preparation and threshing. Although privately owned tractor, harvester and thresher hiring services are emerging, few farmers reported using these services. In West Shewa zone, these services are not available. In East Shewa zone, limited services are available from government and privately-owned tractor and harvester hiring stations. In 1995 about 14% of the sample farmers from east Shewa zone used tractor hiring services on an average of 1.4 ha of land. Harvesting

\(^3\) The recommended application rate is 1 lt/ha for both crops.
and threshing services were utilized by only 4% of the surveyed farmers located in East Shewa.

The Broad Bed Maker (BBM) technology has been tested and is being promoted as a means of overcoming drainage problems associated with black vertisols. Our survey showed that no sample farmer adopted the technology in 1995. Of the total farmers interviewed only 13% had any awareness of BBM. The reason given by this group for not using the technology is that the implement is not available (Table 7.15). Apart from a limited number of implements distributed for testing purposes, the BBM has not been made available to farmers and has not yet been produced for commercial purposes.

Table 7.15. Reasons given by farmers for not using BBM.

<table>
<thead>
<tr>
<th>Reasons</th>
<th>Number</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not available</td>
<td>25</td>
<td>12.8</td>
</tr>
<tr>
<td>Not heard about BBM</td>
<td>167</td>
<td>85.2</td>
</tr>
<tr>
<td>No drainage problem</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>Not suitable to work with</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>Expensive</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>196</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Survey data.

7.4.5. Adoption Patterns and Sequences

Table 7.16 depicts adoption patterns of technology in 1995. From technology available to them, about 93% and 64% of the surveyed farmers adopted one or more types of technology on tef and wheat, respectively. About 15% and 27% of farmers used the three types namely, variety, fertilizer and herbicide as a package, on tef and wheat respectively. Quite a large proportion (58%) of farmers used fertilizer and herbicide together on tef in the survey year. The proportion of farmers that used fertilizer and herbicide together on wheat was
few (13%). No farmer adopted a new tef variety and herbicide together. The number of farmers that adopted an improved variety alone was also very small.

Table 7.16. Patterns of technology adoption on tef and wheat.

<table>
<thead>
<tr>
<th>Technology</th>
<th>Tef</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Percent</td>
</tr>
<tr>
<td>Fertilizer, herbicide and variety</td>
<td>30</td>
<td>15.3</td>
</tr>
<tr>
<td>Fertilizer and herbicide</td>
<td>113</td>
<td>57.7</td>
</tr>
<tr>
<td>Fertilizer only</td>
<td>29</td>
<td>14.8</td>
</tr>
<tr>
<td>Fertilizer and variety</td>
<td>8</td>
<td>4.1</td>
</tr>
<tr>
<td>Herbicide and variety</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Herbicide only</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>Variety only</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>Non-adopters</td>
<td>14</td>
<td>7.1</td>
</tr>
</tbody>
</table>

Source: Survey data.

Figure 7.3 presents the adoption sequences for fertilizer, herbicide, improved variety, and their combinations. An examination of farmers adoption sequences showed that very few number of farmers adopted all three technologies for the first time in the same year. Of the sample farmers only 21% and 7% respectively adopted fertilizer and herbicide together on tef and wheat in the same year. As depicted in the figure most farmers adopted components of a package of the three technologies step by step. For instance, 48% of fertilizer adopters, 34% of herbicide adopters, and 36% of variety adopters (including those farmers who planted an improved varieties only once), adopted only one component of the package in the year they first adopted the technology. They gradually added the new technologies component by component to complete the technological package shown in Table 7.16. Thus, farmers followed a step-wise adoption behaviour, a finding which is consistent with Byerlee and Hesse de Polanco (1986) and Leather and Smale (1991).
Figure 7.3. Pattern and sequence of fertilizer, herbicide, and variety adoption on tef and wheat by farmers.

Note: Only one and two farmers adopt the three technologies together on tef and wheat respectively in the same year.

7.5. Household and Farm Characteristics and Adoption

The adoption behaviour of farmers can be influenced by specific household and farm characteristics. Bivariate (two-way) analysis of survey data was conducted to assess the relationship between farm characteristics and the adoption behaviour of sample farmers. The chi-square and F-test statistics were employed to compare the categorical and means of continuous variables respectively. Table 7.17 presents the relationship between family size groups and rate of adoption. The impact of oxen ownership on adoption is shown in Table 7.18. It appears that the rate of adoption of fertilizer on tef and wheat increases as family size rises. In the case of herbicide, the rate of adoption first increases then decreases with family size. This trend may be explained by labour availability and the cash outlay required for
adoption. Farmers with large families have more resources, particularly labour, oxen and income, than farmers with relatively small families. A similar relationship has been found in the Bako area of Western Ethiopia by Legesse et al. (1992). It appears that farmers falling in the smaller family size group tend not to adopt herbicide because of financial constraints, while farmers in the largest family size group have sufficient labour to perform manual weeding and may not need an alternative weed control practice which involves additional cost. The chi-square test was also conducted to see whether the family size groups differ in varieties adoption. The results show that there was no difference between family size groups in terms of varieties adoption (Table 7.17).

Table 7.17. Adoption of technologies on tef and wheat by family size group.

<table>
<thead>
<tr>
<th>Family size group/technology</th>
<th>Proportion of farmers</th>
<th>Proportion of farmers</th>
<th>Tef</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Adaptors</td>
<td>non-adopters</td>
<td>Adaptors</td>
</tr>
<tr>
<td>Fertilizer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 6 persons</td>
<td>34</td>
<td>83</td>
<td>17</td>
<td>53</td>
</tr>
<tr>
<td>6-8 persons</td>
<td>39</td>
<td>93</td>
<td>7</td>
<td>63</td>
</tr>
<tr>
<td>&gt; 8 persons</td>
<td>27</td>
<td>100</td>
<td>0</td>
<td>67</td>
</tr>
<tr>
<td>$\chi^2$</td>
<td></td>
<td>11.4***</td>
<td>2.63</td>
<td></td>
</tr>
<tr>
<td>Herbicide</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 6 persons</td>
<td>34</td>
<td>64</td>
<td>36</td>
<td>32</td>
</tr>
<tr>
<td>6-8 persons</td>
<td>39</td>
<td>79</td>
<td>21</td>
<td>53</td>
</tr>
<tr>
<td>&gt; 8 persons</td>
<td>27</td>
<td>78</td>
<td>22</td>
<td>48</td>
</tr>
<tr>
<td>$\chi^2$</td>
<td></td>
<td>4.96*</td>
<td>6.63**</td>
<td></td>
</tr>
<tr>
<td>variety</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 6 persons</td>
<td>34</td>
<td>22</td>
<td>78</td>
<td>39</td>
</tr>
<tr>
<td>6-8 persons</td>
<td>39</td>
<td>16</td>
<td>84</td>
<td>43</td>
</tr>
<tr>
<td>&gt; 8 persons</td>
<td>27</td>
<td>22</td>
<td>78</td>
<td>46</td>
</tr>
<tr>
<td>$\chi^2$</td>
<td></td>
<td>1.32</td>
<td>0.59</td>
<td></td>
</tr>
</tbody>
</table>

Source: Survey data. *, **, *** indicate significance at 10%, 5%, and 1% probability level.
The effect of oxen ownership is similar to the effect of family size groups. A pair of oxen is required to cultivate land. Those farmers with 2 or more oxen have sufficient draught power for land preparation and planting. As shown in Table 7.18, the proportion of farmers who adopted fertilizer and herbicide increases as we move from farmers with insufficient draught power to those who have sufficient draught power. Chi-square test show that draught power ownership have a significant impact on the adoption of fertilizer and herbicide, and its impact was the same for both crops (Table 7.18). Again, the influence of draught power availability on improved wheat varieties adoption was not significant.

<table>
<thead>
<tr>
<th>Technology/Oxen ownership</th>
<th>Proportion of farmers Adopter</th>
<th>Tef Non-adopter</th>
<th>Wheat Adopter</th>
<th>Non-adopter</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fertilizer</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 or 1 ox</td>
<td>33</td>
<td>78</td>
<td>22</td>
<td>45</td>
</tr>
<tr>
<td>2 oxen</td>
<td>50</td>
<td>98</td>
<td>2</td>
<td>64</td>
</tr>
<tr>
<td>&gt; 2 oxen</td>
<td>17</td>
<td>100</td>
<td>0</td>
<td>79</td>
</tr>
<tr>
<td>$\chi^2$</td>
<td>23.9***</td>
<td></td>
<td>11.87***</td>
<td></td>
</tr>
<tr>
<td><strong>Herbicide</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 or 1 ox</td>
<td>33</td>
<td>64</td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td>2 oxen</td>
<td>50</td>
<td>76</td>
<td>24</td>
<td>45</td>
</tr>
<tr>
<td>&gt; 2 oxen</td>
<td>17</td>
<td>85</td>
<td>15</td>
<td>59</td>
</tr>
<tr>
<td>$\chi^2$</td>
<td>5.55*</td>
<td></td>
<td>4.73*</td>
<td></td>
</tr>
<tr>
<td><strong>Variety</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 or 1 ox</td>
<td>33</td>
<td>19</td>
<td>81</td>
<td>36</td>
</tr>
<tr>
<td>2 oxen</td>
<td>50</td>
<td>16</td>
<td>84</td>
<td>45</td>
</tr>
<tr>
<td>&gt; 2 oxen</td>
<td>17</td>
<td>32</td>
<td>68</td>
<td>50</td>
</tr>
<tr>
<td>$\chi^2$</td>
<td>4.15</td>
<td></td>
<td>2.13</td>
<td></td>
</tr>
</tbody>
</table>

Source: Survey data.
* * * indicate significance difference between the draught ownership groups at 10% and 1% probability level, respectively.
Table 7.19 presents intensity of fertilizer use on tef and wheat by farm characteristics. Mean comparison was carried out using the F-test to see whether farmers differ in intensity of fertilizer-use. Tef area fertilized was significantly different between family size groups. There was no significant differences between family size groups in terms of the rate of fertilizer application on both crops. As shown in Table 7.19 the tef and wheat areas fertilized were positively associated with the oxen ownership groups. Those farmers belonging to the group with two or more oxen had significantly larger tef and wheat fields fertilized than those farmers group with less than two oxen. The three oxen ownership groups of farmers were also statistically different from each other in terms of the fertilizer application rates on both crops. The farmers with a higher number of oxen cultivate more land and produce more. This determines their ability to use fertilizer, herbicide and other inputs by generating cash from surplus production.

The intensity of herbicide adoption can also be evaluated in terms of area sprayed and application rate per hectare. The results are presented in Table 7.20. As can be seen from the table, the area sprayed and the application rates per hectare were greater for the larger family size group. As noted earlier, the farmers in the largest family size group tended not to adopt herbicide as compared to the medium family size group. However, once they adopted the technology they tended to spray a large area planted to tef and apply about the same rate as that of the medium family size group. The impact of draught power availability on the area sprayed and application rate was positive. Thus, farmers in the group with sufficient draught power spray a greater area of tef and wheat and apply higher rates of herbicide than those farmers with insufficient draught power (Table 7.20).
### Table 7.19. Intensity of fertilizer application on tef and wheat by farm size and draught ownership.

<table>
<thead>
<tr>
<th>Family size and Oxen ownership</th>
<th>Tef</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fertilizer rate (kg/ha)</td>
<td>Area fertilized (ha)</td>
</tr>
<tr>
<td><strong>Family size</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 6 persons</td>
<td>113</td>
<td>0.86</td>
</tr>
<tr>
<td>6 to 8 persons</td>
<td>120</td>
<td>1.18</td>
</tr>
<tr>
<td>&gt; 8 persons</td>
<td>132</td>
<td>1.34</td>
</tr>
<tr>
<td>F value</td>
<td>1.03</td>
<td>5.96***</td>
</tr>
<tr>
<td><strong>Oxen ownership</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 or 1 ox</td>
<td>103</td>
<td>0.81</td>
</tr>
<tr>
<td>2 oxen</td>
<td>126</td>
<td>1.11</td>
</tr>
<tr>
<td>&gt; 2 oxen</td>
<td>140</td>
<td>1.70</td>
</tr>
<tr>
<td>F value</td>
<td>3.75**</td>
<td>15.07***</td>
</tr>
</tbody>
</table>

Source: Survey data.

**, *** indicate significant difference at 5% and 1% probability level, respectively.
Bivariate Analysis

Table 7. 20. Intensity of herbicide application on tef and wheat by family size and draught power ownership groups.

<table>
<thead>
<tr>
<th>Family size/ oxen ownership</th>
<th>Tef</th>
<th></th>
<th></th>
<th>Wheat</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Herbicide rate</td>
<td>Area sprayed (ha)</td>
<td>Herbicide rate</td>
<td>Area sprayed (ha)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(l/ha)</td>
<td></td>
<td></td>
<td>(l/ha)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family size</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 6 persons</td>
<td>0.31</td>
<td>0.67</td>
<td>0.13</td>
<td>0.13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-8 persons</td>
<td>0.40</td>
<td>0.90</td>
<td>0.27</td>
<td>0.30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; persons</td>
<td>0.43</td>
<td>1.06</td>
<td>0.27</td>
<td>0.26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F value</td>
<td>2.32*</td>
<td>3.69**</td>
<td>5.11***</td>
<td>5.12***</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Oxen ownership

| | | | | | |
| 0 or 1 ox | 0.30 | 0.67 | 0.16 | 0.13 | |
| 2 oxen | 0.38 | 0.82 | 0.22 | 0.23 | |
| > 2 oxen | 0.54 | 1.34 | 0.36 | 0.43 | |
| F value | 6.51*** | 8.27* | 5.83*** | 10.03*** | |

Source: Survey data.

*, **, *** indicate significant difference between groups at 10%, 5%, and 1% levels, respectively.

Table 7.21. Proportion of farmers adopted fertilizer on tef and wheat by farm size group.

| Farm size group | Proportion of farmers | Fertilizer on tef | | | Fertilizer on wheat | | | |
|----------------|------------------------|-----------------|---|---|-----------------|---|---|
| | | Adopter | Non-adopter | | Adopter | Non-adopter | |
| ≤ 1.50 ha | 24 | 91.5 | 8.5 | 57.4 | 42.6 | |
| 1.50 to 2.50 ha | 42 | 86.6 | 13.4 | 69.5 | 30.5 | |
| 2.51 to 3.50 ha | 18 | 97.2 | 2.8 | 47.2 | 52.8 | |
| > 3.50 ha | 16 | 100 | 0 | 58.1 | 41.9 | |
| χ² | 7.37* | 5.71 | |

Source: Survey data.

* indicates significance at 10% probability level.
The impact of farm size on rate of adoption of fertilizer and herbicide was also examined using a contingency table ($\chi^2$) analysis. With the exception of fertilizer adoption on tef there was no significant difference between the farm size groups in terms of fertilizer and herbicides adoption (Tables 7.21 and 7.22). This implies that farm size has no impact on the rate of adoption of fertilizer.

With regard to the effect of farm size on intensity of adoption, grouping farmers into size groups revealed interesting trends. It was found that the rate of application of fertilizer was inversely related to farm size. The rate of application declines as farm size increases (Table 7.23). The calculated F-values were significant and they confirm the decline in the fertilizer application rate on both crops as farm size increases. The absolute tef area on which fertilizer was applied increases with farm size. However, the ratio of fertilized area to area devoted to the crop on which fertilizer is used declines (Table 7.24). For instance, farmers who own less than 2.5 ha of land devoted about 99% of tef area to fertilizer, while for farmers who own more than 3.5 ha (large farmers) the proportion was 91%. A similar pattern was observed for the intensity of fertilizer use on wheat.

The inverse relationship between farm size and intensity of fertilizer application suggests an inverse farm size and land productivity relationship. Our findings, therefore, support the inverse size-productivity relation. This issue has been widely debated among
economists, who have suggested various reasons for the existence of the inverse relationship. For example, Sen (1975), Berry and Cline (1979), Carter (1984) and Ellis (1993) have argued that the inverse size-productivity relation arises from differences in labour use and land use intensity between the size groups. They argue that in many developing countries a dual labour market exists, with large farmers using hired labour while small farmers mainly use family labour. These differences in labour utilization lead to different opportunity costs for labour. Small farmers face a low opportunity cost of labour (because they do not value their own labour at the market wage) and high prices for land and capital, while large farmers face a high price for labour combined with low prices for land and capital (because they have access to credit at lower interest rates). Large farmers therefore use labour to the point where its marginal value product equals the market wage rate (factor cost). However, because the effective price of labour is lower on the small farms, they commit labour more intensively and thereby achieve more output per unit of available land resource. The impact of imperfect factor markets on adoption paths for small and large farmers is also discussed in Section 2.3.1. Taslim (1989), on the other hand, attributes the inverse size-productivity relation to motivation and supervision problems. He argues that because large farmers are more dependent on hired labour than small farmers, supervision is more difficult on large farms and this may cause the inverse size-productivity relation. As noted in Chapter 2, small farmers tend to lag behind large farmers in technology adoption. This may reverse the size-productivity relation but, once they adopt the technology, the intensity of resource use may be expected to increase and the inverse size-productivity relation to be re-established.
Table 7.23. Intensity of herbicide and fertilizer adoption by crop and farm size group.

<table>
<thead>
<tr>
<th>Farm size group</th>
<th>Proportion of farmers</th>
<th>Tef</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Appl. rate</td>
<td>Area</td>
</tr>
<tr>
<td><em>Fertilizer</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 1.50 ha</td>
<td>24</td>
<td>138.11</td>
<td>0.76</td>
</tr>
<tr>
<td>1.51 to 2.50 ha</td>
<td>42</td>
<td>122.68</td>
<td>1.01</td>
</tr>
<tr>
<td>2.51 to 3.50 ha</td>
<td>18</td>
<td>114.52</td>
<td>1.54</td>
</tr>
<tr>
<td>&gt; 3.50 ha</td>
<td>16</td>
<td>97.90</td>
<td>1.64</td>
</tr>
<tr>
<td><em>F value</em></td>
<td></td>
<td>2.21*</td>
<td>9.24***</td>
</tr>
<tr>
<td><em>Herbicide</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 1.50 ha</td>
<td>24</td>
<td>0.37</td>
<td>0.61</td>
</tr>
<tr>
<td>1.51 to 2.50 ha</td>
<td>42</td>
<td>0.36</td>
<td>0.80</td>
</tr>
<tr>
<td>2.51 to 3.50 ha</td>
<td>18</td>
<td>0.44</td>
<td>1.11</td>
</tr>
<tr>
<td>&gt; 3.50 ha</td>
<td>16</td>
<td>0.39</td>
<td>1.29</td>
</tr>
<tr>
<td><em>F value</em></td>
<td></td>
<td>0.50</td>
<td>4.39***</td>
</tr>
</tbody>
</table>

Source: Survey data.

*, **, *** indicate significance at 10%, 5% and 1% probability level, respectively.

7.6. Institutional Factors and Adoption

In addition to socioeconomic circumstances, the institutional support systems available to farmers have an important impact on technology adoption. In this section we examine the impact of credit and extension on the rate of adoption of new technologies. Tables 7.25 and 7.26 summarize the effect of extension services on improved varieties, fertilizer and herbicide adoption on tef and wheat. Direct extension visits had a significant effect on the adoption of an improved variety of tef. Similarly, radio ownership had a significant impact on adoption of fertilizer, improved varieties and herbicide on tef. Although, we can observe differences between farmers exposed to different extension methods (agricultural training and visits to demonstration sites) the differences were not statistically significant. In the case of wheat, agricultural training and direct extension visits had a positive impact on new technology
acceptance. Surprisingly, extension methods (close exposure to technology through hosting
demonstration and on farm experiments, and visits to demonstration sites) that enable farmers
to evaluate the performance of technology had no significant influence on adoption decisions
(Table 7.26).

In contrast to evidence relating to extension services, credit had a strong influence on
the rate of adoption of fertilizer, herbicide, and improved varieties (Table 7.27). These results
seem reasonable in view of the absolute poverty and financial constraints farmers face.

Table 7.24. Proportion of tef and wheat area put under fertilizer and herbicide by farm size
group.

<table>
<thead>
<tr>
<th>Farm size groups</th>
<th>Proportion of farmers</th>
<th>Tef</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fertilizer</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 1.50 ha</td>
<td>24</td>
<td>99.3</td>
<td>94.5</td>
</tr>
<tr>
<td>1.5 to 2.50 ha</td>
<td>42</td>
<td>95.3</td>
<td>84.3</td>
</tr>
<tr>
<td>2.51 to 3.50 ha</td>
<td>18</td>
<td>96.6</td>
<td>85.2</td>
</tr>
<tr>
<td>&gt; 3.50 ha</td>
<td>16</td>
<td>91.8</td>
<td>89.9</td>
</tr>
<tr>
<td><strong>Herbicide</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 1.50 ha</td>
<td>24</td>
<td>79.5</td>
<td>47.9</td>
</tr>
<tr>
<td>1.5 to 2.50 ha</td>
<td>42</td>
<td>75.6</td>
<td>46.1</td>
</tr>
<tr>
<td>2.51 to 3.50 ha</td>
<td>18</td>
<td>69.8</td>
<td>66.4</td>
</tr>
<tr>
<td>&gt; 3.50 ha</td>
<td>16</td>
<td>72.2</td>
<td>38.3</td>
</tr>
</tbody>
</table>

Source: Survey data.
Table 7.25. Effect of extension on fertilizer, herbicide, and variety adoption on tef.

<table>
<thead>
<tr>
<th>Extension</th>
<th>Fertilizer</th>
<th>Herbicide</th>
<th>Variety</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Adopter</td>
<td>Non-adopter</td>
<td>Adopter</td>
</tr>
<tr>
<td>Direct visits</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>visited</td>
<td>92</td>
<td>8</td>
<td>76</td>
</tr>
<tr>
<td>Non-visited</td>
<td>91</td>
<td>9</td>
<td>71</td>
</tr>
<tr>
<td>$\chi^2$</td>
<td>0.05</td>
<td>0.48</td>
<td></td>
</tr>
<tr>
<td>Host demonstration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hosted</td>
<td>96</td>
<td>4</td>
<td>79</td>
</tr>
<tr>
<td>Not hosted</td>
<td>91</td>
<td>9</td>
<td>73</td>
</tr>
<tr>
<td>$\chi^2$</td>
<td>0.91</td>
<td>0.44</td>
<td></td>
</tr>
<tr>
<td>visits demonstration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>visited</td>
<td>95</td>
<td>5</td>
<td>77</td>
</tr>
<tr>
<td>Non-visited</td>
<td>90</td>
<td>10</td>
<td>71</td>
</tr>
<tr>
<td>$\chi^2$</td>
<td>1.21</td>
<td>0.77</td>
<td></td>
</tr>
<tr>
<td>Agri. training</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participant</td>
<td>93</td>
<td>7</td>
<td>86</td>
</tr>
<tr>
<td>Non participant</td>
<td>92</td>
<td>8</td>
<td>72</td>
</tr>
<tr>
<td>$\chi^2$</td>
<td>0.02</td>
<td>1.20</td>
<td></td>
</tr>
<tr>
<td>Radio</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Owner</td>
<td>98</td>
<td>2</td>
<td>84</td>
</tr>
<tr>
<td>Non-owner</td>
<td>90</td>
<td>10</td>
<td>70</td>
</tr>
<tr>
<td>$\chi^2$</td>
<td>2.63*</td>
<td>3.28*</td>
<td></td>
</tr>
</tbody>
</table>

Source: Survey data.

*, indicates significance at 10% probability level
Table 7.26. Effect of extension on fertilizer, herbicide, and variety adoption on wheat.

<table>
<thead>
<tr>
<th>Extension</th>
<th>Fertilizer</th>
<th>Herbicide</th>
<th>Variety</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Adopter</td>
<td>Non-adopter</td>
<td>Adopter</td>
</tr>
<tr>
<td>Direct visits</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>visited</td>
<td>67</td>
<td>33</td>
<td>52</td>
</tr>
<tr>
<td>Non-visited</td>
<td>55</td>
<td>45</td>
<td>38</td>
</tr>
<tr>
<td>$\chi^2$</td>
<td>2.8*</td>
<td>3.6**</td>
<td>3.0*</td>
</tr>
<tr>
<td>Host demonstration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hosted</td>
<td>68</td>
<td>32</td>
<td>46</td>
</tr>
<tr>
<td>Not hosted</td>
<td>59</td>
<td>41</td>
<td>44</td>
</tr>
<tr>
<td>$\chi^2$</td>
<td>0.70</td>
<td>0.06</td>
<td>0.68</td>
</tr>
<tr>
<td>visits demonstration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>visited</td>
<td>64</td>
<td>36</td>
<td>47</td>
</tr>
<tr>
<td>Non-visited</td>
<td>59</td>
<td>41</td>
<td>43</td>
</tr>
<tr>
<td>$\chi^2$</td>
<td>0.39</td>
<td>0.41</td>
<td>0.01</td>
</tr>
<tr>
<td>Agri. training</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participant</td>
<td>86</td>
<td>14</td>
<td>71</td>
</tr>
<tr>
<td>Non participant</td>
<td>59</td>
<td>41</td>
<td>42</td>
</tr>
<tr>
<td>$\chi^2$</td>
<td>4.0**</td>
<td>4.6**</td>
<td>4.9**</td>
</tr>
<tr>
<td>Radio</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Owner</td>
<td>73</td>
<td>27</td>
<td>48</td>
</tr>
<tr>
<td>Non-owner</td>
<td>57</td>
<td>43</td>
<td>43</td>
</tr>
<tr>
<td>$\chi^2$</td>
<td>3.4*</td>
<td>0.26</td>
<td>1.18</td>
</tr>
</tbody>
</table>

Source: Survey data.

**, * Indicate significance at 5% and 10% probability level, respectively.
Table 7.27. Effect of credit on fertilizer, herbicide, and variety adoption on tef and wheat.

<table>
<thead>
<tr>
<th>Technology/adoption</th>
<th>Tef</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Credit</td>
<td>Non-credit</td>
</tr>
<tr>
<td><strong>Fertilizer</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adoption</td>
<td>96</td>
<td>69</td>
</tr>
<tr>
<td>Non-adoption</td>
<td>4</td>
<td>31</td>
</tr>
<tr>
<td>( \chi^2 )</td>
<td>27.2***</td>
<td></td>
</tr>
<tr>
<td><strong>Herbicide</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adoption</td>
<td>77</td>
<td>53</td>
</tr>
<tr>
<td>Non-adoption</td>
<td>23</td>
<td>47</td>
</tr>
<tr>
<td>( \chi^2 )</td>
<td>8.1**</td>
<td></td>
</tr>
<tr>
<td><strong>Variety</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adoption</td>
<td>24</td>
<td>0</td>
</tr>
<tr>
<td>Non-adoption</td>
<td>76</td>
<td>100</td>
</tr>
<tr>
<td>( \chi^2 )</td>
<td>9.5***</td>
<td></td>
</tr>
</tbody>
</table>

Source: Survey data.

**, *** indicate significance at 5% and 1% probability level.

7.7. Conclusions

Tef and wheat are the principal crops in the study area. Farmers on average have 2.49 ha of land of which 82% is allocated to crop production. Tef and wheat together occupy about 85% of cultivated land. In the study area, cattle are kept primarily as a source of draught power for crop production, the average number of oxen owned being 2. About 33% of farmers do not have the number of oxen required for cultivation.

In East and West Shewa zones, a large proportion of farmers have adopted fertilizer and herbicide on tef and wheat. Adoption of improved varieties has lagged behind, partly because of supply side constraints but mainly because of the unavailability of seed. Lack of awareness and expensiveness of seed has also contributed to the delay and low rate of adoption of the improved varieties.
Great variations were observed between the rates of adoption of fertilizer and herbicides on the two crops. The rates of adoption of the two technologies were higher on tef than on wheat. Tef is a higher value crop and therefore receives a higher priority in input allocation. It was found that the amounts of fertilizer and herbicide applied by farmers were below research recommendations. In the case of fertilizer many farmers did not use the recommended types of fertilizers in combination. It was found that availability of labour and oxen play an important role in fertilizer and herbicide adoption decisions. The rate of application of fertilizer on tef rises with family size and oxen ownership groups, the rate was higher for the large family size and oxen ownership groups. However the rate of application is inversely related to farm size. This suggests that those farmers who fall in the smaller farm size groups apply more fertilizer than farmers in the larger farm size groups. Thus, smaller farmer tend to intensify their production compared to larger farmers.

Finally, this chapter identified some variables that had an impact on fertilizer, herbicide, and varieties adoption. To validate their importance they were further tested in the tobit and duration analysis described in Chapters 8 and 9.
CHAPTER 8

EMPIRICAL ANALYSIS OF RATE AND INTENSITY OF TECHNOLOGY ADOPTION IN EAST AND WEST SHEWA ZONES

8.1. Introduction

As pointed out in Chapter 3, agricultural technology adoption is determined by a number of economic, social, institutional, and agro-climatic factors. In this chapter factors expected to influence technology adoption and intensity of use are examined. In order to identify factors affecting adoption of improved wheat varieties, we estimated probit regression models using the survey data. Tobit and Heckman models were estimated to analyze factors influencing intensity of fertilizer and herbicide use on tef and wheat.

This chapter is divided into six sections. The next section discusses methodological considerations in technology adoption analysis. This is followed by Section 8.3 in which the empirical models are specified. Models which predict adoption and intensity of use for improved variety and intensity of fertilizer and herbicide use are specified. These specifications are based on our own findings, discussed in Section 7.4.5 and a number of findings elsewhere in developing countries reported in Byerlee and Pesse de Polanco (1986) and Lethear and Smale (1991). The probit estimation results for improved varieties adoption are discussed in Section 8.4. Section 8.5 examines factors affecting intensity of fertilizer and herbicide adoption. The final section of this chapter suggests conclusions.
In analysing the adoption behaviour of farmers, a number of different techniques have been employed by researchers. They range from simple descriptive statistics to complicated qualitative response models. Descriptive statistical tools (comparison of mean, percentage, cross-tabulation, correlation, etc.) are simple and widely used both independently and to supplement advanced estimation models. They indicate the direction of impact of a variable. However, as shown in many empirical studies, the adoption behaviour of farmers is affected by numerous factors, and these simple statistical techniques which follow variable by variable analysis fail to predict the combined effects of explanatory factors on adoption behaviour. Moreover, such techniques do not allow analysis of the quantitative importance of explanatory variables and do not separate the influence of other variables (Feder et al., 1985).

General linear models, however, can be used to estimate the joint effect of explanatory variables (Dhrymes, 1986); but, since the dependent variable does take zero values, the application of the general linear regression technique leads to inconsistent estimates and fails to analyze the process by which zero values are generated (Coady, 1995). Indeed the general linear model totally eliminates observation of non-adopters and only analyzes data on adopters. In other words, the model treats non-adopters as though they have zero demand for the technology (Akinola, 1984), which can lead to sample selection bias in estimates (Coady, 1995). The zero demand assumption is unrealistic and may lead to wrong policy conclusions.

It has also been observed that the adoption of a new technology is not a completely instantaneous process. Not all potential adopters adopt the new technology at once. Adoption is a long term adjustment process where the adjustment is affected by stimulus variables such as profitability, farm size or credit availability. Differences in the stimulus factors determine the time farmers wait before adopting a technology. Each potential adopter makes rational and
strategic decisions (whether to adopt or not and when to adopt) based on the environment under which he or she operates. In the light of this analysis, dropping zeros from the analysis is not justified.

Qualitative response models have been developed to estimate the combined effects of explanatory factors on adoption decisions. These models also allow analysis of the quantitative importance of each explanatory variable on adoption decisions. The qualitative response models make use of data collected from technology adopters and non-adopters. They are therefore an improvement on the general linear model in which adoption is represented by a dichotomous endogenous variable. Among these qualitative choice models, the Linear Probability Model (LPM) was the first to be used extensively because of its computational simplicity (Amemiya, 1981); it is also used to obtain quick estimates during the preliminary stages of constructing non-linear models. It is described as,

\[ y_i = \beta'x_i + \epsilon_i \quad i = 1, \ldots, n \quad (8.1) \]

where \( y_i \) is a vector of the dependent variable which takes the value 1 if adoption occurs and 0 otherwise, \( x_i \) is the matrix of explanatory variables and \( \beta \) is a vector of unknown parameters. In this specification \( y_i \) is interpreted as a probability. As shown below (equation 8.2) the expected value of \( y_i \) reduces to the probability that \( y_i \) equals one:

\[ E(y_i) = 1 \cdot p(y_i = 1) + 0 \cdot p(y_i = 0) = p(y_i = 1) \quad (8.2) \]

When the assumption of \( E(\epsilon_i) = 0 \) is applied to equation (8.1) it reduces to \( E(y_i) = F(\beta'x_i) \).

This model has at least three methodological limitations in estimating the relationship between explanatory variables, \( x_i \), and the dichotomous dependent variable, \( y_i \). First, the predicted values of probability are not constrained to lie inside the zero-one interval as any probability should (Dhrymes, 1986; Greene, 1993; Griffiths et al., 1993). Since the linear

---

1 Adoption is a process of use or nonuse of new technology. In modelling qualitative responses the dependent variable takes the value 1 if adoption occurs and 0 otherwise.
probability function is unbounded, the predicted value of the dependent variable may sometimes be greater than one or less than zero, which may in turn produce negative variances (Greene, 1993). Second, the disturbance term of the linear probability model often exhibits heteroscedasticity (Greene, 1993; Gujarati, 1992; Maddala, 1983; Amemiya, 1981; Goldberger, 1964). Since $y$ takes on values one or zero, $e_i$ can assume only two values for any given value of $x_i$. That is:

$$\begin{align*}
\text{if } y_i = 0 & \text{ then } e_i = -\beta'x_i \\
\text{and if } y_i = 1 & \text{ then } e_i = 1 - \beta'x_i
\end{align*}$$

(8.3)

As shown below (equation 8.4) the variance of this model changes systematically with values of explanatory variables, i.e.,

$$\begin{align*}
\text{var}(e_i) &= E(e_i^2) = p(y_i = 0) \cdot (-\beta'x_i)^2 + p(y_i = 1) \cdot (1 - \beta'x_i)^2 \\
\text{var}(e_i) &= \beta'x_i(1 - \beta'x_i) + \sigma^2
\end{align*}$$

(8.4)

As a result the standard error and t-value are incorrect and hypothesis tests based on these statistics are invalid (Aldrich and Nelson, 1985) and may lead to wrong conclusions. Various transformation approaches have been proposed to correct for this biased variance problem. For example, Goldberger (1964) has suggested a two-step, weighted least square estimator. However, this does not provide a satisfactory solution because the probability estimates will differ from the true value, and can still lie outside the zero-one interval for some values of $x_i$ (Amemiya, 1981; Maddala, 1983; Dagenais, 1969; Gujarati, 1992).

Third, the LPM assumes a linear relationship between the adoption decision and the explanatory variables and therefore does not allow for non-linear relationships in economic variables (Akinola, 1984). Theoretical as well as empirical studies show that adoption decision function is not linear but curvilinear (Gertrell et al., 1973; Liao, 1994).

In view of these problems and given the availability of advanced computer software for estimation, the LPM is now used less frequently than in the past, except as a basis for comparison with other non-linear models. In particular, the LPM has been superseded by
Empirical Analysis of Rate and Intensity of Adoption

models based on the probit, logit and tobit functional forms. These models give reliable estimates and overcome the problems associated with LPM. The advantages of the probit and logit models over the LPM are discussed by Amemiya (1981) and Aldrich and Nelson (1985).

8.2.1. The Probit Model

To describe the probit model let I be an index or unobserved variable defined as,

\[ I_i = \beta'x_i + e_i \]

\[ y = 1 \quad \text{if } \beta'x_i + e_i > I^* \]

\[ y = 0 \quad \text{if } \beta'x_i + e_i < I^* \]

i = 1, ..., n.

Where \( I^* \) is a critical value of index \( I_i \). In this model the probability of observing a response, i.e. whether a new technology is adopted or not, is defined in terms of the level of the unobserved index I and the standard cumulative normal distribution is used to transform the index I into a probability value. The index I is a linear combination of explanatory variables, and may take any value between \( -\infty \) and \( \infty \), while its transformation ensures that all corresponding probability values lie between 0 and 1.

This model has many plausible characteristics: in particular, it determines the decision variable y by \( y = 0 \) if \( I < I^* \), and by \( y = 1 \) if \( I \geq I^* \). Here I can be defined as a technology "adopting potential" index. If this calculated "adopting potential" index for a farmer exceeds the farmer's personal critical value of this index (\( I^* \)), the farmer will adopt the new technology. Thus one can interpret a low \( I^* \) as a high underlying likelihood that a farmer will adopt, and high \( I^* \) as a low underlying likelihood that a farmer will not adopt. In the probit model the critical values are assumed to be distributed normally among individuals (Finney, 1971; Kennedy, 1979). Thus, we have the following probability for adopters (\( y = 1 \)) and non-
adoption \((y = 0)\).

\[
\Pr(y_i = 1 \mid I_i) = \Pr(I^* < I_1 \mid I_i) = F(I_1) = F(\beta'x_i)
\]

\[
\Pr(y_i = 0 \mid I_i) = \Pr(I^* > I_1 \mid I_i) = 1 - F(I_1) = 1 - F(\beta'x_i)
\]  

(8.6)

where \(F(.)\) is cumulative distribution function. Assumptions about the distribution of \(F(.)\) result in different models. The normal and logistic are of the most commonly assumed distributions about \(F(.)\). If we assume \(e_i\) is normally distributed, we will have a probit model which is described as,

\[
Prob (y_i = 1) = \int_{-\infty}^{\infty} f(t) dt = F(\beta'x_i)
\]

(8.7)

where \(F(.)\) and \(f(.)\) are the cumulative and density functions of the normal distribution, respectively. If a logistic distribution is assumed, we obtain a logit model which is expressed as,

\[
Prob (y_i = 1) = \frac{e^{\beta'x_i}}{1 + e^{\beta'x_i}}
\]

(8.8)

For \(n\) independent observations, the likelihood for the probit model is given by,

\[
L = \prod_{i=1}^{n} [F(\beta'x_i)]^{y_i} [1 - F(\beta'x_i)]^{1-y_i}
\]

(8.9)

and the log likelihood function is,

\[
lnL = \sum_{i=1}^{n} [y_i ln F(\beta'x_i) + (1 - y_i) ln (1 - F(\beta'x_i))].
\]

(8.10)

The model is estimated using the maximum likelihood method of estimation.

The probit and logit models give similar results unless the sample is very large.
The choice between the two models depends on the availability of computer programmes and on personal preference and experience. The signs of the parameters indicate the direction of effects but the partial derivative interpretation of the linear regression model cannot be directly applied to these two models. For both probit and logit models, \( E(y_i) = \text{Prob}(y_i = 1 \mid \beta'x_i) = F(\beta'x_i) \). For the probit model a change induced in the expected value of \( y_i \) (which is the same as a change in \( \text{Prob}(y_i = 1) \)) due to a unit change in \( x_i \) can be estimated using the following formula,

\[
\frac{\partial E(y_i)}{\partial x_i} = \left( \frac{dF(\beta'x_i)}{d(\beta'x_i)} \right) \beta = f(\beta'x_i)\beta
\]

(8.11)

where \( f(.) \) is the probability density function that corresponds to the cumulative distribution, \( F(.) \). For the logistic distribution,

\[
\frac{\partial E(y_i)}{\partial x_i} = \left( \frac{e^{\beta'x_i}}{(1 + e^{\beta'x_i})^2} \right) \beta
\]

(8.12)

To evaluate the marginal effect of an explanatory variable other explanatory variables will be fixed at their mean values. The marginal effect is then interpreted in terms of the change in the probability of adopting a technology.
8.2.2. Models for Limited Dependent Variables

Surveys of innovation adoption, labour supply, household consumption etc. may include zero observations and the choice of statistical techniques to deal with zero observations can be crucial for the empirical results that are produced (Jones and Yen, 1994). Inappropriate treatment of zero observations can result in biased and inconsistent estimates (Amemiya, 1984). Models that describe data with zero observations must take into account two decisions: the decision to use or not and, if the first option is chosen, how much to use. Early studies dealing with technology adoption, labour supply, and consumer goods modelled the quantity decision at the expense of dropping zero observations (Bockstael et al., 1990). Data on intensity of adoption is continuous, falling in an interval (0-100), with some observation piling-up at the limiting value, zero. The probit model illustrated above is not suitable for such data (Ghosh, 1991). If a probit model is used to analyze such data, it treats a farmer who adopted the recommended level of fertilizer and a farmer who applied one tenth of the recommendation in the same way.

Alternative models, such as the tobit, Heckman and double hurdle models which take into account zero observations are available (Tobit, 1958; Heckman, 1976; Cragg, 1971). These models follow different procedures and produce different estimates. For example, the tobit model assumes the decision to adopt and the amount of use to be related. As noted by Cragg (1971), in some situations the decisions to acquire durable goods and the amount of the acquisition may not be intimately related. Thus, for the analysis of intensity of technology adoption, valid hypothesis testing and unbiased estimation accommodating the limited nature of the dependent variable are required. From the models that can analyze limited dependent variables, two models, the tobit and Heckman models, were used to estimate the intensity of fertilizer and herbicide adoption on tef and wheat. These two models are applied for the purpose of comparison.
Agricultural technologies such as fertilizer, herbicides, and improved seeds give optimum benefits when they are applied at recommended levels. Application above or below the recommended level will usually result in lower benefit provided the recommendation is right. In Ethiopia many farmers who use fertilizer and herbicide do not apply recommended levels (Hailu et al., 1992; Legesse et al., 1992). The amount of fertilizer applied varies from farmer to farmer and from one area to the other. Under such conditions the problem concerning the intensity of use needs to be addressed. The tobit model is an appropriate method for predicting the intensity of adoption when the dependent variable takes values of zero and greater than zero (Maddala, 1983). The tobit model is extensively used to analyze intensity of adoption of technology and demand for durable goods.

To specify the tobit model, let $I_i$ denote an unobservable index variable. The decision making process of potential adopters may be expressed as,

$$
\begin{align*}
  y_i = I_i &= \beta'x_i + e_i & \text{if } \beta'x_i + e_i > 0 \\
  y_i &= 0 & \text{if } \beta'x_i + e_i \leq 0 \\
  e_i &\sim N(0, \sigma^2), \quad i=1,\ldots,n.
\end{align*}
$$

Where $y_i$ is the observed response for the $i^{th}$ farmer ($y_i$ is continuous for adopters, and $y_i = 0$ for non-adopters). Zero is a critical value of the index. The tobit model, therefore, measures not only the probability that a farmer will adopt a technology, but also the extent of adoption of the technology once adoption has taken place. If $I_i$ is greater than zero the observed variable $y_i$ becomes a continuous function of the explanatory variables, and zero otherwise. The likelihood function for the tobit model is given by,

$$
L = \prod_{i > 1} F(\beta'x_i)^{y_i} \prod_{i = 0} (1 - F(\beta'x_i))^{1-y_i}
$$

(8.14)
where $L$ is the likelihood function and $F(.)$ is the standard normal probability distribution function. The probability of adoption and non-adoption given characteristics $x_i$ is found by,

$$P(y_i = 0) = 1 - F\left(\frac{\beta'x_i}{\sigma}\right)$$

(8.15)

$$P(y_i > 0) = F\left(\frac{\beta'x_i}{\sigma}\right)$$

where $F(.)$ is evaluated at $(\beta'x_i)/\sigma$ and $\sigma$ is the standard error. The conditional expectation of the amount used is shown by,

$$E(y_i | y_i > 0) = \beta'x_i + \sigma f\left(\frac{\beta'x_i}{\sigma}\right)$$

(8.16)

where $f(.)$ is evaluated at $(\beta'x_i)/\sigma$. The expected value of the amount of fertilizer and herbicide used, given the knowledge that it is positive, is obtained using the expression,

$$E(y_i | y_i > 0) = \beta'x_i + \sigma \left( \frac{\beta'x_i}{\sigma} \right)$$

(8.17)

### 8.2.2.2. The Heckman Model

The Heckman model follows a two-step estimation procedure. Factors that influence the decision whether to adopt or not can be estimated using the probit model. In the second step of the estimation, zero observations are dropped and the Ordinary Least Square (OLS)
regression model is employed to predict the intensity of adoption.

To characterize this two-step estimation procedure, consider the tobit model given in equation (8.13) and the non-zero observation $y_i$:

$$E(y_i|y_i > 0) = \beta'x_i + E(e_i|e_i > -\beta'x_i)$$
$$= \beta'x_i + \sigma \phi_i / \Phi_i \quad (8.18)$$

where $\phi_i = f(\beta'x_i/\sigma)$ and $\Phi_i = F(\beta'x_i/\sigma)$ are the density function and the distribution function of the standard normal at $\beta'x_i/\sigma$. As shown by Maddala (1983), equation (8.18) can be written as,

$$y_i = \beta'x_i + \sigma \frac{\phi_i}{\Phi_i} + v_i \quad (8.19)$$

where $v_i$ is the error term and $E(v_i) = 0$. Since $\phi_i$ and $\Phi_i$ are not known, this model can not be estimated using the OLS estimation method.

Heckman (1976) suggested using estimates of $\phi_i / \Phi_i$ obtained from the probit model. This ratio is denoted as $\lambda$ and represents the inverse Mill-ratio. The intensity of adoption is then predicted by OLS, using the estimates of $\phi_i / \Phi_i$ i.e., $\lambda$ in place of the population parameters as an explanatory variable. This reflects the probability that an observation belongs to the selected sample in the second step. This technique eliminates the potential sample selection bias (Heckman, 1979; Jha and Hojjati, 1994).

For these models, specification tests about the parameters are performed using the standard procedure for a maximum likelihood estimator. The Likelihood Ratio, Wald and Lagrange Multipliers are applicable to test parametric restrictions, choices between these test statistics being a matter of convenience. The usual practice is to test the hypothesis that all slope coefficients are not different from zero against the alternative hypothesis that at least one coefficient is different from zero. Hypothesis testing for each individual coefficient is usually
done using the t-statistic method.

Along with one of these diagnostic checking statistics, the Likelihood Ratio Index (LRI) can be used to assess the goodness of fit of the models. The LRI is analogous to $R^2$ (the measure of goodness of fit for linear regression models) but cannot be interpreted in exactly the same way. It is defined as,

$$LRI = 1 - \frac{L_{\text{max}}}{L_0}$$  \hfill (8.20)

where $L_{\text{max}}$ is the likelihood function for the unrestricted model and $L_0$ is likelihood function for the restricted model. If all the slope coefficients are zero, LRI equals zero. The value of LRI increases as the fit of the model improves; however, it does not reach the value one (Greene, 1993; Pindyck and Rubinfeld, 1981).

The number of correct predictions is also used to assess the predictability of qualitative response models. The procedure is to compare the predicted probability of each observation with a threshold probability value. The cut-off probability value is 0.5. The predicted value of the dependent variable takes the value one if the predicted probability is greater than 0.5. Thus, when most values of the dependent variable are correctly predicted, the model is understood to fit the data well.

At the household level the probit and tobit models are appropriate models to analyze individual adoption behaviour at a given period in time. However, both models fail to analyze individual adoption behaviour over time as they do not allow for the time farmers wait before adopting a technology. Nor do these models account for the cumulative effects of time-varying variables on adoption. They are static in nature and do not capture the dynamic aspects of adoption process. Models which do account for dynamic aspects of the adoption process are discussed in Chapter 9.
8.3. Empirical Model Specification

Farmers' adoption decisions for improved wheat varieties, fertilizer, and herbicide were modelled using primary survey data and the probit, tobit, and Heckman models. The latter two models were estimated to predict the intensity of fertilizer and herbicide use, while the former was estimated to predict adoption of improved varieties of wheat.

The operational definition of adoption of improved varieties, fertilizer, and herbicide is based on the use or non-use of these technologies in a specific year. For this study farmers who used improved varieties, fertilizer, and herbicide on their fields, in 1995, were classified as adopters irrespective of the rates they used.

In Ethiopia, agronomists and policy makers have been advocating the package approach since the inception of agricultural extension services. Currently an intensification programme which advocates the promotion of a full package is being implemented by regional agricultural bureaux. As evidenced by this study (see Section 7.4.5 and Beyene et al., 1991) farmers do select and adopt components of a technological package one at a time rather than adopting a full package. Since individual components of a package are adopted at different times, separate empirical models were specified for each technology and for the two crops.

The data on which the empirical models based were discussed in Section 6.2. Justification and definition of variables thought to affect adoption and intensity of adoption were given in Section 6.3, and the hypotheses to be tested presented in the same section.

The empirical models for improved wheat varieties adoption, and intensity of use of fertilizer and herbicide on tef and wheat were specified as a function of explanatory variables thought to affect adoption. The definition and measurement of the variables used in the empirical models are given in Table 8.1. A model of adoption of improved wheat varieties was specified as a function of variables in set A in Table 8.1. A tobit model for fertilizer adoption
on tef and wheat was specified as a function of variables in set A and set B (from set B each model takes corresponding proxy variable for risk). Similarly a tobit model for herbicide adoption was constructed as a function of variables in set A and dummy variable for farmers perception about herbicide price.

A Heckman model was specified for the two technologies and crops as a function of explanatory variables specified for the tobit model plus the variable $\lambda$ which was created by dividing the predicted probability density function by cumulative distribution function estimated in the probit model for each individual in the sample.

All variables are used as quantified by respondents except the index of awareness (INFO) and family labour availability (FLBR). Three extension communication methods: direct visits by development agent, practical demonstration and training are used to enhance farmers' awareness of the new technologies. The need to capture influence from these methods and at the same time to reduce the number of variables has necessitated the construction of a proxy variable which represents awareness. Hence a variable INFO was created as follows:

$$INFO = (DEXTV + VDEH + TRNG)/3$$

where the variable DEXTV represents the number of visits a development agent made per month; the variable VDEH denotes visits by farmers to demonstration and trial sites (a farmer who visits demonstrations and on-farm trials is assumed to have more exposure to information compared to a farmer who does not visit demonstration or trial sites) and TRNG represents participation in agricultural training. The first variable takes values zero, one or two, while the last two variables are dummies. It is difficult to know which extension method raises farmers awareness about new technology more so the three methods were given equal weight in constructing INFO. The variable family labour availability (FLBR) is measured in man-equivalent. The conversion factors used are indicated in the appendix A3.

A maximum likelihood estimator was used to estimate the probit and tobit models. In
In the case of the Heckman model, a maximum likelihood estimator was applied first, to identify variables determining the decision to adopt or not, then OLS regression was used. LIMDEP computer software version 7 (Greene, 1996) was used to estimate the empirical models.

### Table 8.1: Definition and measurement of variables used in the empirical model specification

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unit/Type</th>
<th>Description/Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dependent</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VRAD</td>
<td>Dummy</td>
<td>Adoption of improved varieties in 1995: 1, if yes, 0 otherwise</td>
</tr>
<tr>
<td>IFAD$_t$</td>
<td>percent</td>
<td>Amount of fertilizer/ha on tef as percent of the recommendation</td>
</tr>
<tr>
<td>IFAD$_w$</td>
<td>percent</td>
<td>Amount of fertilizer/ha on wheat as percent of the recommendation</td>
</tr>
<tr>
<td>IHAD$_t$</td>
<td>percent</td>
<td>Amount of herbicide/ha on tef as percent of the recommendation</td>
</tr>
<tr>
<td>IHAD$_w$</td>
<td>percent</td>
<td>Amount of herbicide/ha on wheat as percent of the recommendation</td>
</tr>
<tr>
<td><strong>Explanatory</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AGE</td>
<td>Years</td>
<td>Age of household head in years</td>
</tr>
<tr>
<td>EDUC</td>
<td>Dummy</td>
<td>Education of household head: 1 if literate, 0 otherwise</td>
</tr>
<tr>
<td>GNDR</td>
<td>Dummy</td>
<td>Sex of household head: 1, if male, 0 otherwise</td>
</tr>
<tr>
<td>LOCT</td>
<td>Dummy</td>
<td>Location of the study area: 1, if East Shewa, 0 otherwise</td>
</tr>
<tr>
<td>FLBR</td>
<td>Man-equi</td>
<td>Family labour availability measured in man-equivalent</td>
</tr>
<tr>
<td>INFO</td>
<td>Index</td>
<td>Index of awareness</td>
</tr>
<tr>
<td>FRSZ</td>
<td>ha</td>
<td>Total land owned by the household measured in hectares</td>
</tr>
<tr>
<td>DMKT</td>
<td>km</td>
<td>Distance from farm to the market in kilometres</td>
</tr>
<tr>
<td>CRDT</td>
<td>Dummy</td>
<td>Access to official credit: 1, if credit obtained, 0 otherwise</td>
</tr>
<tr>
<td>OXEN</td>
<td>Number</td>
<td>Number of oxen owned by the household</td>
</tr>
<tr>
<td><strong>Explanatory Set-B</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FPIP</td>
<td>Dummy</td>
<td>Farmers perception about input price: 1, if response was too expensive, 0 otherwise</td>
</tr>
<tr>
<td>PRKT</td>
<td>Dummy</td>
<td>Farmers risk aversion behaviour: 1, if response was yes to the question “Would you apply fertilizer on tef, if you expect rainfall is insufficient?”, 0 otherwise</td>
</tr>
<tr>
<td>PRKW</td>
<td>Dummy</td>
<td>Farmers risk aversion behaviour: 1, if response was yes to the question “Would you apply fertilizer on wheat, if you expect rainfall is insufficient?”, 0 otherwise</td>
</tr>
</tbody>
</table>

#### 8.4. Wheat Varieties Adoption: Probit Analysis

Table 8.2 presents the coefficients of the probit model for the adoption of improved wheat varieties. The log likelihood ratio test shows that the explanatory variables taken together influenced the probability of adopting improved wheat varieties. The LRI is 0.74; so the model fitted the data well. The model correctly classified 93% of sampled farmers into adopters and non-adopters.

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$^*$Calculated chi-square (146) is greater than critical value (with a degree of freedom of 11) of chi-square at 1% level.
On the basis of asymptotic t-test and conventional significance levels three of the eleven variables included in the model were significantly related to the adoption of improved wheat varieties. The effects of the significant variables were consistent with theoretical expectations.

The variables that significantly influenced variety adoption were location, extension and oxen ownership. The variable location had a positive and significant coefficient. This suggests that farmers in location I (East Shewa) were more likely to adopt improved wheat varieties than farmers in location II (West Shewa). Location is a proxy variable for the environment under which farmers make adoption decisions. It represents variations in the quality of extension services, physical factors (e.g. soils), infrastructure, availability of seeds, and market opportunities. Location I has an advantage over location II in terms of infrastructure and

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>dF/dx</th>
<th>T-ratio</th>
<th>Coefficient</th>
<th>dF/dx</th>
<th>T-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>0.6000</td>
<td>0.237</td>
<td>0.954</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Age</td>
<td>0.0078</td>
<td>0.003</td>
<td>0.494</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Education</td>
<td>0.0549</td>
<td>0.022</td>
<td>0.133</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Location</td>
<td>3.8533</td>
<td>1.524</td>
<td>6.166***</td>
<td>3.3631</td>
<td>1.321</td>
<td>8.321***</td>
</tr>
<tr>
<td>Labour</td>
<td>-0.1904</td>
<td>-0.075</td>
<td>-1.144</td>
<td>-0.1212</td>
<td>-0.0476</td>
<td>-1.096</td>
</tr>
<tr>
<td>Farm size</td>
<td>0.1126</td>
<td>0.045</td>
<td>0.616</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Distance to market</td>
<td>0.0011</td>
<td>0.0004</td>
<td>0.096</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Index of awareness</td>
<td>0.6765</td>
<td>0.267</td>
<td>1.747*</td>
<td>0.5707</td>
<td>0.2242</td>
<td>1.739*</td>
</tr>
<tr>
<td>Credit</td>
<td>0.3436</td>
<td>0.136</td>
<td>0.543</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Oxen ownership</td>
<td>0.2769</td>
<td>0.109</td>
<td>1.765*</td>
<td>0.2035</td>
<td>0.0807</td>
<td>1.673*</td>
</tr>
<tr>
<td>Perception of price</td>
<td>0.4201</td>
<td>0.166</td>
<td>0.898</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Constant</td>
<td>-4.1506</td>
<td>2.75***</td>
<td>-1.9468</td>
<td>3.571***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log likelihood</td>
<td>-30.9251</td>
<td></td>
<td></td>
<td>-32.9792</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Correctly predicted(%)</td>
<td>93</td>
<td></td>
<td></td>
<td>93</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* , ** , *** significant at 10%, 5% and 1% levels respectively
Note: a) dF/dx indicates partial derivative of the probability of adopting with respect to the vector of characteristics (x). They are computed at the means of x. b) It was assumed that variables with a t-ratio of less than one have no effect on adoption of improved variety. Based on this assumption a preferred model was estimated. Statistical test was conducted to test whether this assumption is realistic or not. The calculated chi-square (4) was less than the critical value of chi-square (18.47) at one percent level. Therefore, dropping the variables which have t-ratio less than one is justified.
market opportunities. Water logging problems are also less severe in 4 of the 6 PAs sampled from location I, which means that the risk of water logging is less in location I than in location II if improved varieties are planted. As anticipated, the effect of extension on varieties adoption was positive and significant. This implies that farmers who had interactions with extension agents were more likely to adopt improved wheat varieties than those who had no exposure to extension messages. This result is consistent with the study by Bisrat (1980). Oxen ownership also had a significant impact on improved wheat varieties adoption and its impact was in agreement with theoretical expectations.

Table 8.3 shows the effects of selected variables on the predicted probability of adopting improved wheat varieties using coefficients specified in Table 8.2. The predicted probabilities indicate that location had a stronger effect on varieties adoption than oxen ownership and index of awareness. The likelihood of adoption for a farmer in location I, who has exposure to extension, and who has a sufficient number of oxen was 97.7%. For a similar type of farmer in location II the probability of adopting improved varieties was only 8.5%. In the case of the extension variable, the predicted probability of adopting wheat varieties fell with the decline in index of awareness. This implies that farmers with limited exposure to information were less likely to adopt improved wheat varieties than those who had better exposure to information.

Table 8.3. The probability of adopting improved wheat varieties for selected farmers.

<table>
<thead>
<tr>
<th>Location</th>
<th>Location I</th>
<th>Location II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxen ownership</td>
<td>2 oxen</td>
<td>0 oxen</td>
</tr>
<tr>
<td>Index of awareness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 (Good exposure)</td>
<td>97.7</td>
<td>94.3</td>
</tr>
<tr>
<td>0.5 (Fair exposure)</td>
<td>95.5</td>
<td>90.2</td>
</tr>
<tr>
<td>0 (No exposure)</td>
<td>92.3</td>
<td>84.4</td>
</tr>
</tbody>
</table>

Source: Calculated based on coefficients given in Table 8.2 for the reduced model. The probabilities are calculated for farmers having 3.369 man-equivalent labour.
In the probit model, the coefficients of gender, age, education, farm size, labour, farmers' perceptions of seeds price, distance to market and credit were not significant. Thus, their influence on improved wheat varieties adoption were neutral. The coefficients of labour, distance to market and farmers' perceptions about seeds prices bear unexpected signs. However, the unexpected signs may have no implications for adoption as their impact on adoption were statistically neutral.

8.5. Adoption and Intensity of Use of Fertilizer and Herbicide

As argued in Section 8.1, factors that stimulate adoption and the level of use of a technology may be different. Two econometric analytical models, tobit and Heckman, were employed to identify determinants of adoption and intensity of adoption of fertilizer and herbicide. The two models follow different procedures to predict intensity of adoption. The tobit model simultaneously predicts the probability of adoption and the probability of intensity of use after adoption. On the other hand, the Heckman model draws on the assumption that determinants of adoption and intensity of adoption are different; it first predicts the probability of adoption using binary choice models, then it estimates the intensity of use using an OLS estimator corrected for sampling bias. The results of the two models are discussed in the following sections.

8.5.1. Adoption and Intensity of Use: Tobit Analysis

The coefficients of the tobit models used to examine factors related to the adoption and intensity of adoption of fertilizer and herbicide on both crops are shown in Table 8.4, 8.5, 8.8 and 8.9. Initially, models that included the full set of variables considered relevant on a priori
Empirical Analysis of Rate and Intensity of Adoption

grounds were estimated. Of these variables, some were consistently insignificant in the models tested, having a t-ratio of less than one. The impact of such variables on adoption assumed to be very weak. Therefore, those variables which consistently had a t-ratio of less than one were omitted and the resulting preferred models were estimated for each technology on both crops. A statistical test was conducted to verify whether the coefficients on the omitted variables are jointly zero. The null hypotheses were accepted (see Table 8.20). This imply that dropping the variables with a t-ratio less than one is statistically justified. The estimated models were highly significant on the basis of a log likelihood test, and correctly predicted 95% of tef growers and 80% of wheat growers as fertilizer users and non-users. Similarly the models correctly predicted more than 80% of farmers as herbicide adopters and non-adopters.

The estimated coefficients are not comparable with each other because the magnitudes of the coefficients depend on the unit of measurements used. Moreover, some of the variables are expressed as indices. As they are, the coefficients indicate the direction of effects of an individual variable on the decision to adopt and intensity of use after adoption. The asymptotic t-value was used to determine whether an individual coefficient is statistically associated with the adoption decision or not.

Among the possible determinants of the intensity of fertilizer adoption, location, distance to market, credit, oxen ownership and risk aversion behaviour of farmers were found to significantly influence adoption and intensity of fertilizer adoption on tef. The variables location, oxen ownership and farmers' perception of fertilizer price were found to determine the intensity of fertilizer use on wheat.
Table 8.4. Factors influencing intensity of fertilizer use on tef and wheat: Tobit estimates for model with full set of variables.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Tef</th>
<th>coefficient</th>
<th>T-ratio</th>
<th>Wheat</th>
<th>coefficient</th>
<th>T-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>-5.6855</td>
<td>-0.977</td>
<td></td>
<td>-1.8302</td>
<td>-0.177</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>-0.0785</td>
<td>-0.643</td>
<td></td>
<td>0.0324</td>
<td>0.103</td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td>2.5883</td>
<td>0.587</td>
<td></td>
<td>10.522</td>
<td>1.307</td>
<td></td>
</tr>
<tr>
<td>Location</td>
<td>34.033</td>
<td>6.842***</td>
<td></td>
<td>67.670</td>
<td>6.318***</td>
<td></td>
</tr>
<tr>
<td>Labour</td>
<td>-0.0539</td>
<td>-0.040</td>
<td></td>
<td>-1.5714</td>
<td>-0.776</td>
<td></td>
</tr>
<tr>
<td>Farm size</td>
<td>0.6415</td>
<td>0.283</td>
<td></td>
<td>2.7612</td>
<td>0.631</td>
<td></td>
</tr>
<tr>
<td>Distance to market</td>
<td>-0.1984</td>
<td>-1.801*</td>
<td></td>
<td>0.1977</td>
<td>0.808</td>
<td></td>
</tr>
<tr>
<td>Index of awareness</td>
<td>2.0092</td>
<td>0.442</td>
<td></td>
<td>7.0728</td>
<td>1.009</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>17.614</td>
<td>3.228***</td>
<td></td>
<td>7.2774</td>
<td>0.591</td>
<td></td>
</tr>
<tr>
<td>Oxen ownership</td>
<td>1.9329</td>
<td>1.882**</td>
<td></td>
<td>3.7824</td>
<td>1.650*</td>
<td></td>
</tr>
<tr>
<td>Perception of price</td>
<td>-0.1518</td>
<td>-0.844</td>
<td></td>
<td>-0.3202</td>
<td>-1.938**</td>
<td></td>
</tr>
<tr>
<td>Risk aversion</td>
<td>-0.3942</td>
<td>-2.476***</td>
<td></td>
<td>-0.2154</td>
<td>-1.097</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>55.344</td>
<td>4.882***</td>
<td></td>
<td>-18.766</td>
<td>-0.581</td>
<td></td>
</tr>
<tr>
<td>Log likelihood</td>
<td>-833.3782</td>
<td>-95.62</td>
<td></td>
<td>-55.766</td>
<td>-4.750</td>
<td></td>
</tr>
</tbody>
</table>

Correctly predicted(%) 95 80

*, **, *** significant at 10%, 5%, and 1% respectively.

Table 8.5. Factors influencing intensity of fertilizer use on tef and wheat: Tobit estimates for preferred model.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Tef</th>
<th>coefficient</th>
<th>T-ratio</th>
<th>Wheat</th>
<th>coefficient</th>
<th>T-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Education</td>
<td>-</td>
<td>-</td>
<td></td>
<td>9.7839</td>
<td>1.371</td>
<td></td>
</tr>
<tr>
<td>Location</td>
<td>33.255</td>
<td>7.124***</td>
<td></td>
<td>62.463</td>
<td>7.731***</td>
<td></td>
</tr>
<tr>
<td>Distance to market</td>
<td>-0.1978</td>
<td>-1.989**</td>
<td></td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>credit</td>
<td>15.036</td>
<td>3.189***</td>
<td></td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Oxen ownership</td>
<td>2.1328</td>
<td>2.214**</td>
<td></td>
<td>4.6517</td>
<td>2.250**</td>
<td></td>
</tr>
<tr>
<td>Perception of price</td>
<td>-</td>
<td>-</td>
<td></td>
<td>-0.2783</td>
<td>-1.794*</td>
<td></td>
</tr>
<tr>
<td>Risk aversion</td>
<td>-0.3914</td>
<td>-2.809***</td>
<td></td>
<td>-0.2154</td>
<td>-1.093</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>52.080</td>
<td>5.567***</td>
<td></td>
<td>5.6647</td>
<td>0.794</td>
<td></td>
</tr>
<tr>
<td>Log likelihood</td>
<td>-835.3686</td>
<td>-31.085</td>
<td></td>
<td>-54.399</td>
<td>4.825</td>
<td></td>
</tr>
</tbody>
</table>

Correctly predicted(%) 95 80

*, **, *** significant at 10%, 5%, and 1% respectively.
The estimates of the tobit model are more easily interpreted when the impact of the variables on adoption are expressed in probabilities. The probability of adopting and intensity of fertilizer use were predicted by changing values of the significant variables holding other continuous variables at their mean values and by setting values of dummy variables equal to zero. The predicted probabilities of adopting fertilizer are shown in Table 8.6 and 8.7. Fixing all explanatory variables at their mean values as usually done (Greene, 1996), the probability of adopting fertilizer on tef and wheat would be 98% and 67%, respectively.

It was found that location had a strong impact on the probability of adoption and intensity of use. The predicted probability of adopting fertilizer on tef was 99.7% for a farmer located in location I who has one ox and access to credit. The likelihood of adoption drops to 95.9% for tef for a similar farmer located in location II (Table 8.6). The intensity of fertilizer use falls from 103 kg/ha to 69 kg/ha for tef for a farmer having similar access to resources but in location II. The predicted probability of adopting fertilizer on wheat had a similar trend as that of the predicted probability of adopting fertilizer on tef. For example, the predicted probability of adopting fertilizer for a farmer who perceives fertilizer is expensive was 92.7% and this drops to 62.1% for similar farmer but located in location II (Table 8.7). In general intensity of fertilizer use was lower in location II than in location I. As discussed earlier, the variable location is a proxy for differences in infrastructure, institutional factors and access to market. The predicted probabilities correctly reflected the impact of these difference on adoption.
The variable oxen ownership was directly associated with the adoption and intensity of fertilizer use. Other factors being equal, the predicted probability of adopting fertilizer declines as the number of oxen owned decreases. For example, the probability of adopting fertilizer on wheat by a farmer in location I who perceives fertilizer as expensive and owns 3
oxen, was 94.8%. The quantity of fertilizer he could be expected to use was 114 kg/ha. The probability that a farmer located in the same area but had no ox would adopt was 91.4% and average application rate was 99.5 kg/ha. Oxen are the main source of draught power for crop production in the study area. The ownership of oxen affects production through its impact on the area cultivated and timeliness of farm operations. Thus, farmers with sufficient oxen (2 or more) can produce more and afford to invest more in fertilizer. They may also have greater capacity to absorb the risk associated with new technologies than those farmers who have no oxen.

Distance to market was another important factor affecting fertilizer adoption and its application rate on tef. The predicted probability of adopting fertilizer on tef was less for a farmer located 100 km away from the market than the farmer located 25 km away from the market. This variable is a surrogate for a number of factors and reflects the effects of output price, transport costs and availability of input on adoption. For farmers who are located far away from the market, output price may not serve as an incentive because of increased transport costs for marketing output and transporting materials from the market to their farms. Availability of fertilizer may also vary with distance to market. In Ethiopia, fertilizer prices are pan territorially fixed so there is no incentive for private fertilizer dealers to transport it to distant areas. As a consequence, private fertilizer distributors and retailers tend to concentrate in areas closer to towns. The Agricultural Inputs Supply Enterprise (AISE), a public organization, is responsible for distribution of fertilizer in areas not preferred and therefore not covered by private distributors and retailers. However, as reported by Mulat (1994), this organization is inefficient in fertilizer distribution and there may therefore be differences in availability between areas closer to the market and those further away. These factors might have contributed to the difference in the probability of adopting fertilizer and intensity of use.
In the context of small farmers, the shortage of working capital is often emphasized as a major constraint on the adoption of new technologies. Credit programmes and projects are meant to relieve this constraint. Even when credit is available, farmers may not have equal access to credit because of lack of information, lack of cash for down-payments and long bureaucratic procedures involved in obtaining credit. Lack of resources for collateral might constrain access to credit, but this is not the case in Ethiopia since there is no collateral arrangement for input credit. As shown in Table 8.4 and 8.5 the coefficient of the variable credit was significantly different from zero in the case of intensity of fertilizer use on tef. This result suggests that availability of credit facilitates adoption and intensity of use of fertilizer. Other factors being equal, the predicted probability of adopting fertilizer was higher for farmers who had access to credit than for those who had no access to credit.

The coefficients of extension, education and age had the expected signs. The positive association between extension and intensity of adoption is consistent with the hypothesis that extension will positively encourage farmers to increase intensity of use of fertilizer. However, when this positive association is subjected to statistical testing, the coefficients were not significantly different from zero for either crop. One possible explanation for the insignificant effect of extension on the intensity of adoption of fertilizer might be related to farmers' awareness about fertilizer. Fertilizer has been used by some farmers since the 1970s. Nearly all farmers know or have heard about it and its benefits. That being so, there may not be a great difference in awareness between adopters and non-adopters or between farmers who applied higher rates and those who used lower rates of fertilizer. Fertilizer adoption and

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3 The procedure to obtain credit in Ethiopia involves the following: the individual peasant presents his demand to his PA and PAs to their SCs stating input requirement by type and quantity. All such requests are forwarded to wereda MOA for validation. If the requests are found to be in order, the wereda MOA forwards its recommendation to the financing bank. The bank appraises the request and, if approved, a loan contract is signed between the SC and the bank. Finally, the bank advises the distributors to deliver the stated input (Mulat, 1994).
intensity of application appears to be better explained by other factors such as credit and access to resources rather than extension.

Family labour availability was expected to enhance adoption and intensity of fertilizer use on tef and wheat. As shown in Table 8.4 the coefficients of this variable, for both crops, were negatively signed, signalling a negative association between availability of family labour and intensity of adoption. However, the coefficients were not significantly different from zero.

It was expected that the variable education would positively influence adoption of new technologies. This is because educated farmers are more likely to be aware of the existence of new technologies. Moreover, farmers who read and write are more likely to serve as leaders of different farmers' organization. Such farmers have more opportunity to interact with extension agents, input suppliers, and financial institutions. They may have better access to information than illiterate farmers and may therefore be readier to adopt new technology. However, in this study, the coefficient of the variable education was not significantly different from zero. Hence, education did not improve farmers' decision making ability. This could be attributed to the level of education that most farmers had attained. Most farmers had less than three years of education. This level of education is not sufficient to improve farmers' decision making ability. Another possible explanation for this outcome is that information about fertilizer has been made available to all farmers through the various extension services. Therefore, there might be no variation between farmers in terms of information. Theoretically, the education level of farmers is expected to have a great impact on the adoption of complex technology but fertilizer is a simple technology and its adoption may not require a high level of education.
**Empirical Analysis of Rate and Intensity of Adoption**

Table 8.8. Factors influencing intensity of herbicide use on tef and wheat: Tobit estimates for model with full set of variables.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Tef</th>
<th>T-ratio</th>
<th>Wheat</th>
<th>T-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>T-ratio</td>
<td>Coefficient</td>
<td>T-ratio</td>
</tr>
<tr>
<td>Gender</td>
<td>-4.1345</td>
<td>-0.0566</td>
<td>-17.863</td>
<td>-1.685*</td>
</tr>
<tr>
<td>Age</td>
<td>-0.0869</td>
<td>-0.470</td>
<td>0.6847</td>
<td>2.696***</td>
</tr>
<tr>
<td>Education</td>
<td>-5.1313</td>
<td>-0.928</td>
<td>3.7375</td>
<td>0.501</td>
</tr>
<tr>
<td>Location</td>
<td>-3.9104</td>
<td>-0.685</td>
<td>1.5121</td>
<td>0.186</td>
</tr>
<tr>
<td>Labour</td>
<td>-0.1338</td>
<td>-0.079</td>
<td>1.7951</td>
<td>0.780</td>
</tr>
<tr>
<td>Farm size</td>
<td>2.5121</td>
<td>0.962</td>
<td>5.9605</td>
<td>1.670*</td>
</tr>
<tr>
<td>Distance to market</td>
<td>-1.1209</td>
<td>-6.587***</td>
<td>-1.7824</td>
<td>-7.544***</td>
</tr>
<tr>
<td>Index of awareness</td>
<td>0.8136</td>
<td>0.170</td>
<td>1.2286</td>
<td>0.199</td>
</tr>
<tr>
<td>Credit</td>
<td>6.8269</td>
<td>0.950</td>
<td>20.3590</td>
<td>1.945**</td>
</tr>
<tr>
<td>Oxen ownership</td>
<td>6.3996</td>
<td>3.753***</td>
<td>5.0027</td>
<td>2.279**</td>
</tr>
<tr>
<td>Perception of price</td>
<td>-9.5772</td>
<td>-1.703*</td>
<td>-4.3076</td>
<td>0.572</td>
</tr>
<tr>
<td>Constant</td>
<td>111.04</td>
<td>6.399***</td>
<td>78.991</td>
<td>3.237***</td>
</tr>
<tr>
<td>σ</td>
<td>30.7450</td>
<td>15.933</td>
<td>34.1290</td>
<td>12.203</td>
</tr>
<tr>
<td>Log likelihood</td>
<td>-732.6481</td>
<td>81</td>
<td>-466.449</td>
<td>82</td>
</tr>
<tr>
<td>Correctly predicted(%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*, **, *** indicate significant at 10%, 5% and 1% levels respectively.

Table 8.8 and 8.9 show the estimated coefficients of the tobit model and the associated asymptotic t-values for adoption and intensity of use of herbicide on tef and wheat. Among the variables included in the model, distance to market and oxen ownership had a strong impact on adoption and intensity of herbicide use on tef. In the case of wheat, the age and gender of the household head, farm size, distance to market, credit and oxen ownership were significantly related to the adoption and intensity of use of herbicide. All the significant variables had expected signs with the exception of gender. Education, differences in location and availability of labour had neutral impacts on the intensity of use of herbicide on both crops. The signs of the coefficients of the insignificant variables were not consistent across the two crops. The disparity observed might be attributed to chance or statistical noise as the coefficients of the variables were not statistically different from zero.
### Table 8.9. Factors influencing intensity of herbicide on tef and wheat: Tobit estimates for preferred model.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Tef</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>T-ratio</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farm size</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance to market</td>
<td>-1.0351</td>
<td>-6.615***</td>
</tr>
<tr>
<td>Credit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxen ownership</td>
<td>6.9223</td>
<td>4.448***</td>
</tr>
<tr>
<td>Perception of price</td>
<td>-10.693</td>
<td>-1.948**</td>
</tr>
<tr>
<td>Constant</td>
<td>104.32</td>
<td>8.584***</td>
</tr>
<tr>
<td>o</td>
<td>31.094</td>
<td>15.927</td>
</tr>
<tr>
<td>Log likelihood</td>
<td>-734.7917</td>
<td></td>
</tr>
<tr>
<td>Correctly predicted(%)</td>
<td>85</td>
<td></td>
</tr>
</tbody>
</table>

*, **, *** indicate significant at 10%, 5% and 1% levels respectively.

The predicted probabilities of adopting herbicide and intensity of use on tef and wheat by farmers for selected variables are shown in Table 8.10 and 8.11. The probability of adopting herbicide on tef for a farmer who perceived herbicide as not expensive and farmed 25 km away from a market was 99.8% with an application rate of 1.07 lt/ha (Table 8.10). As shown in Table 8.11 the probability of adopting herbicide on wheat for a farmer who had access to credit, had one pair of oxen and located 25 km away from market was 99.7% and the rate of application was 1.13 lt/ha. For a similar farmer but located 100 km away from market this probability drops to 13% and he becomes a non-adopter. In general, the probability of adopting herbicide and intensity of herbicide use declines as the number of oxen owned and farm size decreases. If we compare a credit farmer who has 3.5 ha and one pair of oxen with a non-credit farmer having similar resources, the probability of adopting herbicide on wheat falls from 63% to 40%, where the later probability indicates non-adoption.

The predicted probability also depicts an interesting relationship between distance to market and intensity of use of herbicide on the two crops. For the purpose of illustration, two
farmers located at 25 km and 100 km from market were considered. The probability that a farmer with access to credit, no oxen and located at 25 km away from market would adopt herbicide on wheat was 99.4%. The rate he is expected to apply was 1.02 lt/ha. However, for a farmer with similar access to resources, but located 100 km away from the market, the probability of adopting herbicide on wheat drops to 7%. Given the censored regression model we used, predicted probabilities less than 50% indicate non-adoption. Thus, market interaction becomes weakened as the distance from the market increases and the farmer who is located 100 km away from market is predicted to not adopt herbicide on wheat.

Table 8.10. Predicted probability of adopting herbicide on tef and intensity of application.

<table>
<thead>
<tr>
<th>Distance to market</th>
<th>One pair of oxen</th>
<th>No oxen</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Herbicide</td>
<td>Herbicide not</td>
</tr>
<tr>
<td></td>
<td>expensive</td>
<td>expensive</td>
</tr>
<tr>
<td>Probab</td>
<td>Intensity (lt/ha)</td>
<td>Probab</td>
</tr>
<tr>
<td>25 km</td>
<td>99.5</td>
<td>0.97</td>
</tr>
<tr>
<td>100 km</td>
<td>55.2</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Source: The probabilities are computed using the coefficients given in Table 8.9.
Table 8.11. Predicted probability of adopting herbicide on wheat and intensity of application.

<table>
<thead>
<tr>
<th>Variable</th>
<th>One pair of oxen</th>
<th>No oxen</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Credit</td>
<td>Non-credit</td>
</tr>
<tr>
<td></td>
<td>Probability</td>
<td>Intensity (lt/ha)</td>
</tr>
<tr>
<td>Distance to market</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25 km</td>
<td>99.7</td>
<td>1.13</td>
</tr>
<tr>
<td>100 km</td>
<td>12.7</td>
<td>0</td>
</tr>
<tr>
<td>Farm size</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.0 ha</td>
<td>52.4</td>
<td>0.04</td>
</tr>
<tr>
<td>3.5 ha</td>
<td>62.6</td>
<td>0.18</td>
</tr>
</tbody>
</table>

Source: The probabilities are computed for a farmer 40 years of age using the coefficients given in Table 8.9.

8.5.2. Adoption and Intensity of Use: Heckman Method of Analysis

As noted earlier, the Heckman's method of analysis involves two-steps, the probit and OLS, estimation procedures. The estimated coefficients of the probit models for fertilizer and herbicide adoption on the two crops are shown in Tables 8.12 to 8.15. The log likelihood ratio statistics are significant for the four models specified. The explanatory variables included in the models taken together had an impact on the adoption of fertilizer and herbicide on tef and wheat. The models correctly predicted 81% to 98% of farmers into adopters and non-adopters.

Results indicate that farm location and oxen ownership had a strong influence on farmers' decisions whether to adopt fertilizer on wheat or not. Thus, farmers with a sufficient number of oxen (2 or more) were more likely to adopt fertilizer than farmers who have an insufficient number of oxen. Farmers in location I were more likely to adopt fertilizer on wheat than their counterparts in location II. As noted above, this may be attributed to differences between the two locations in terms of infrastructure, physical factors, and information.

The probit estimation results for fertilizer adoption on tef in Table 8.12 and 8.13 show
that the coefficients of the variables farm size, oxen ownership, distance to market, and age had significant impacts on the adoption decisions of farmers. The effects of the first two variables were positive while distance to market and age had negative impact on fertilizer adoption. In other words, the probability of adopting fertilizer on tef increases with an increase in farm size, labour availability and number of oxen owned. However, the probability of adopting fertilizer on tef falls with an increase in distance to market and age of farmer. These findings did conform to our theoretical expectation and are consistent with the findings of Yohannes et al. (1990) and Chilot et al. (1996).

With regard to herbicide adoption on tef and wheat the coefficients of the variable distance to market were highly significant (Table 8.14 and 8.15) and appear to be a disincentive for adopting herbicide on both crops. For a farmer located far away from market, transport costs for outputs and inputs are high, implying a higher realised price for input and lower price for output. Moreover, the availability of inputs may also be a constraint as distance from market increases. These problems may discourage farmers from adopting the technology. Oxen ownership had a positive and strong influence on herbicide adoption on tef, suggesting that farmers who have a sufficient number of oxen appeared to adopt herbicide as compared to those who have insufficient oxen. Farm size had a similar effect on adoption of herbicide on wheat. With an increase in farm size there may not be sufficient family labour to perform weeding operation on time and adequately so the shortage of labour might encourage adoption of herbicide on large farms.
### Table 8.12. Determinants of fertilizer adoption on tef and wheat: Probit estimates for model with full set of variables.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Tef</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>T-ratio</td>
</tr>
<tr>
<td>Gender</td>
<td>-0.4499</td>
<td>0.466</td>
</tr>
<tr>
<td>Age</td>
<td>-0.1244</td>
<td>-1.672*</td>
</tr>
<tr>
<td>Education</td>
<td>-0.5485</td>
<td>-0.400</td>
</tr>
<tr>
<td>Location</td>
<td>1.6745</td>
<td>1.090</td>
</tr>
<tr>
<td>Labour</td>
<td>0.4812</td>
<td>1.304</td>
</tr>
<tr>
<td>Farm size</td>
<td>0.8852</td>
<td>1.754*</td>
</tr>
<tr>
<td>Distance to market</td>
<td>-0.1084</td>
<td>-1.745*</td>
</tr>
<tr>
<td>Index of awareness</td>
<td>-0.6584</td>
<td>-0.448</td>
</tr>
<tr>
<td>Credit</td>
<td>0.7584</td>
<td>0.748</td>
</tr>
<tr>
<td>Oxen ownership</td>
<td>2.4503</td>
<td>1.752*</td>
</tr>
<tr>
<td>Perception of price</td>
<td>-1.402</td>
<td>-1.066</td>
</tr>
<tr>
<td>Risk aversion</td>
<td>0.1064</td>
<td>0.087</td>
</tr>
<tr>
<td>Constant</td>
<td>12.672</td>
<td>1.572</td>
</tr>
<tr>
<td>Log likelihood</td>
<td>-11.4025</td>
<td>-56.1787</td>
</tr>
<tr>
<td>Correctly predicted(%)</td>
<td>98%</td>
<td>81%</td>
</tr>
</tbody>
</table>

*, **, *** indicate significant at 10%, 5% and 1% levels respectively.
Table 8.13. Determinants of fertilizer adoption on tef and wheat: Probit estimates for preferred model.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Tef</th>
<th>Coefficient</th>
<th>T-ratio</th>
<th>Wheat</th>
<th>Coefficient</th>
<th>T-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>-0.1032</td>
<td>-2.498***</td>
<td>-</td>
<td>0.3228</td>
<td>1.113</td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td>-</td>
<td>-</td>
<td>0.3228</td>
<td>1.113</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Location</td>
<td>1.9709</td>
<td>2.223**</td>
<td>1.7888</td>
<td>4.943***</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Labour</td>
<td>0.4369</td>
<td>1.613*</td>
<td>-0.0821</td>
<td>-0.986</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Farm size</td>
<td>0.9983</td>
<td>2.147**</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Distance to market</td>
<td>-0.0969</td>
<td>-2.241**</td>
<td>0.0144</td>
<td>1.656*</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Index of awareness</td>
<td>-</td>
<td>-</td>
<td>0.4039</td>
<td>1.463</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Oxen ownership</td>
<td>2.3060</td>
<td>2.605***</td>
<td>0.3277</td>
<td>2.738**</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Perception of price</td>
<td>-1.5793</td>
<td>-1.500</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>12.672</td>
<td>2.215**</td>
<td>-1.6901</td>
<td>-2.182</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Log likelihood</td>
<td>-13.4025</td>
<td>-56.7612</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Correctly predicted(%)</td>
<td>98%</td>
<td></td>
<td>81%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* *, **, *** indicate significant at 10%, 5% and 1% levels respectively.

Table 8.14. Determinants of herbicide adoption on tef and wheat: Probit estimates for model with full set of variables.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Tef</th>
<th>Coefficient</th>
<th>T-ratio</th>
<th>Wheat</th>
<th>Coefficient</th>
<th>T-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>-0.26601</td>
<td>-0.711</td>
<td>-0.66705</td>
<td>-1.492</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>0.0004192</td>
<td>0.043</td>
<td>0.015331</td>
<td>1.486</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td>-0.013814</td>
<td>-0.048</td>
<td>0.041028</td>
<td>0.137</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Location</td>
<td>-0.049716</td>
<td>-0.169</td>
<td>0.50780</td>
<td>1.593</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Labour</td>
<td>0.012638</td>
<td>0.152</td>
<td>0.055559</td>
<td>0.583</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Farm size</td>
<td>0.040253</td>
<td>0.298</td>
<td>0.24999</td>
<td>1.793*</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Distance to market</td>
<td>-0.53224</td>
<td>-6.313***</td>
<td>-0.055439</td>
<td>-6.449***</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Index of awareness</td>
<td>0.36986</td>
<td>0.143</td>
<td>0.25287</td>
<td>1.001</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>0.49441</td>
<td>1.393</td>
<td>0.41541</td>
<td>1.011</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Oxen ownership</td>
<td>0.32322</td>
<td>2.769***</td>
<td>0.12083</td>
<td>1.181</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Perception of price</td>
<td>-0.53172</td>
<td>-1.584</td>
<td>-0.075113</td>
<td>-0.247</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>4.3834</td>
<td>4.894***</td>
<td>2.4067</td>
<td>2.648</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Log likelihood</td>
<td>-69.97507</td>
<td>-66.11064</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Correctly predicted(%)</td>
<td>86%</td>
<td></td>
<td>83%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*, ***, *** indicate significant at 10% and 1% levels respectively.
Empirical Analysis of Rate and Intensity of Adoption

Table 8.15. Determinants of herbicide adoption on tef and wheat: Probit estimates for preferred model.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Tef Coefficient</th>
<th>T-ratio</th>
<th>Wheat Coefficient</th>
<th>T-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>-</td>
<td>-</td>
<td>-0.6124</td>
<td>-1.447</td>
</tr>
<tr>
<td>Age</td>
<td>-</td>
<td>-</td>
<td>0.0162</td>
<td>1.772*</td>
</tr>
<tr>
<td>Location</td>
<td>-</td>
<td>-</td>
<td>0.5469</td>
<td>1.768*</td>
</tr>
<tr>
<td>Farm size</td>
<td>-</td>
<td>-</td>
<td>0.2609</td>
<td>1.900**</td>
</tr>
<tr>
<td>Distance to market</td>
<td>-0.0512</td>
<td>-6.502***</td>
<td>-0.5503</td>
<td>-6.498***</td>
</tr>
<tr>
<td>Index of awareness</td>
<td>-</td>
<td>-</td>
<td>0.2597</td>
<td>1.042</td>
</tr>
<tr>
<td>Credit</td>
<td>0.4452</td>
<td>1.393</td>
<td>0.3788</td>
<td>0.940</td>
</tr>
<tr>
<td>Oxen ownership</td>
<td>0.3216</td>
<td>3.015***</td>
<td>0.1323</td>
<td>1.335</td>
</tr>
<tr>
<td>Perception of price</td>
<td>-0.5599</td>
<td>-1.726*</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Constant</td>
<td>4.2109</td>
<td>5.917***</td>
<td>2.3819</td>
<td>2.745***</td>
</tr>
<tr>
<td>Log likelihood</td>
<td>-70.4219</td>
<td>-</td>
<td>-66.3154</td>
<td></td>
</tr>
<tr>
<td>Correctly predicted(%)</td>
<td>86%</td>
<td></td>
<td>83%</td>
<td></td>
</tr>
</tbody>
</table>

*, *** indicate significant at 10% and 1% levels respectively.

Table 8.16 and 8.17 gives the estimates of the linear regression models for the amount of fertilizer used by farmers. The amounts used were expressed as percentages of the research recommendation. The variables location and family labour were found to be significant. Location and farmer perceptions of fertilizer price emerged as significant in the case of intensity of fertilizer use on wheat. None of the other variables affected the intensity of fertilizer use on both crops. With the exception of family labour availability, the effects of location and farmers' perceptions of fertilizer price were consistent with the tobit estimates. Contrary to expectations, the coefficient of family labour availability was negatively signed, suggesting a negative relationship between family labour availability and intensity of fertilizer use. A possible explanation for this outcome is that large families have more dependents and there is greater subsistence pressure on them. Because of this they may tend to use fertilizer on relatively productive crops such as wheat, barley or sorghum. The other possible explanation for the negative impact of labour is that investment on fertilizer is usually made...
during the time when many families are experiencing transitory food shortage. Large families are more affected by the transitory food shortage and may use their available resource, cash, to secure food. Thus, they may not have sufficient resources to buy fertilizer, which they therefore apply at lower rates. If this result does reflect this phenomenon, it provides an indication of how farmers with large family sizes are responding to technology transfer programmes.

The coefficients of the linear regression model for the intensity of use of herbicide on tef and wheat are shown in Table 8.18 and 8.19. Location and oxen ownership had a significant effect on the intensity of herbicide adoption on tef. The positive coefficient of oxen ownership shows that owning one additional ox would increase the herbicide application ratio (the amount used as a percentage of the recommended level) by about 2.4%. On the other hand, the value of the coefficient and the positive sign of credit indicate that access to credit increases the herbicide application ratio by about 16%.
Table 8.16. Factors influencing intensity of fertilizer adoption on tef and wheat: OLS estimates for model with full set of variables.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Tef Coefficient</th>
<th>T-ratio</th>
<th>Wheat Coefficient</th>
<th>T-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>-2.2854</td>
<td>-0.477</td>
<td>0.3594</td>
<td>0.045</td>
</tr>
<tr>
<td>Age</td>
<td>0.0825</td>
<td>0.689</td>
<td>0.0580</td>
<td>0.310</td>
</tr>
<tr>
<td>Education</td>
<td>2.1118</td>
<td>0.601</td>
<td>7.4856</td>
<td>1.211</td>
</tr>
<tr>
<td>Location</td>
<td>29.930</td>
<td>7.658***</td>
<td>44.6860</td>
<td>3.250***</td>
</tr>
<tr>
<td>Labour</td>
<td>-1.8954</td>
<td>-1.775*</td>
<td>-1.3409</td>
<td>-0.797</td>
</tr>
<tr>
<td>Farm size</td>
<td>-2.0026</td>
<td>1.173</td>
<td>0.5995</td>
<td>0.212</td>
</tr>
<tr>
<td>Distance to market</td>
<td>-0.0916</td>
<td>-0.878</td>
<td>-0.0055</td>
<td>-0.036</td>
</tr>
<tr>
<td>Index of awareness</td>
<td>0.4796</td>
<td>0.152</td>
<td>0.6891</td>
<td>0.129</td>
</tr>
<tr>
<td>Credit</td>
<td>2.3235</td>
<td>0.456</td>
<td>3.8805</td>
<td>0.458</td>
</tr>
<tr>
<td>Oxen ownership</td>
<td>1.0132</td>
<td>0.889</td>
<td>2.2257</td>
<td>1.121</td>
</tr>
<tr>
<td>Perception of price</td>
<td>1.4444</td>
<td>0.365</td>
<td>-9.4772</td>
<td>0.930</td>
</tr>
<tr>
<td>Risk aversion</td>
<td>-1.4765</td>
<td>-0.374</td>
<td>5.8538</td>
<td>0.930</td>
</tr>
<tr>
<td>( \lambda )</td>
<td>-14.253</td>
<td>-1.379</td>
<td>28.5300</td>
<td>1.450</td>
</tr>
<tr>
<td>Constant</td>
<td>71.0300</td>
<td>23.577***</td>
<td>33.5880</td>
<td>1.012</td>
</tr>
</tbody>
</table>

*\*, *** indicate significant at 10% and 1% levels respectively.

Note: \( \lambda \) is defined as \( f(.) / F(.) \) where \( f(.) \), and \( F(.) \) are density and distribution function of the standard normal.

Table 8.17. Factors influencing intensity of fertilizer adoption on tef and wheat: OLS estimates for preferred model.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Tef Coefficient</th>
<th>T-ratio</th>
<th>Wheat Coefficient</th>
<th>T-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Education</td>
<td>-</td>
<td>-</td>
<td>7.0895</td>
<td>1.541</td>
</tr>
<tr>
<td>Location</td>
<td>30.275</td>
<td>8.569***</td>
<td>42.338</td>
<td>5.272***</td>
</tr>
<tr>
<td>Labour</td>
<td>-1.9484</td>
<td>-1.972**</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Farm size</td>
<td>-1.5514</td>
<td>-1.014</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Oxen ownership</td>
<td>-</td>
<td>-</td>
<td>1.8481</td>
<td>1.128</td>
</tr>
<tr>
<td>Perception of price</td>
<td>-</td>
<td>-</td>
<td>-9.9718</td>
<td>-1.998**</td>
</tr>
<tr>
<td>( \lambda )</td>
<td>-19.109</td>
<td>-2.190**</td>
<td>20.455</td>
<td>1.535</td>
</tr>
<tr>
<td>Constant</td>
<td>70.7950</td>
<td>12.824***</td>
<td>46.747</td>
<td>3.761***</td>
</tr>
</tbody>
</table>

*\*, *** indicate significant at 10% and 1% levels respectively.

Note: \( \lambda \) is defined as \( f(.) / F(.) \) where \( f(.) \), and \( F(.) \) are density and distribution function of the standard normal.
Table 8.18. Factors influencing intensity of herbicide adoption on tef and wheat: OLS estimates for model with full set of variables.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Tef</th>
<th></th>
<th>Wheat</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>T-ratio</td>
<td>Coefficient</td>
<td>T-ratio</td>
</tr>
<tr>
<td>Gender</td>
<td>0.3691</td>
<td>0.064</td>
<td>5.9987</td>
<td>0.594</td>
</tr>
<tr>
<td>Age</td>
<td>-0.0256</td>
<td>-0.184</td>
<td>0.1461</td>
<td>0.577</td>
</tr>
<tr>
<td>Education</td>
<td>-1.5852</td>
<td>-0.364</td>
<td>2.3089</td>
<td>0.407</td>
</tr>
<tr>
<td>Location</td>
<td>-5.0744</td>
<td>-1.127</td>
<td>-17.866</td>
<td>-1.911**</td>
</tr>
<tr>
<td>Labour</td>
<td>0.3674</td>
<td>0.262</td>
<td>2.6228</td>
<td>1.475</td>
</tr>
<tr>
<td>Farm size</td>
<td>0.2063</td>
<td>0.095</td>
<td>-3.4264</td>
<td>-0.733</td>
</tr>
<tr>
<td>Distance to market</td>
<td>0.1845</td>
<td>0.529</td>
<td>0.1787</td>
<td>0.231</td>
</tr>
<tr>
<td>Index of awareness</td>
<td>-0.2919</td>
<td>-0.081</td>
<td>-3.7714</td>
<td>-0.744</td>
</tr>
<tr>
<td>Credit</td>
<td>-8.9831</td>
<td>-1.380</td>
<td>13.722</td>
<td>1.325</td>
</tr>
<tr>
<td>Oxen ownership</td>
<td>1.6636</td>
<td>0.987</td>
<td>1.8622</td>
<td>0.918</td>
</tr>
<tr>
<td>Perception of price</td>
<td>0.5865</td>
<td>0.119</td>
<td>3.4921</td>
<td>0.592</td>
</tr>
<tr>
<td>( \lambda )</td>
<td>-15.3780</td>
<td>-0.976</td>
<td>-16.738</td>
<td>0.689</td>
</tr>
<tr>
<td>Constant</td>
<td>47.914</td>
<td>2.344***</td>
<td>23.019</td>
<td>0.921</td>
</tr>
</tbody>
</table>

**, *** indicate significant at 5% and 1% levels respectively.

Table 8.19. Factors influencing intensity of herbicide adoption on tef and wheat: OLS estimates for preferred model.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Tef</th>
<th></th>
<th>Wheat</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>T-ratio</td>
<td>Coefficient</td>
<td>T-ratio</td>
</tr>
<tr>
<td>Location</td>
<td>-5.8285</td>
<td>-1.603*</td>
<td>-16.720</td>
<td>-3.232***</td>
</tr>
<tr>
<td>Labour</td>
<td>-</td>
<td>-</td>
<td>2.6385</td>
<td>1.771*</td>
</tr>
<tr>
<td>Credit</td>
<td>-7.4623</td>
<td>-1.370</td>
<td>16.944</td>
<td>2.113**</td>
</tr>
<tr>
<td>Oxen ownership</td>
<td>2.3741</td>
<td>2.044**</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>( \lambda )</td>
<td>-6.4937</td>
<td>-1.022</td>
<td>-12.319</td>
<td>-2.039</td>
</tr>
<tr>
<td>Constant</td>
<td>56.483</td>
<td>8.435***</td>
<td>39.704</td>
<td>3.719</td>
</tr>
</tbody>
</table>

**, *** indicate significant at 5% and 1% levels respectively.
Table 8.20. Summary statistics to test the null hypothesis that the coefficients of omitted variables are jointly not different from zero.

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Tef</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tobit</td>
<td>Heckman</td>
</tr>
<tr>
<td></td>
<td>Probit</td>
<td>OLS</td>
</tr>
<tr>
<td><strong>Fertilizer</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log-likelihood</td>
<td>-835(-833) &amp; -13(-11) &amp; -787(-785) &amp; -625(-623) &amp; -57(-56) &amp; -524(-518)</td>
<td></td>
</tr>
<tr>
<td>Number of restrictions</td>
<td>7 &amp; 5 &amp; 9 &amp; 6 &amp; 6 &amp; 8</td>
<td></td>
</tr>
<tr>
<td>Calculated $\chi^2$</td>
<td>4 &amp; 4 &amp; 4 &amp; 4 &amp; 2 &amp; 12</td>
<td></td>
</tr>
<tr>
<td>Critical value of $\chi^2$ at 1%</td>
<td>18.47 &amp; 15.08 &amp; 21.66 &amp; 16.81 &amp; 16.81 &amp; 20.09</td>
<td></td>
</tr>
<tr>
<td>Null hypothesis</td>
<td>accepted &amp; accepted &amp; accepted &amp; accepted</td>
<td>accepted &amp; accepted</td>
</tr>
<tr>
<td><strong>Herbicide</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log-likelihood</td>
<td>-735(-733) &amp; -70(-70) &amp; -635(-631) &amp; -467(-466) &amp; -66(-66) &amp; -378(-371)</td>
<td></td>
</tr>
<tr>
<td>Number of restrictions</td>
<td>8 &amp; 7 &amp; 8 &amp; 5 &amp; 3 &amp; 8</td>
<td></td>
</tr>
<tr>
<td>Calculated $\chi^2$</td>
<td>4 &amp; 0 &amp; 8 &amp; 2 &amp; 0 &amp; 14</td>
<td></td>
</tr>
<tr>
<td>Critical value of $\chi^2$ at 1%</td>
<td>20.09 &amp; 18.47 &amp; 20.09 &amp; 15.08 &amp; 11.34 &amp; 20.09</td>
<td></td>
</tr>
<tr>
<td>Null hypothesis</td>
<td>accepted &amp; accepted &amp; accepted &amp; accepted</td>
<td>accepted &amp; accepted</td>
</tr>
</tbody>
</table>

Notes: (a) Figures in parentheses indicate the log-likelihood for the models with all variables present.
(b) The number of restrictions equals the number of explanatory variables omitted.
The test statistics is defined as $-2(L_0 - L_{max})$, where $L_0$ and $L_{max}$ the values of the log-likelihood functions for the restricted and unrestricted models respectively.
If calculated $\chi^2$ is less than the critical value of $\chi^2$ the null hypothesis is accepted.
This study shows that location and oxen ownership had a strong effect on the adoption and intensity of use of fertilizer and herbicide irrespective of the models used. Location was more important in fertilizer adoption and its intensity of use, while distance to market was more influential in herbicide adoption and intensity of use. Distance to market was consistently significant in the tobit and probit models and fail to explain intensity of adoption in the OLS models for the two crops and technologies. There are some variables which were significant in the tobit analysis but not in the probit model. For example, risk and credit were significant for fertilizer adoption on tef in the tobit model, but not significant in the probit model. Similarly the variable that represents farmers' perception of input price was significant for wheat in the tobit model and insignificant in the probit model.

On the other hand, the impact of labour was not consistent across the models. The impact of labour on fertilizer adoption on tef was positive, while its effect on the intensity of use of fertilizer in the OLS model was negative. Surprisingly, the impact of this variable on the intensity of use of herbicide on wheat in the OLS model was positive and so was not in harmony with theoretical expectation. The coefficients of this variable were not significantly different from zero in the tobit models which suggests its effect on the adoption and intensity of use of fertilizer and herbicide was neutral.

As noted, some of the variables were significant in the tobit model, and not significant in the Heckman model or vice versa. There are also variables which were significant in both models. These suggest that some factors were related to the decision to adopt or not, while those variables that were significant in both models had an impact, not only on the decision to adopt or not, but also on how much to adopt. However, the degree of effect of the variables on adoption and intensity of adoption may vary. Their effects may be approximated by the

\[ \text{Empirical Analysis of Rate and Intensity of Adoption} \]
value of asymptotic t-value. If the t-value is large, the chance that the variable will have a weak effect on adoption is low. On the other hand, if the t-value is small the chance that the variable will have a neutral effect on adoption or intensity of adoption is high. Our findings suggest that there are factors which have an impact on both adoption and extent of use simultaneously and factors which influence adoption only.

8.6. Conclusions

In this chapter, factors affecting the adoption of improved varieties and intensity of use of fertilizer and herbicide were examined using probit model for the former technology and tobit and Heckman models for the latter two technologies. The results show that economic variables, in particular oxen ownership and distance to market, were the most significant factors affecting adoption and intensity of use of the technologies. It was also observed from the empirical results that location is a key factor affecting both adoption and intensity of adoption. Location failed to be of importance only in the tobit models estimated for herbicide adoption. Herbicide adoption was more influenced by distance to market. Being a proxy variable, location reflects the combined effect of agro-climatic, soil, infrastructural, and institutional factors. Differences in these factors would have great impact on the probability of adopting technology and on its intensity of use.

Farm size and farmers' perceptions of input prices were found to be significant in three of the models estimated. Based on the models in which these variables were found to be significant, we conclude that farm size appears to affect adoption decisions positively. On the other hand, farmers' perception of input price seems to discourage intensity of use of fertilizer and herbicide.
The empirical results further show that gender and risk aversion were significant in only one or two of the models specified. We can conclude that these variables do not seem to contribute much to adoption and the intensity of use of the technologies we are dealing with. The impact of age on adoption and intensity of adoption was also weak as it was significant in only a few models. In the few cases where this variable was significant, it had a negative impact on the decision to adopt fertilizer on tef, and a positive impact on the adoption and intensity of use of herbicide on wheat.

Finally, the coefficients of some of the variables examined were significant in both the adoption models and the intensity models. Other variables appear to be influential in one or other of the models but not both. From this outcome we conclude that some variables influence either adoption or intensity of adoption or both.

This chapter has identified variables that are important in influencing technology adoption and intensity of use at a given time. The results help to identify variables to be examined in the duration analysis which deals with the speed of adoption over time in the next chapter.
THEORETICAL AND EMPIRICAL ANALYSIS OF DURATION MODELS AND ITS APPLICATION TO AGRICULTURAL TECHNOLOGY ADOPTION

9.1. Introduction

Farmers do not adopt new technologies exactly at the same time. They usually wait until they have sufficient information and the resources required for adoption. Since farmers differ in access to information and resources, waiting times also differ from farmer to farmer. The length of time farmers wait before adopting new technology has been a focus of many empirical studies. However, most studies have not directly modelled the waiting-time so the relationships between explanatory variables and the wait have not been adequately investigated. Most studies have concentrated on a cross-sectional analysis of adoption at a point in time. The objective of the work reported in this chapter is to examine the dynamic aspect of the adoption process using duration analysis to identify the economic, social and institutional factors responsible for the delay in adoption of fertilizer and herbicide. Identification of these factors is of great importance for designing programmes for technology generation and transfer. Duration analysis can be used to identify time-invariant and time-varying variables which are important in research and extension policies formulation.

This chapter is divided into 6 sections. The next section briefly introduces the concept of duration data and duration analysis and the following section explains duration data distributions. The distribution of duration data is modified by the explanatory variables; therefore, Section 9.4 describes duration models which incorporate explanatory variables. Section 9.5 presents models specified to predict the effect of explanatory variables on the conditional probability of adopting fertilizer and herbicide. The results of two empirical
models, Weibull and exponential, are discussed in Section 9.6. The final section provides some concluding remarks.

9.2. Duration Data and Duration Analysis

Duration data are data that have beginning and end points. Such data therefore represent the length of time that elapses from the beginning of some event either until it ends or until the measurement is taken. Data of this nature includes strike duration, length of unemployment spells, interval between conceptions, time until business failure, length of time from introduction of new technology to its adoption, survival times of heart transplant patients, interval between purchases etc. The time origin of these data need not be and usually is not at the same calendar time for each individual observation. The entry into a certain state could be staggered and the duration measured from the individual’s own date of entry. For example, if a technology was introduced in 1980 and an individual farmer started his farming in 1985, the entry time for that individual would be 1985, but for a farmer who had already started farming sometime before 1980 the entry time would be 1980.

Duration analysis presents numerical and graphical summaries of duration data. It also allows the researcher to investigate the effects of explanatory variables on the duration of stay of an individual in a given state. The central concept used in duration analysis is conditional probability (Kiefer, 1988), in that it provides estimates of the likelihood that the state occupied by an individual will end in the next short interval period given that it has lasted to that period.

The application of duration analysis is well established in biomedical and engineering research. In biomedical research the method has been used to compare two or more treatment groups and to identify factors that affect the survival times of treatment groups (eg. survival times of heart transplant recipients, time to occurrence of symptoms of a disease etc.). In
engineering research, the method has been applied to determine service life of industrial and
electronic components. More recently, it has been applied to economic problems involving the
analysis of data on the time to occurrence of particular economic events. Examples of time
dependent economic variables to which this method is applicable include time to adoption of
new technologies, duration of unemployment, lifetimes of firms, payback periods for loans and
time to invention from research in investment. In economic studies the method has been used
mainly to analyze data on lengths of spells of unemployment, but recently Hannan and
and Burton et al. (1997) have used it to capture dynamic aspects of adoption processes. In
particular, the latter three studies used duration analysis to analyze the adoption of agricultural
technologies.

9.3. Duration Data Distribution

Probability theory plays a fundamental role in duration data analysis, probabilities of
central interest being the survival function, $S(t)$, and the hazard function, $h(t)$. The cumulative
distribution function, $F(t)$ and the probability density function, $f(t)$ are also useful in deriving
the two functions. To illustrate the concept of a duration data distribution, let $T$ be a non­
negative continuous random variable denoting the duration of stay in a given state. The
cumulative distribution function of $T$ is then given by,

$$F(t) = \int_0^t f(u) \, du = \text{pr}(T \leq t)$$

(9.1)

where $t$ is a "realization" of $T$. This function represents the probability that the survival time
is less than some value of time, $t$. The probability of an individual not adopting until or beyond
time $t$ is given by the survival function:
To define the hazard function, consider the probability that the random variable associated with an individual's duration, $T$, lies between $t$ and $t + \Delta t$, conditional on $T$ being greater than or equal to $t$, (i.e. $\Pr(t \leq T < t + \Delta t \mid T \geq t)$). The hazard function $h(t)$ is then the limiting value of this probability divided by the time interval $\Delta t$, as $\Delta t$ tends to zero:

$$h(t) = \lim_{\Delta t \to 0} \left(\frac{\Pr(t \leq T < t + \Delta t \mid T \geq t)}{\Delta t}\right)$$  \hspace{1cm} (9.3)

By definition of conditional probability, $h(t)$ can be derived from equation 9.3.

$$h(t) = \lim_{\Delta t \to 0} \left(\frac{F(t + \Delta t) - F(t)}{\Delta t} \right) \frac{1}{S(t)}$$  \hspace{1cm} (9.4)

$$= \frac{f(t)}{S(t)}.$$

The hazard function specified in equation 9.3 represents the instantaneous rate of leaving a state (e.g. death in medical trials and adoption in technology adoption studies) in the short interval of length $\Delta t$ after $t$, given that it was not left before $t$ (Collet, 1994; Lancaster, 1990; Lawless 1982). In technology adoption studies the instantaneous rate corresponds to the conditional probability of a farmer adopting a technology at time $t$, given that he or she has not adopted before.

The hazard function describes the way in which the instantaneous probability of a failure or event for an individual changes with time. In the case of technology adoption, the probability of making the adoption decision may change with time. Thus, if it is assumed that the probability of adopting a technology increases as more information about the technology is received over time, the availability of information encourages farmers to adopt and this in turn shortens the time to adoption of new technology.
Some parametric distributions are particularly useful in the analysis of duration data. These include the exponential, Weibull, log-normal, gamma, log-gamma, log-logistic and generalized F distributions. Among these, the exponential and Weibull distributions are the most commonly used. The log-normal and gamma distributions are generally less convenient computationally, but are still employed (Kalbfleich and Prentice, 1980). Table 9.1 shows the survival and hazard functions for some of these distributions. The exponential distribution model is characterized by a constant hazard function, \( h(t) = \lambda \); the instantaneous failure rate does not depend on time \( t \), hence the conditional chance of failure or adoption over time is the same irrespective of the time an individual stayed in a given state. Because of this constant hazard rate, the exponential distribution is considered to be "memoryless" in the sense that the passage of time does not influence its hazard rate. However, time has an impact on the hazard functions of other distributions. For example, the Weibull distribution has a monotonically increasing or decreasing hazard function, depending on the parameter \( p \); when \( p < 1 \) \((p > 1)\), the hazard function monotonically decreases (increases) over time, while it reduces to the exponential function when \( p = 1 \).

<table>
<thead>
<tr>
<th>Distribution</th>
<th>Hazard Function, ( h(t) )</th>
<th>Survival Function, ( S(t) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exponential</td>
<td>( \lambda )</td>
<td>( S(t) = \exp(-\lambda t) )</td>
</tr>
<tr>
<td>Weibull</td>
<td>( \lambda P(\lambda t)^{p-1} )</td>
<td>( S(t) = \exp(-(\lambda t)^p) )</td>
</tr>
<tr>
<td>Normal</td>
<td>( \phi/\Phi )</td>
<td>( \Phi(-P \log(\lambda t)) )</td>
</tr>
<tr>
<td>Logistic</td>
<td>( \lambda P(\lambda t)^{p-1}/(1+ (\lambda t)^p) )</td>
<td>( 1/(1+ (\lambda t)^p) )</td>
</tr>
<tr>
<td>Log-logistic</td>
<td>( \lambda P(\lambda t)^{p-1}/(1+ (\lambda t)^p) )</td>
<td>( S(t) = 1/(1+ (\lambda t)^p) )</td>
</tr>
</tbody>
</table>

Source: Cox and Oakes (1984) and Greene (1996). Parameters \( \lambda \) and \( P \) indicate scale and shape. \( \Phi \) and \( \phi \) indicate cumulative and probability density functions of standard normal distribution.
The choice of distribution for empirical investigation depends on the particular economic problem being addressed, the convenience of the distribution for statistical inferences and the availability of simple forms for \( h(t), S(t) \) and \( f(t) \). Some distributions, such as Gompertz distribution, have no simple forms for these functions. Furthermore, when the hazard is affected by the passage of time one has to use a distribution with a non-constant hazard function. Once a decision has been made regarding which distribution to use, its parameters can be estimated using the maximum likelihood procedure. To illustrate how likelihood is constructed, consider \( n \) completed durations and \( m \) censored durations. Each completed duration at \( t \) and each censored duration contributes terms \( f(t, \theta) \), (the density of failure or adoption at \( t \)), and \( S(m, \theta) \), (the probability of surviving beyond \( m \)), to the likelihood, respectively. The likelihood function from the total independent observation will be,

\[
L^*(\theta) = \prod_{i=1}^{n} f(t_i, \theta) \prod_{j=1}^{m} S(m_j, \theta),
\]

where \( \theta \) is a vector of scale and shape parameters, which for the moment contains parameters \( \lambda \) and \( P \). The log likelihood function, \( L(\theta) = \ln L^*(\theta) \), is,

\[
L(\theta) = \sum_{i=1}^{n} \ln f(t_i, \theta) + \sum_{j=1}^{m} \ln S(m_j, \theta)
\]

which has completed durations contributing a density term \( f(t, \theta) \) and censored duration contributing a probability \( S(m, \theta) \). Alternatively the log-likelihood function can be expressed in terms of the hazard function:

\[
L(\theta) = \sum_{i=1}^{n} \ln h(t_i, \theta) + \sum_{j=1}^{m} \ln S(m_j, \theta)
\]

The maximum likelihood procedure can be used to estimate the parameter \( \theta \).
9.4. Modelling Effects of Explanatory Variables

The models discussed in the preceding section have dealt with distributions of duration data. In practice, however, these distributions can be affected by a number of explanatory variables. For this reason comprehensive models that incorporate the effects of explanatory variables need to be specified. Each of the distributions noted above can accommodate and predict the effects of explanatory variables on the hazard rate.

In the presence of explanatory variables the hazard function at time $t$ is defined as being conditional on the value of $x$ (Peterson, 1986; Lancaster, 1990):

$$h(t,x) = \lim_{\Delta t \to 0} \left( \frac{\text{pr}(t \leq T < t + \Delta t \mid T \geq t, x)}{\Delta t} \right)$$

where $x$ is a vector of explanatory variables.

In duration analysis there are two main ways of specifying a hazard function: the proportional hazard model and the accelerated lifetime models. Both of these models are more commonly used in economic studies and are discussed in the following sub-sections.

9.4.1. Proportional Hazard Model

The proportional hazard model is widely used in economic and biomedical research and is expressed as follows:

$$h(t, x, \theta, \beta) = h_0(t, \theta)g(x, \beta)$$ (9.9)
where $h_0(t, \theta)$ denotes the baseline hazard, i.e., a hazard for the individual under "standard" conditions, and assuming any parametric distribution; $\beta$ is a vector of unknown parameters characterizing the explanatory variables; $\theta$ is a vector of scale and shape parameters; and $g(x, \beta)$ represents a function linking explanatory variables to survival, where increasing $g(x, \beta)$ corresponds to increasing risk, i.e., to decreasing durations. The vector $x$ for the moment includes only time-invariant variables and acts multiplicatively on the baseline hazard.

The function $g(x, \beta)$ can be specified in various ways, including a linear form. The following specification is often preferred because of its convenience:

$$g(x, \beta) = \exp(\beta'x). \tag{9.10}$$

In this specification, non-negativity of $g(x, \beta)$, i.e., $g(x, \beta) > 0$, does not impose any restrictions on $\beta$. Moreover, estimation and interpretation is simple as the model becomes linear in logarithms. This allows for the usual partial derivative interpretation of the $\beta$s. Thus, for the model 9.10 the marginal effect would be,

$$\frac{\partial \ln h(t, x, \theta, \beta)}{\partial x} = \frac{\partial \ln g(\beta'x)}{\partial x} \cdot \beta \tag{9.11}$$

The sign of $\beta$ indicates the direction of the effect of $x$ while its values show the proportional effect of $x$ on the conditional probability of completing a duration. However, in the case where proportional hazard model is formulated as,

$$h(t, x, \theta, \beta) = \exp(\beta'x)h_0(t, \theta), \tag{9.12}$$

the usual partial derivative interpretation is not appropriate.

---

1 In duration analysis the explanatory variables included in a vector $x$ are set to some meaningful "standard" conditions (Cox and Oakes 1984), say $x = 0$ or the mean value of $x$. The model under this condition gives a baseline hazard, $h_0(t, \theta)$. The changes induced by values greater than zero or values greater or less than the mean value of the explanatory variable are characterized in terms of parameter $\beta$. Hence, $h_0(t, \theta)$ can be interpreted as the hazard function for the average individual in the sample.
The parameters of the proportional hazard model can be estimated using the maximum likelihood procedure (Kiefer, 1988) or partial likelihood approach suggested by Cox (1972, 1975). The latter procedure is applied when the form of the baseline hazard function, \( h_0(t, \theta) \), is not specified and the assumption of constant hazard is relaxed. To illustrate the partial likelihood approach, consider \( n \) completed durations ordered from the smallest to the largest \( (t_1 < t_2 < \ldots < t_n) \). Assume also that there is no censoring and there are no tied observations (i.e. when two or more farmers adopted at the same time). The conditional probability that the first individual leaves the state it occupied at duration \( t_i \), given that any of the \( n \) individuals could have been left its state at \( t_i \), is:

\[
\frac{h(t_i, x_1, \theta, \beta)}{\sum_{i=1}^{n} h(t_i, x, \theta, \beta)}
\]  

(9.13)

If we assume the proportional hazard, \( h(t, x, \theta, \beta) = g(\beta'x)h_0(t, \theta) \), i.e. adopt an arbitrary baseline, expression 9.12 reduces to,

\[
\frac{g(x_1, \beta)}{\sum_{i=1}^{n} g(x_i, \beta)}
\]  

(9.14)

which represents the contribution of the shortest duration observed to the partial likelihood. Any individual \( j \) who converts to adopter would contribute,

\[
\frac{g(x_j, \beta)}{\sum_{i, j} g(x_i, \beta)}
\]  

(9.15)

to the likelihood (Cox and Oakes, 1984). The log likelihood function resulting from the individuals contribution is,

\[
L(\theta) = \sum_{i=1}^{n} [\ln g(x_i, \beta) - \ln(\sum_{j=i}^{n} g(x_j, \beta))].
\]  

(9.16)
Censored observations do appear in the second term of the log likelihood (i.e. the denominator). They do not enter in the numerator as there is no information on their exact durations.

9.4.2. Accelerated Lifetime Model

In the proportional hazard model (equation 9.12) explanatory variables act multiplicatively on the baseline hazard. In the accelerated lifetime model the explanatory variables are introduced in such a way that they have a direct effect on individuals' waiting time rather than on the baseline hazard. The hazard function of this model takes the general form:

\[ h(t, x, \beta) = h_0(t g(x, \beta))g(x, \beta). \]  

(9.17)

As can be seen from equation 9.17, the explanatory variables act multiplicatively on time, \( t \), and thereby alter the rate at which failure occurs. In other words, the role of the explanatory variable is to accelerate or decelerate the individual duration in a given state.

The exponential specification with \( h_0 \) exponential and \( g(x, \beta) = \exp(\beta'x) \) is both a proportional hazard and an accelerated lifetime model (Kiefer, 1988). Thus, Kalbfleisch and Prentice (1980) note that the exponential and Weibull regression models can be considered to be special cases of either the accelerated model or the proportional hazard model. Thus, equation 9.12 and 9.17 are equivalent specifications.

Cox and Oakes (1984), Collet (1994) and Kalbfleisch and Prentice (1980) have discussed the possibility of incorporating time-varying variables in the proportional hazard model. Time-varying variables can also be introduced in the accelerated lifetime model. The procedure for combining time-invariant and time-varying variables and analysing them using LIMDEP computer software is illustrated by Greene (1996). Other computer software that can estimate accelerated lifetime and proportional hazard models follow different procedures for
combining the two data sets. However, we do not demonstrate these procedures here, since in this study we followed the procedure developed by Greene (1996).

9.5. Heterogeneity and Specification Test

There are many sources of uncertainty in the specification of duration models in economics, the main areas being those that arise from the choice of functional forms, explanatory variables and distribution assumptions for unobservable heterogeneity (Pudney, 1989). Heterogeneity arises in duration models when different individuals in the population have potentially different distributions of the dependent variables. Explanatory variables are introduced to account for the differences in the distributions in the dependent variables for the individuals in a population. If full control is not achieved (i.e. if explanatory variables are omitted) accurate inference cannot be made. For example, the presence of heterogeneity may lead to downwardly biased estimates of duration dependence (Kiefer, 1988), i.e. the hazard appears to be decreasing over time when it is actually constant. Therefore, diagnostic testing, once a model has been fitted, is important.

Test statistics such as the likelihood ratio, Wald and Lagrange Multiplier can be used to perform diagnostic tests for duration models. Choice between these three methods is a matter of convenience. The approach in diagnostic testing is to test the joint hypothesis that all the slope coefficients are zero against the alternative hypothesis. If one or more coefficient is significant, the data provide evidence to suggest that the duration of stay in a given state is related to those significant explanatory variables.
9.6. Analytical Model Specification

Farmers seldom adopt new technologies immediately they become available, but usually postpone adoption until sufficient information, and additional resources required for adoption become available. Also, farmers differ in access to resources, information and in their risk aversion behaviour. Because of these differences some farmers adopt a new technology readily while others wait for a number of years and are slow in adopting. In our study, few farmers adopted fertilizer and herbicide in the year they were introduced; most waited 2 to 24 years before adopting them and some had still not adopted the technologies at the time the data for this study was collected.

In this study, an attempt was made to model the adoption behaviour of farmers and, in particular, the time farmers have waited before adopting fertilizer and herbicide. It is assumed that the times waited before adopting these technologies are determined by a set of factors consisting of time-invariant and time-varying variables. The model that predicts the relationship between explanatory variables and the conditional probability of adopting fertilizer and herbicide was specified in terms of a hazard function. The hazard function for adopting fertilizer on tef during a year t, given that the farmer had not adopted before, was specified as a function of explanatory variables in set A and the variable FPIP from set B in Table 8.1 plus the time-varying variables PRICE(t) and REFORM(t). Moreover, the variable AGE in set A, Table 8.1, was replaced by the time-varying variable AGE(t). The Weibull distribution was assumed in specifying the hazard function. The hazard function for adopting fertilizer on wheat was specified as a function of variables used for fertilizer adoption on tef assuming the exponential distribution. Similarly, the hazard function for adopting herbicide on the two crops was specified as a function of the explanatory variables in set A, Table 8.1, and corresponding farmers' perceptions of input price and time-varying variables including the cereals price index.
(PINDEX(t)), REFORM(t) and AGE(t).

The dependent variable used was the time farmers waited before adopting fertilizer and herbicide, and measured by the number of years elapsed since the introduction of fertilizer and herbicide. For an individual observation, the year of introduction was set to $t=1$, then each succeeding year $t$ increased by unit (year) until the technology was finally adopted. For farmers who started farming after the technologies were introduced, the times they waited before adopting the technologies were counted from the year they started farming to the year they finally adopted them. For the farmers who had not adopted yet, the duration was right-censored at the year of data collection.

The explanatory variables used in the empirical model originated from a formal survey and from published sources. Both time-invariant and time-varying variables hypothesized to affect duration of adoption were collected. The variables included in the models were discussed in detail in Section 6.3, and descriptions and measurements of the time-invariant explanatory variables were summarized in Table 8.1. Therefore, we do not repeat here discussion of the rationale for including each variable in the analytical model and how they were measured; instead, those time-varying variables that were not described in Table 8.1 are listed below.

- **AGE(t)** Cumulative age of household head. This was measured by augmenting the initial age of a farmer (i.e. the age of a farmer at the time when the technology was introduced or when the farmer started his own farming) by one each year up to the year he finally adopted the technologies.
- **PINDEX(t)** Cereals Price Index.
- **FRTPR(t)** Weighted average price of fertilizers (DAP and Urea prices)
- **RPRICE(t)** Relative output price. This variable was proxied by dividing the cereals price index by the weighted average price of.
fertilizer.

\textbf{CLTIME}(t) \quad \text{Calendar time. This was measured by counting actual years starting from when the farmer was exposed to a technology (i.e. the year a technology was introduced or the farmer started farming, whichever is relevant) and augmented by one year up to the year an individual farmer adopted the technology.}

\textbf{REFORM}(t) \quad \text{Dummy variable to measure the effects of economic reform. The dummy variable was set equal to one for the post-reform period, and zero otherwise.}

9.7. \textit{Duration Analysis: Non-Parametric Models Estimation Result}

An initial step in duration data analysis is to summarize and show how duration data (survival times) for all the individuals in the sample are distributed. In technology-adoption studies, summaries of survival times may depict the speed of adoption of different technologies and facilitate comparisons. The summaries may also help in comparing adoption behaviours of individuals sampled from different populations. Graphic or numerical summaries of estimates of survival and hazard functions can be used for these purposes. In this type of analysis, no specific assumptions of the underlying distribution are made. Therefore, the method is said to be non-parametric. In the presence of censored data, the Kaplan-Meier method is an appropriate method to estimate the survival and hazard functions. Our survey data consist of adopters and non-adopters so we applied the Kaplan-Meier method to summarize the durations farmers waited before adopting fertilizer and herbicide.
The cumulative survival rate was plotted against time (Figure 9.1). Here, time denotes the number of years elapsed from the introduction of fertilizer until the year of adoption or the year the data were collected for censored observations. At the time fertilizer was introduced, the value of the cumulative survival rate was 1, this is to say \( t \) takes value zero as fertilizer has not yet been adopted. From Figure 9.1 it can be seen that the cumulative survival rate declined sharply in the first three intervals, while the pace of decline was more gradual after the first three intervals, i.e. after approximately the 7th year. Thus, the speed of diffusion of fertilizer was rapid in the early stages of the study period but became more sluggish later. In the case of herbicide adoption, the cumulative survival rate declined gradually from the very beginning.
and persistently throughout the study period, i.e. over each interval of time only a few farmers adopted herbicide (Table 9.2). The median time of adoption for herbicide was greater than the median time of adoption for fertilizer. This large median time of adoption plus persistent gradual decline in survival rate for herbicide adoption suggests that the pace of diffusion of herbicide was slower than that for fertilizer, which has a relatively small median time of adoption and survival rate that dropped sharply in the initial years of adoption.

The following reasons may explain the differences in fertilizer and herbicide adoption behaviour. First, agricultural policy has tended to neglect the use of herbicide. Policy makers assume that surplus labour exists in rural areas and so have not supported the use of herbicide. On the other hand, fertilizer promotion received support from both government and donor organizations and priority has been given to fertilizer in foreign currency allocation. Second, fertilizer was treated as part of the core technological package promoted by programmes and projects in the study area, whereas this was not the case for herbicide. Third, formal credit is available for fertilizer purchase but not available for herbicide. Farmers therefore have to use their own funds or informal sources of credit to finance herbicide purchase. The timing of herbicide purchases coincides with the time when farmers are short of money and the possibility of self-financing is therefore very limited while informal credit is expensive. Fourth, although the share of fertilizer cost is more than the share of herbicide cost in total production, the cost of fertilizer is underestimated because of direct and indirect subsidies (fertilizer is stored in MOA’s stores and MOA bears the salaries of its staff who are involved in fertilizer distribution) for fertilizer. No subsidy is available for herbicide and it is mainly imported, distributed and retailed by private dealers.
Figure 9.2. Cumulative survival rate of herbicide adoption on tef.

Note: Horizontal axis is time (year).

9.8. Duration Analysis: Parametric Models Estimation Results

As noted above, the non-parametric method of duration data analysis indicates the speed at which technologies are adopted by sample farmers but cannot explain the basic causes underlying the adoption rate. Therefore, in the remaining part of this section we discuss the results from parametric models that can explain factors which speed up or slow down the rate at which technologies are adopted. Theoretical considerations indicate that time-invariant and time-varying factors will influence a farmer's decision to adopt or forego adoption of technology. Duration models were estimated to examine the effects of these variables in the speed of adoption of fertilizer and herbicide. The maximum likelihood procedure was used to estimate the models.
Initially, the empirical models were estimated assuming a Weibull distribution for the duration data. The estimated parameters, particularly $P$, were subjected to statistical tests to verify the appropriateness of the Weibull distribution. Except for fertilizer adoption on tef, the shape parameter, $P$, was not significantly different from one for the models estimated; this implies constant baseline hazard for fertilizer adoption on wheat and herbicide adoption on both crops suggesting that the passage of time had no influence on the conditional probability of adopting fertilizer on wheat and adopting herbicide on tef and wheat. An exponential model is appropriate for estimating a relationship with constant hazard. Therefore, the results reported for fertilizer adoption on wheat and herbicide adoption for both crops were estimated using the exponential model. The Weibull model which was estimated for fertilizer adoption on tef has a baseline hazard of $\lambda P(\lambda t)^{P-1}$. As stated in Section 9.3 the baseline hazard of this model either monotonically increases or decreases with the passage of time.

The duration analysis results are shown in Tables 9.2, 9.3, 9.4, 9.5, 9.6, 9.7 and 9.8. The first two tables present the estimated results of models that included full sets of the variables considered relevant on a priori grounds as affecting fertilizer and herbicide adoption. The last two tables show the results from the restricted models in which those variables that had t-values of less than one, in models with full sets of variables, were removed. Based on the Likelihood Ratio Test (LRT), the models specified for fertilizer and herbicide were significant at a level of 1%. This indicates that the explanatory variables, taken together, jointly influenced the conditional probability of adopting fertilizer and herbicide. The values of parameters $\lambda$ and $P$ and the median time of adoption are reported at the bottom of each table. The estimated value of $P$ for the fertilizer adoption on tef was significantly different from one, suggesting positive duration dependence of adoption probabilities. Again, in the presence of explanatory variables, the median time of fertilizer adoption was less than the median time of herbicide adoption, suggesting that fertilizer was adopted more rapidly than herbicide and this is
consistent with non-parametric results reported in the preceding section.

As shown in Table 9.2 and 9.3, farmers' perceptions of input prices, education and extension were not significant in all the models estimated. Possible reasons for the lack of significance of education and extension have been explained in Section 8.5. Since most farmers perceive inputs as expensive, the variable used to proxy farmers' perceptions of input prices lacks sufficient variability to classify farmers into adopters and non-adopters. As predicted by the model, there was no difference between male and female headed households in terms of speed of adoption. A statistical test conducted to verify whether the coefficients on the omitted variables are jointly zero failed to reject the null hypothesis, implying that dropping these variables is statistically justified (see Table 9.8). The reasons for omitting variables are discussed in Section 8.5.1.
Table 9.2. Determinants of the conditional probability of fertilizer adoption on tef and wheat: model with full set of variables.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Tef - Weibull model</th>
<th>Wheat - Exponential model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>T-ratio</td>
</tr>
<tr>
<td>Age(t)</td>
<td>-0.0155</td>
<td>-2.729***</td>
</tr>
<tr>
<td>Gender</td>
<td>-0.0377</td>
<td>-0.184</td>
</tr>
<tr>
<td>Education</td>
<td>0.0684</td>
<td>0.457</td>
</tr>
<tr>
<td>Location</td>
<td>0.2516</td>
<td>1.584</td>
</tr>
<tr>
<td>Labour</td>
<td>-0.0248</td>
<td>-0.560</td>
</tr>
<tr>
<td>Farm size</td>
<td>-0.0144</td>
<td>-0.204</td>
</tr>
<tr>
<td>Index of awareness</td>
<td>-0.1862</td>
<td>-1.404</td>
</tr>
<tr>
<td>Deflated output price(t)</td>
<td>0.1254</td>
<td>2.923***</td>
</tr>
<tr>
<td>Distance to market</td>
<td>-0.0060</td>
<td>-1.369</td>
</tr>
<tr>
<td>Credit</td>
<td>0.7352</td>
<td>3.578***</td>
</tr>
<tr>
<td>oxen</td>
<td>0.0810</td>
<td>1.575</td>
</tr>
<tr>
<td>Perceptions of input price</td>
<td>-0.1177</td>
<td>-0.692</td>
</tr>
<tr>
<td>Reform(t)</td>
<td>-0.6425</td>
<td>-3.439***</td>
</tr>
<tr>
<td>Constant</td>
<td>-2.1834</td>
<td>4.079***</td>
</tr>
<tr>
<td>P</td>
<td>1.3001</td>
<td>2.778***</td>
</tr>
<tr>
<td>λ</td>
<td>0.1376</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>5.4835</td>
<td></td>
</tr>
<tr>
<td>Log-likelihood</td>
<td>-505</td>
<td></td>
</tr>
</tbody>
</table>

* ** *** indicate significant at 10%, 5% and 1% levels respectively.
Table 9.3. Determinants of the conditional probability of herbicide adoption on tef and wheat, model with full set of variables - Exponential model estimates.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Tef</th>
<th></th>
<th>Wheat</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>T-ratio</td>
<td>Coefficient</td>
<td>T-ratio</td>
</tr>
<tr>
<td>Age(t)</td>
<td>-0.0014</td>
<td>-0.187</td>
<td>0.0150</td>
<td>1.410</td>
</tr>
<tr>
<td>Gender</td>
<td>-0.2059</td>
<td>-0.714</td>
<td>-0.0765</td>
<td>-0.669</td>
</tr>
<tr>
<td>Education</td>
<td>0.2209</td>
<td>1.024</td>
<td>0.3045</td>
<td>1.086</td>
</tr>
<tr>
<td>Location</td>
<td>-0.4967</td>
<td>-2.142**</td>
<td>-0.1876</td>
<td>-0.569</td>
</tr>
<tr>
<td>Labour</td>
<td>-0.0601</td>
<td>-0.871</td>
<td>-0.0266</td>
<td>-0.300</td>
</tr>
<tr>
<td>Farm size</td>
<td>0.0753</td>
<td>0.773</td>
<td>0.3218</td>
<td>2.391***</td>
</tr>
<tr>
<td>Index of awareness</td>
<td>0.0339</td>
<td>0.188</td>
<td>0.2745</td>
<td>1.155</td>
</tr>
<tr>
<td>Output price index(t)</td>
<td>0.0027</td>
<td>6.330***</td>
<td>0.0026</td>
<td>4.261***</td>
</tr>
<tr>
<td>Distance to market</td>
<td>-0.0418</td>
<td>-5.481***</td>
<td>-0.0697</td>
<td>-6.367***</td>
</tr>
<tr>
<td>Credit</td>
<td>0.4770</td>
<td>1.650***</td>
<td>0.4083</td>
<td>1.008</td>
</tr>
<tr>
<td>oxen</td>
<td>0.1481</td>
<td>2.394***</td>
<td>0.1783</td>
<td>2.318**</td>
</tr>
<tr>
<td>Perceptions of input price</td>
<td>-0.3187</td>
<td>-1.481</td>
<td>-0.0840</td>
<td>-0.297</td>
</tr>
<tr>
<td>Reform(t)</td>
<td>-0.1957</td>
<td>-0.846</td>
<td>0.3686</td>
<td>1.257</td>
</tr>
<tr>
<td>Constant</td>
<td>-1.2053</td>
<td>1.721*</td>
<td>-1.8150</td>
<td>1.793*</td>
</tr>
<tr>
<td>P</td>
<td>1.0000</td>
<td></td>
<td>1.0000</td>
<td></td>
</tr>
<tr>
<td>( \lambda )</td>
<td>0.0882</td>
<td></td>
<td>0.0491</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>7.8604</td>
<td></td>
<td>14.1045</td>
<td></td>
</tr>
<tr>
<td>Log-likelihood</td>
<td>-503</td>
<td></td>
<td>-322</td>
<td></td>
</tr>
</tbody>
</table>

*, **, *** indicate significant at 10%, 5% and 1% levels respectively.

Input prices may play an important role in technology adoption decisions. A model which included fertilizer price was estimated to predict the effect of price on adoption of fertilizer on tef and wheat. In both cases the coefficients on fertilizer price were not significant. Furthermore, in the presence of this variable, the effect of output price on fertilizer adoption was weak. It has to be noted that input and output prices have been increasing together, having a correlation coefficient of 0.85 which indicates the existence of a multicollinearity problem. Therefore, the variable input price was not included independently as an explanatory variable in the models, but instead was used to deflate output price.
In Ethiopia economic and political reforms have been going on since 1990. It was assumed that economic reform could have a positive or negative effect on the adoption of technology. Economic reform included market liberalization, deregulation of prices of outputs and the involvement of the private sector in input trade. These reform components might have created favourable conditions for farmers to adopt fertilizer and herbicide. On the other hand, devaluation of the local currency has raised the costs of fertilizer and herbicide and this might have had a negative impact on the adoption of these technologies.

Duration analysis allows us to predict the effect of economic reform on technology adoption. In our study the effects of pre- and post-reform periods were represented by a dummy variable. In the models which included this dummy variable, its coefficients for fertilizer on wheat and herbicide on both crops were not significantly different from zero. These results suggest that the effect of reform on herbicide and fertilizer adoption was neutral. However, the economic reform coefficient for fertilizer application on tef was negative and significant. There are two possible reasons for the suggested negative impact of economic reform on fertilizer adoption on tef. First, currency devaluation was one of the reform measure undertaken in Ethiopia. Following the devaluation of the birr, the fertilizer price was increased by 40% in 1993, while the tef price declined by 9% in the same year. Tef being the main cash earner for farmers, this means their purchasing power did not improve. Therefore, the increase in fertilizer price might have served as a disincentive to fertilizer adoption. Second, tef is a high value crop and farmers give priority to tef in input allocations. The pace of adoption of fertilizer and herbicide was more rapid for tef than other cereals. At the time the economic reform programme was launched, most farmers had already adopted fertilizer on tef and the diffusion process had already reached its later stages. Thus, the rate of diffusion increased at lower rates and we would not expect to observe much switching from non-adopter to adopter, as only relatively few potential adopters remained.
Table 9.4 and 9.5 gives the results of the preferred models for fertilizer and herbicide adoption on tef and wheat. Among the variables included in the models, location, oxen ownership, output price and distance to market were found to determine the conditional probability of adopting fertilizer and herbicide on both crops. These variables have the expected signs and are significant in more than one of the models estimated for the two types of technology and crops. Farm size, age of household head, reform and labour were significant in one model each although labour carries an unexpected sign. The variable access to credit had a positive impact on the adoption of fertilizer and herbicide on tef.

Table 9.4. Determinants of the conditional probability of fertilizer adoption on tef and wheat: preferred model.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Tef - Weibull model</th>
<th>Wheat - Exponential model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>T-ratio</td>
</tr>
<tr>
<td>Age(t)</td>
<td>-0.0174</td>
<td>-3.395***</td>
</tr>
<tr>
<td>Location</td>
<td>0.2438</td>
<td>1.719*</td>
</tr>
<tr>
<td>Labour</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Index of awareness</td>
<td>-0.1599</td>
<td>-1.281</td>
</tr>
<tr>
<td>Deflated output price(t)</td>
<td>0.1303</td>
<td>3.090***</td>
</tr>
<tr>
<td>Distance to market</td>
<td>-0.0068</td>
<td>-1.623*</td>
</tr>
<tr>
<td>Credit</td>
<td>0.6927</td>
<td>3.553***</td>
</tr>
<tr>
<td>oxen</td>
<td>0.0719</td>
<td>1.531</td>
</tr>
<tr>
<td>Reform(t)</td>
<td>-0.6352</td>
<td>-3.451***</td>
</tr>
<tr>
<td>Constant</td>
<td>-2.2543</td>
<td>4.532***</td>
</tr>
<tr>
<td>P</td>
<td>1.3018</td>
<td>2.835***</td>
</tr>
<tr>
<td>λ</td>
<td>0.1370</td>
<td>0.0810</td>
</tr>
<tr>
<td>Median</td>
<td>5.5055</td>
<td>8.5606</td>
</tr>
<tr>
<td>Log-likelihood</td>
<td>-506</td>
<td>-391</td>
</tr>
</tbody>
</table>

*, **, *** indicate significant at 10%, 5% and 1% levels respectively.

Note: Variables which had t-ratio less than one in model that included all variables considered relevant on a priori ground are dropped.
The most important variable affecting the conditional probability of adopting fertilizer and herbicide adoption was the deflated output price and output price index\(^2\). The coefficients of the output price were consistently significant for all the models estimated and had the expected sign in the fertilizer and herbicide models respectively. This indicates that adoption of the two technologies increases with an increase in output price. However, it should be noted that the output price index exhibited an upward trend and so may not reflect only the effect of output price, but may also respond to the impact of other time trend variables such as improvement in availability of inputs and information.

\(^2\) Time series data are not available on herbicide price. Therefore, the cereals price index was used in the model of herbicide adoption.
A variable representing calendar time was included in the models as a proxy for time trend variables to examine the effect of trend variables. In the presence of this variable, the output price-index was significant in only one of the four models estimated. The calendar-time variable was also only significant in two of the four models estimated. These results clearly indicate that there is collinearity between these two variables and the variable calendar-time was therefore removed from the model. In the absence of the calendar-time variable, the deflated output price and output price index became significant in all models estimated for fertilizer and herbicide respectively. Since other time-trend variables are not controlled, we cannot be sure whether the result we found is attributed only to the output price ratio and output price index.

The coefficients of the variables shown in Table 9.2 to 9.5 can be interpreted as follows. When an independent variable is increased by 1, holding all other variables constant, the estimated hazard of adopting a technology must be multiplied by the exponential of the coefficient for that variable. For example, if we consider the coefficient for the variable output price, which is equal to 0.1303 for fertilizer adoption on tef (Table 9.4), a one unit increase in the output price, when all other variables remain unchanged, multiplies the expected hazard of fertilizer adoption by \( e^{0.1303} \approx 1.139 \). In other words, it increases the estimated relative hazard of adopting to 1.139 of its starting value. Figure 9.3 depicts the simulated hazard rate for fertilizer adoption on tef for a farmer who has access to credit and information, has two oxen and is located at least 75 km away from the nearest market. The horizontal axis represents output price and time. Simulated hazard rates were calculated by fixing price at its initial value as well as by allowing it to vary over time. The smooth line shows simulated hazard for fixed price. When price is fixed at its initial value the hazard rate steadily rises with time indicating the combined effect of other variables on the hazard rate. However, when the price is allowed to vary according to its historical time path the hazard rate fluctuates showing
an overall increasing trend. Thus, the conditional probability of adopting fertilizer increases as output price increases. This reduces the time taken to adopt fertilizer. The fluctuations in the simulated hazard may reflect fluctuations in output prices and changes in other time trend variables, particularly fertilizer supply. There has been a big upward jump in output price following the 1984 drought. At the same time fertilizer supply has been increased to overcome food shortage problems and the increase in the hazard rate is partly attributed to this factor.

Figure 9.3. Simulated hazard rate for fertilizer adoption on tef. Weibull distribution.

Note: The estimated hazard is for a farmer in location 1, who has fair exposure (see Table 8.3), has access to credit, has 2 oxen and located 75 km away from market.

Oxen ownership is another important variable found to affect the hazard rate. The positive and significant coefficient of oxen ownership shows that ownership of oxen increases the conditional probability of adopting fertilizer and herbicide. Using the same reasoning and interpretation method we noted above, the addition of an ox increases the conditional probability of adopting fertilizer on wheat by 23% and, therefore, reduces the expected time
taken to adopt fertilizer.

Figure 9.4 presents the estimated hazard of herbicide adoption by distance to market for a farmer owning a sufficient number of oxen (i.e. one pair of oxen) and a farmer owning no oxen. The estimated hazard rate for a farmer who owns one pair of oxen was greater than the estimated hazard rate for a non-oxen-owning farmer. This suggests that the time taken by non-oxen-owning farmers to adopt fertilizer were longer than farmers with one pair of oxen or more.

Figure 9.4. Simulated hazard by distance to market for herbicide adoption on tef: Exponential distribution.

Note: The estimated hazard is for farmers who are in location II, has no access to credit and assumes herbicide price is expensive.

Distance to market was significant in all the models estimated for herbicide. Since it was also negative, the evidence suggests that the conditional probability of adopting herbicide
declines as distance from market increases (Figure 9.4). For instance, holding other variables constant, a one unit increase in distance from market reduces the estimated relative hazard of adopting herbicide on tef to 96% of its starting value. In the study area, herbicide was provided by private dealers. The private herbicide dealers concentrated in areas closer to markets. Farmers who are located closer to the market have better access to input at lower prices. Because of this, they tend to exhibit a greater conditional probability of adoption.

According to the empirical results, the location variable appears to have a significant effect on the conditional probability of adopting fertilizer and herbicide. The positive and significant impact of the coefficient of location in the model estimated for fertilizer adoption implies that the times taken to adopt fertilizer were shorter in location I than in location II. Reasons for the importance of this variable in determining rates of adoption were discussed in Section 8.5.

The fact that the farm size coefficient is positive and significant seems to influence the conditional probability of adopting herbicide on wheat. With increases in farm size the conditional probability of adopting herbicide on wheat increases. The age of the household head was negatively related to fertilizer adoption on tef. This implies that older farmers waited a longer time to adopt fertilizer on tef compared to younger farmers. Age had no significant impact on the adoption of herbicide on both crops. Access to credit was significant and positive for fertilizer and herbicide adoption on tef. This implies that access to credit increases the conditional probability of adopting the two technologies on tef so duration of adoption was shorter for farmers who had access to credit than those who had no access.

A goodness-of-fit check was made to assess the underlying assumptions of correct specification and homogeneity being made in estimating the model. Two approaches were followed. The first approach is to use graphical analysis to check the adequacy of the fitted model. As in many other models, this procedure is based on an analysis of residuals.
duration models residuals are not directly identified but they can be estimated using the integrated hazard, which is defined as:

\[ H(t) = \int_0^t h(u) \, du = -\log S(t). \]  

(9.18)

The residuals will, under the null hypothesis of homogeneity, behave like observations drawn from a unit exponential distribution. If a fitted model is correct, the estimated minus log of the survival function for the integrated hazard evaluated at \( H(t; \beta'x) \) should equal \( H(t; \beta'x) \). This implies that for a model that fitted the data well (i.e., the specification is correct and important explanatory variables are not omitted) the minus log of the survival function for the integrated hazard plotted against the integrated hazard for uncensored observations should lie approximately along a 45° line. A plot that displays a systematic departure from the 45° line indicates that the model needs to be modified either by changing the form of specification or by including other important variables.

The second approach incorporates individual specific differences that were not controlled because of unobserved variables (variables that account for variations in distribution of sample observations). Estimating the model in the presence of this variable removes problems that could arise because of heterogeneity. Following the procedure discussed by Greene (1993 and 1996) let \( v_i \) denotes individual specific difference and \( v_i \) has gamma distribution. Dropping the subscript, the survival function that accounts for heterogeneity is described as:

\[ S(t) = \int_0^\infty S(t|v) \, dv \]  

(9.19)

and the hazard function for Weibull distribution is expressed as,

\[ h(t) = S(t) \lambda \exp(\beta'x) \]  

(9.20)
where $\theta$ is variance of $v$ and $\theta$ equals zero for Weibull and exponential models. So the further $\theta$ deviate from zero, the effect of heterogeneity is more (Greene, 1996).

Equation 9.20 was estimated to assess and improve the goodness-of-fit of the models and the results for fertilizer adoption on tef are reported in Table 9.6. The value of $\theta$ for fertilizer adoption on tef is significantly different from zero, signalling the existence of heterogeneity. It has to be noted that the most important variables identified to affect adoption under the assumption of homogeneous population are also significant in the model that incorporated individual specific difference, extension become significant and carries an odd sign. For herbicide adoption on both crops and fertilizer adoption on wheat, the values of $\theta$ were not significantly different from zero, so heterogeneity is not a problem in the models.

Figures 9.5 to 9.8 show plots of minus log of survival function for the integrated hazard against the integrated hazard for fertilizer and herbicide adoption on tef and wheat. The plots of the minus log of survival functions appear to lie along the 45° line and indicate that the specification of the models is correct. As noted above the graphic method indicated correct form of specification of the model for fertilizer adoption on tef, while the second diagnostic method indicated the problem of heterogeneity. We can conclude from these diagnostic results that the heterogeneity problem might be due to omitted variables rather than the form of the specification. Given the important variables remain significant in the presence of a variable that accounts for heterogeneity we argue that our models describe the adoption process well. However, including some important variables (such as profitability, risk, etc.) which we fail to include because of data limitation may improve the prediction power of the models.
Table 9.6. Estimation results for fertilizer adoption on tef: preferred model for which heterogeneity effect was removed.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>T-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age(t)</td>
<td>-0.0101</td>
<td>-1.648*</td>
</tr>
<tr>
<td>Location</td>
<td>-0.1336</td>
<td>0.872</td>
</tr>
<tr>
<td>Labour</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Index of awareness</td>
<td>-0.3504</td>
<td>-2.239**</td>
</tr>
<tr>
<td>Deflated output price(t)</td>
<td>0.2982</td>
<td>5.722***</td>
</tr>
<tr>
<td>Distance to market</td>
<td>-0.0105</td>
<td>-2.114**</td>
</tr>
<tr>
<td>Credit</td>
<td>0.6454</td>
<td>2.891***</td>
</tr>
<tr>
<td>oxen</td>
<td>0.0149</td>
<td>0.262</td>
</tr>
<tr>
<td>Reform(t)</td>
<td>-1.0301</td>
<td>-4.640***</td>
</tr>
<tr>
<td>Constant</td>
<td>-1.9684</td>
<td>3.092***</td>
</tr>
<tr>
<td>0</td>
<td>1.4397</td>
<td>3.496***</td>
</tr>
<tr>
<td>λ</td>
<td>0.2826</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>2.2458</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>3.8234</td>
<td></td>
</tr>
<tr>
<td>Log-likelihood</td>
<td>-503</td>
<td></td>
</tr>
</tbody>
</table>

* ** *** indicate significant at 10%, 5% and 1% levels respectively.
Figure 9.5. Plot of minus log of survival function for fertilizer adoption on tef.

Figure 9.6. Plot of minus log of survival function for fertilizer adoption on wheat.
Figure 9.7. Plot of minus log of survival function for herbicide adoption on tef.

Figure 9.8. Plot of minus log of survival function for herbicide adoption on wheat.
9.9. Conclusions

Duration analysis has not been widely used in adoption studies. The few studies that have used duration analysis have demonstrated the importance of this method for analysing adoption behaviour. In this study we applied duration analysis to examine factors that determine farmers' adoption behaviour over time in traditional Ethiopian agriculture. The durations farmers waited before adopting fertilizer and herbicide were modelled as functions of time-invariant and time-varying variables. The variables hypothesized to affect farmers' wait before adopting the technologies were estimated using the Weibull and exponential models. Application of duration analysis has allowed us to analyse time-varying variables and has enabled us to examine the dynamic aspects of adoption process which usually change with changes in internal and external circumstances under which farmers operate. This method is also flexible enough to incorporate censored observations.

A summary of results is shown in Table 9.7. Among the variables tested, output price, oxen ownership and location had strong impact on the conditional probability of adopting fertilizer and herbicides. As evidenced by P (the shape parameter for the Weibull distribution) value, the baseline hazard for fertilizer use on tef increased with time. This means that fertilizer use increased with the passage of time. On the other hand, the estimated P values for fertilizer adoption on wheat and herbicide adoption on both crops were not significantly different from one suggesting constant baseline hazard. So passage of time had no effect on adoption of herbicide on both crops and fertilizer use on wheat.
## Theoretical and Empirical Analysis of Duration Models

Table 9.7: Summary of results for fertilizer and herbicide adoption on tef and wheat.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Fertilizer</th>
<th></th>
<th></th>
<th>Herbicide</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tef</td>
<td>Wheat</td>
<td>Tef</td>
<td>Wheat</td>
<td>Tef</td>
<td>Wheat</td>
</tr>
<tr>
<td></td>
<td>Model with all variables</td>
<td>Preferred model</td>
<td>Model with all variables</td>
<td>Preferred model</td>
<td>Model with all variables</td>
<td>Preferred model</td>
</tr>
<tr>
<td>Age(t)</td>
<td>NS</td>
<td>-</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Gender</td>
<td>NS</td>
<td>-</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Education</td>
<td>NS</td>
<td>-</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Location</td>
<td>NS</td>
<td>-</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Labour</td>
<td>NS</td>
<td>-</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Farm Size</td>
<td>NS</td>
<td>-</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Index of awareness</td>
<td>NS</td>
<td>-</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Output Price(t)</td>
<td>NS</td>
<td>-</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Distance to market</td>
<td>NS</td>
<td>-</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Credit</td>
<td>NS</td>
<td>-</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Oxen</td>
<td>NS</td>
<td>-</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Perceptions of input price</td>
<td>NS</td>
<td>-</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Reform(t)</td>
<td>NS</td>
<td>-</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Log-likelihood</td>
<td>-506</td>
<td>-507</td>
<td>-390</td>
<td>-391</td>
<td>-503</td>
<td>-505</td>
</tr>
<tr>
<td>Restricted Log-likelihood</td>
<td>-544</td>
<td>-544</td>
<td>-422</td>
<td>-422</td>
<td>-560</td>
<td>-560</td>
</tr>
<tr>
<td>Degree freedom</td>
<td>13</td>
<td>8</td>
<td>13</td>
<td>7</td>
<td>13</td>
<td>7</td>
</tr>
<tr>
<td>$\chi^2$</td>
<td>27.69</td>
<td>20.09</td>
<td>27.69</td>
<td>18.48</td>
<td>27.69</td>
<td>18.48</td>
</tr>
<tr>
<td>Critical value of $\chi^2$ at 1%</td>
<td>27.69</td>
<td>20.09</td>
<td>27.69</td>
<td>18.48</td>
<td>27.69</td>
<td>18.48</td>
</tr>
</tbody>
</table>

Note: + and - with asterisk indicate whether the relationships are positive or negative and *, **, and *** indicate significance levels at 10%, 5% and 1% levels; NS denotes that variables have been included in the model but are not significant; while -, indicate omitted variables.
Table 9.8. Summary statistics for testing the null hypothesis that the coefficients of omitted variables are jointly not different from zero.

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Fertilizer</th>
<th>Herbicide</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tef</td>
<td>Wheat</td>
</tr>
<tr>
<td>Log-likelihood</td>
<td>-507(-506)</td>
<td>-391(-390)</td>
</tr>
<tr>
<td>Number of restrictions</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Calculated $\chi^2$</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Critical value $\chi^2$ at 1%</td>
<td>15.08</td>
<td>16.81</td>
</tr>
<tr>
<td>Null hypothesis</td>
<td>accepted</td>
<td>accepted</td>
</tr>
</tbody>
</table>

Notes:  
(a) Figures in parentheses indicate the log-likelihood for the models with all variables present.  
(b) The number of restrictions equals the number of explanatory variables omitted.  
The test statistics is defined as $-2(L_0 - L_{max})$, where $L_0$ and $L_{max}$ the values of the log-likelihood functions for the restricted and unrestricted models respectively. If the calculated $\chi^2$ is less than the critical value of $\chi^2$ the null hypothesis is accepted.

Of all the variables estimated, output price appears to be the most important factor affecting the conditional probability of adopting fertilizer and herbicide on both crops. The coefficients of this variable were significant and positive in all the models estimated. This suggests that an increase in output price increases the conditional probability of adopting fertilizer and herbicide, and so shortens the time taken to adopt them. It is worth noting that the effect of other trend variables (improvement in availability of input and betterment of information) were not controlled and we cannot be certain whether the result we found is totally attributed to the output price.

Oxen ownership is another important variable affecting adoption and duration of adoption. It increases the conditional probability of adopting the two types of technology. Hence, the expected times taken to adopt fertilizer and herbicide reduce as the number of oxen increases. Distance to market was significant in fertilizer adoption on tef and herbicide adoption on both crops. This variable appears to have a strong impact on the conditional probability of adopting herbicide and the wait before adoption was longer for farmers at a
distance than those who are located closer to market. This is due to the fact that herbicide is more available in areas closer to market than in distant areas.

Access to credit was found to be important in influencing fertilizer and herbicide adoption on tef. Its effect was positive suggesting that the conditional probability of adopting the two types of technology was greater for farmers who have access to credit than those who have no access to credit. Farm size seems to be important in enhancing adoption of herbicide on wheat. With the exception of the age of household heads on tef, personal characteristics do not appear to be important in influencing duration of adoption. As evidenced by the gradual decline in survival rates and larger median time for herbicide adoption the speed of adoption was slow compared to the speed of adoption of fertilizer. Thus, farmers waited longer periods before adopting herbicide than in adopting fertilizer.
SUMMARY AND CONCLUSIONS

10.1. Summary of Main Findings

In the study area, smallholdings dominate agricultural production and productivity on these farms is low. However, new agricultural technology has been promoted among smallholder farmers over the last two and a half decades to increase productivity. The types of technology extended include fertilizer, improved varieties (of tef, wheat, barley, chickpeas etc.), herbicides, pesticides and various improved agronomic practices. The adoption and intensity of use of these technologies have not been adequately investigated previously, so information concerning them is limited. In this study, adoption, intensity of adoption and duration of adoption of technology have been examined. Three types of technology, fertilizer, improved varieties and herbicide, which have been relatively widely accepted by farmers were chosen for analysis. Emphasis is placed on tef and wheat because of their importance in the economy of the study area and the economy of the nation as a whole. The objectives of the study were to examine the adoption and diffusion of these three types of technology and the factors affecting their adoption, and to gain a better understanding of the ways in which farmers make adoption decisions, at a point in time and over time.

Chapters 2 to 5 provided background information and established the conceptual framework for the empirical chapters. Two related concepts were discussed: adoption and diffusion where adoption refers to the decision to adopt or not, and diffusion refers to the spread of a technology among members of a social system. Two modes of adoption, adoption of a whole package and sequential or step-wise adoption of components of a package, which
have been identified in the agricultural technology adoption literature were also discussed. In this study, we assumed step-wise adoption of components of a package in modelling adoption decisions of farmers at a point in time and over time.

The theoretical studies reviewed in Chapter 3 have shown that the diffusion patterns of most technologies follow an S-shaped curve, where the S-shaped diffusion path is determined by the spread of information and economic attributes of the technology. Many empirical studies have also investigated factors affecting technology adoption in different environments. In particular, they have documented a number of economic, social, institutional, infrastructural and agro-climatic factors which affect adoption and diffusion of agricultural technology. They have also shown that the factors that have an impact on technology adoption may be different from one environment to the other; hence their effects may also be different from area to area and from technology to technology. In general, therefore, the direction and degree of impact of adoption determinants are not uniform. Moreover, adoption rates vary among different groups of farmers due to differences in access to resources (land, labour and capital), credit and information and differences in farmers' perceptions of risks, input prices and profit associated with new technology.

The study area is located in the central highlands of Ethiopia stretching about 250 kms to the East and West of Addis Ababa. Chapter 6 described how data for this study were collected through a single visit survey conducted in four weredas, namely Ada and Lume in the East Shewa zone, and Dandi and Ejere in the West Shewa zone. A three-stage sampling procedure was applied to selected weredas, peasant associations and sample farmers randomly. Data that include personal, household, and farm characteristics, plus use of input and technology, were collected from 200 sample farmers using a structured questionnaire. Interviews were conducted by trained enumerators. To supplement the primary data secondary data, were collected from different institutions using guidelines prepared for this purpose.
Farmers' adoption decisions on improved wheat varieties, fertilizer and herbicide were modelled using the survey data and probit, tobit, Heckman and duration models. The tobit and Heckman models were estimated to predict the intensity of use of fertilizer and herbicide; a probit was estimated to predict adoption of improved wheat varieties; finally, duration models were estimated to examine dynamic aspects of farmers adoption behaviour over time. Descriptive statistics including percentages, comparison of means and cross-tabulation were also used. Thus, this study has drawn on simple descriptive statistics as well as econometric models of varying degrees of complexity to examine the adoption behaviour of farmers. The main results found are summarized and presented below.

The sample households have an average family size of 6.9 persons, which is greater than the national average of 5 persons. This suggests the existence of potential family labour availability on the farm. Despite this potential, it was found that on average only 2.6 persons per family permanently work on farm and labour hiring appears to be common during labour peaks. The average farm size in the study area is 2.49 ha and most of the farmers (66%) have 2.5 ha or less. The crops grown by farmers are tef, wheat, barley, chickpeas, sorghum, vetch, lentils and faba-beans. Tef and wheat together occupies 84% of cultivated land, and tef alone accounts for 60% of cultivated land. Farmers also keep livestock, which are a source of both food and draught power for crop cultivation. The average number of oxen owned was 2, which is equal to the number of oxen required for cultivation; however, about 33% of farmers do not have sufficient oxen for cultivation.

The proportion of farmers who adopted fertilizer on tef and wheat were 92% and 61% respectively. About 93% and 84% of tef and wheat fields were fertilized in 1995 with application rates of 122 and 93 kg/ha respectively. Improved varieties were adopted by only 20% and 43% of farmers on 16% and 48% of tef and wheat fields, respectively. Post-emergence herbicide was adopted by 74% and 44% of farmers on 70% and 48% of their tef
and wheat fields. Regarding mode of adoption, about 15% and 27% of farmers used improved varieties, fertilizer and herbicide as a package on tef and wheat respectively in 1995. Turning to patterns of adoption, very few farmers adopted all three types of technology together, for the first time, in the same year; most farmers adopted components of a package of the three types of technology in a step-wise manner, adding one component at a time until they arrived at the package they are currently using.

On the whole, a large proportion of farmers were found to have adopted fertilizer and herbicide on tef and wheat in East and West Shewa zones. The rate of adoption is greater than the national level figures quoted in Chapter 1. However, the adoption of improved varieties, particularly of tef varieties, has lagged behind, partly because of supply side constraints but mainly because of the unavailability of seed and absence of distribution channels. Lack of awareness and expensiveness of seed has also contributed to the delay and low rate of adoption of the improved varieties.

Great variations were observed between the rates of adoption of fertilizer and herbicides on the two crops. The rates of adoption of the two technologies were higher on tef than on wheat. Tef is a high value crop and therefore receives a high priority in input allocation. It was found that the amount of fertilizer and herbicide applied by farmers were below research recommendations. Also, in the case of fertilizer, many farmers did not use the recommended types of fertilizers in combination and the recommended split-application method for urea was not accepted by many farmers.

Having summarized the study's main findings with regard to the adoption and intensity of use of fertilizer, herbicide and improved varieties in the study area, we can now turn to the factors affecting adoption, intensity of use and duration of adoption of these technologies. The estimated econometric models revealed important results for adoption and intensity of adoption of the three types of technology. Three variables - location, oxen ownership and the
index of awareness- were found to have a positive influence on adoption of improved wheat varieties. Location was also found to have a strong effect on the probability of adopting and the intensity of use of fertilizer on tef and wheat too; the probability of adoption and the extent of use of fertilizer were more for a farmer in East Shewa zone than a similar farmer in West Shewa zone. Location is a proxy variable for differences in quality of extension services, soils, topography, infrastructure, availability of inputs, and market opportunities. East Shewa zone is better than West Shewa zone in terms of infrastructure and market opportunities, including generally higher prices for tef produced in East Shewa zone (particularly, Ada area). Our results therefore show that smallholder farmers respond to market opportunities and availability of infrastructure.

Oxen ownership was directly related to the adoption and intensity of use of fertilizer and herbicide on both crops. The reason appears to be that ownership of oxen affects production through its impact on the area cultivated and timeliness of farm activities. Thus, farmers with sufficient oxen can produce more and afford to invest more in fertilizer and herbicide. They may also have greater capacity to absorb risks than farmers who have no oxen.

Adoption and intensity of use of fertilizer and herbicide on tef and wheat decline as distance to market increases. In Ethiopia marketing infrastructure, particularly rural roads and warehouses, are poorly developed, as are input supply channels, and competition is weak (though fertilizer marketing has improved since 1993). Such problems become aggravated as distance to market increases, since access to infrastructure becomes more limited and transport costs for input and output rise. These conditions reduce incentives for adoption. In addition, credit was found to have a significant impact on the intensity of fertilizer and herbicide use on tef; thus, the probability of adopting fertilizer was higher for farmers who had access to credit than for those who had no access to credit. Bivariate analysis provided a similar result for credit.
To sum up, apart from location which was consistently significant in most of the models, economic variables, particularly oxen ownership and distance to market, were found to be the most important factors affecting adoption and intensity of use of fertilizer and herbicide. Farm size and farmers' perceptions of input prices were found to be significant in three of the models estimated. Farm size appears to have a positive impact on the adoption of fertilizer on tef and intensity of use of herbicide on wheat. With an increase in farm size there may not be sufficient family labour to perform weeding operations in time and adequately so the shortage of labour might encourage adoption of herbicide on relatively large farms. On the other hand, farmers' perceptions of input prices seem to discourage intensity of use of fertilizer and herbicide.

Gender and risk aversion were significant in only one of the models specified. We can conclude that the impact of these variables on adoption and intensity of use of technologies was not strong. No study has examined the effect of gender on adoption. Extension workers give more attention to male-headed households and interaction between female-headed households and extension workers is limited. Moreover, female-headed households depend on male child labour for land cultivation and this may affect timeliness of farm activities and thereby adoption of technologies. Our findings do not support this observation and the effect of gender on adoption requires further investigation as these results are not consistent with what we expected when this research was initiated. The impact of age on adoption and intensity of adoption was also weak, being significant in only two models. In the cases where this variable was significant, it had a negative impact on the decision to adopt fertilizer on tef and a positive impact on the adoption and intensity of use of herbicide on wheat. Education and the index of awareness had no effect on the intensity of use of fertilizer and herbicide as they were not significant in any models.
Duration analysis has been employed to assess farmers' adoption behaviour and the factors influencing their behaviour over time. It was used to analyse the effects of time-varying and time-invariant variables and address issues other studies have overlooked because of methodological constraints. In fact, the effect of time-varying variables cannot be examined using the static models such as probit, tobit and Hechman. The durations farmers waited before adopting fertilizer and herbicide were modelled as functions of two sets (time-varying and time-invariant) of variables. Among the variables tested, price, oxen ownership and location had a strong impact on the conditional probability of adopting fertilizer and herbicides and are consistent with theoretical expectations. As evidenced by the P (shape parameter) value, the baseline hazard for fertilizer use on tef increased with time. This suggests that the effect of output price on the baseline hazard was positive. This means that an increase in the output price increases the conditional probability of adopting fertilizer and hence shortens the time taken to adopt fertilizer. Oxen ownership also increases the conditional probability of adopting the two types of technology. The distance to market appears to have a strong impact on the conditional probability of adopting herbicide; farmers who are far away from market waited a longer time before adopting compared to farmers close to market. The effect of distance to market on fertilizer adoption was neutral. As evidenced by the gradual decline in survival rate and larger median time for herbicide adoption, the speed of diffusion of herbicide was slower compared to the speed of diffusion of fertilizer. Thus, farmers waited longer periods in adopting herbicide than in adopting fertilizer. With the exception of the impact of the age of household heads on fertilizer adoption on tef, personal characteristics are not important in influencing durations of adoption. It should be noted that moving to duration analysis enabled us to analyze the effect of time-varying variables and the dynamic aspects of adoption process induced by these variables. Our findings from duration analysis suggest that the rate of adoption of a technology could be different (see Figures 9.1 to 9.3) at different points in time.
This phenomenon cannot be depicted if only probit, tobit and Heckman models are used. Duration analysis also allowed us to compare the rates of adoption between groups (example, oxen owner and nonowning) of farmers and between technologies at different points in time.

10.2. Policy Implications

As noted above, the price of output (i.e. relative price for fertilizer model and output price index for herbicide model) is one of the main determinants of duration in fertilizer and herbicide adoption. The empirical results suggest that an increase in output price increases the probability of adopting the two types of technology, thereby reducing the duration farmers wait to adopt them. This implies that early adoption can be encouraged and productivity thereby increased by providing farmers with adequate price incentives. Conversely, inadequate price incentives lead to a decline in the probability of adoption and lengthier durations of adoption; thus, a decline in output prices has a negative effect on productivity and total production.

In the light of the results documented in this study and the steady increase in input prices and fluctuations of output prices that has been observed in Ethiopia over the past years, future efforts to sustain and accelerate adoption require in the short term public sector intervention in the market through price stabilization schemes and subsidies on transport and distribution for selected inputs and farmers. Successful implementation of such policies and their intensity and duration, however, will require further study to avoid misallocation of resources and inefficiency. Moreover, the intervention should gradually phase out when the private sector is well developed and fair competition is created. It may be noted that such a suggestion is inconsistent with the current worldwide emphasis on privatization and free market. In the context of Ethiopia where farmers are very poor, and their purchasing power is low because of widespread poverty and chronic food shortages, such policies will be valid
Summary and Conclusions

until the country is able to feed itself from domestic production or able to finance food imports by exporting commodities for which it has comparative advantage.

The second notable finding of this study is the distinction between farmers who have sufficient oxen (2 or more) and those who have not, in terms of intensity and duration of adoption. Oxen owners tend to apply higher rates of fertilizer and herbicide and adopted more rapidly than non-owners. Differences in intensity and duration of adoption widen income disparities between these groups. Furthermore, lack of oxen may encourage farmers to 'sell' land or transfer their use rights on land to other persons. This may make some farmers landless and accelerate migration to cities, thus exacerbating economic and social problems in urban areas. Thus, attention should be given to solving the traction power problem through the provision of a medium-term credit programme for oxen purchase and short-term credit for veterinary services. Over the past few years credit for oxen purchase has been provided by the Development Bank of Ethiopia and the Commercial Bank of Ethiopia. However, access to this type of credit is very limited. The credit programme requires Service Cooperatives (SC) to make an application, sign a loan contract, and assume responsibility (for repayment and purchase of oxen) on behalf of concerned members. However, most SCs are not interested in such arrangements. The mechanism in place also provides opportunities for corruption and marginalizes the actual borrowers. Therefore, a mechanism should be developed whereby non-oxen owners would assume responsibility for the loan and be fully involved in loan negotiations and arrangements. One possible option is to establish rural credit cooperatives which can provide credit for oxen purchase and deal directly with the individuals concerned, supervising the programme from a close distance.

Another result worth noting is the decline in adoption and intensity of adoption as the distance to market increases. This outcome partly arises from variations in market opportunities and differences in availability of infrastructure required for adoption. As distance
increases, transport costs increase and depress the effect of output prices on the one hand, and aggravate the effect of input prices by increasing adoption costs on the other. Currently, the private sector is less interested in providing services in areas far from markets and tends to concentrate on areas which have a better infrastructure. Under such conditions, establishing and reinforcing grass-roots institutions, particularly SCs, is crucial for the development of rural areas and well-being of farmers. The SCs facilitate access to profitable markets and provide input to members at reasonable prices. There is a need to give financial (i.e. in the form of credit) and technical (i.e. in the form of training in financial management and administration) support to the SCs to enable them serve their members adequately. Since the variations in the intensity and speed of adoption are partly attributed to differences in availability of infrastructure and market opportunities, investment in infrastructure and improvement in output and input marketing systems are crucial and would result in high levels of adoption. Such actions may also reduce income disparities that could be induced due to differential technology adoption between different regions.

Credit was significant in five of the models estimated and in the bivariate analysis. This suggests that the probability and intensity of adoption of fertilizer and herbicide is influenced by access to credit. Hence, the credit programme extended to farmers should be strengthened and should include provision for improved varieties. One of the problems observed in the implementation of the existing formal credit programme was that farmers do not settle overdue loans on time, and recovery rate was low. Recently a task force was setup at wereda, zone, regional and national levels to put pressure on farmers to repay overdue loans. Members of this task force were drawn from the wereda, zonal and regional administration offices, agricultural bureaux and banks. It has to be noted that the sustainablity of such a system is questionable and the involvement of the administration structure and agricultural bureaux in loan collection is undesirable. To sustain the positive impact of credit on adoption, the role of the agricultural
bureaux should be limited to educational activities and a mechanism should be devised in which
the creditor banks enforce loan disbursement and overdue loan collection.

As discussed in Chapter 4, smallholder farmers are the most important category of
farmers in Ethiopia in terms of both area cultivated and total production, and account for more
than 95% of rural population. They are also producers of the country’s main export
commodities (coffee, skins and hides and pulses) and therefore are an important source of
foreign currency earnings for the country. Despite these contributions, past regimes have not
given attention to the development of smallholder farms. They have not only neglected
smallholder farmers but have pursued policies that discriminated against them. As a result
public resource allocation was biased towards commercial farms in the 1960s and towards
state farms and cooperatives in the 1970s and 1980s. These large farms have not only been
given priority in fertilizer and improved seed provision from government sources (the only
available source at that time), but were allowed to purchase these inputs at subsidised prices
which were about 10% less for fertilizer and improved seeds than what smallholder farmers
paid for the same kind and amount of inputs.

Despite this discrimination, a substantial proportion of smallholder farmers adopted
fertilizer and their productivity levels were better than cooperative farms (Table 4.5). Within
smallholder groups the intensity of adoption of fertilizer was inversely related to farm size. This
relationship implies higher productivity on small farms. Therefore, our findings (see Chapter
7, Table 7.23 for intensity of fertilizer application by farm size groups) support the current
emphasis placed on smallholder farmers to overcome Ethiopia’s food insecurity problem
through intensification of agriculture on smallholder farms. However, the current
intensification programme lacks marketing and infrastructure development components and
appropriate policy measures are required to sustain continuous use of the new technologies.
In Ethiopia, a good year or two improves production levels in surplus producing areas. Since
there is no effective marketing system, the price of grain dramatically drops, as it did in 1996. If such increases in production come from increased input use, farmers may not be able to cover the costs of these inputs (in particular, fertilizer and improved varieties) when grain prices fall dramatically. As a result they may not continue to use the new technologies in subsequent years.

Three possible policy measures are therefore suggested to improve marketing components of the intensification programme. First, there is a need to strengthen service cooperatives in rural areas, especially in remote areas where private business has little incentive for investment in agricultural output and input marketing because of poor infrastructure development. Credit should be provided to service cooperatives to enable them to develop such infrastructure and obtain sufficient working capital so that they can become involved in marketing outputs and inputs for their members. Second, private dealers in agricultural commodities and inputs were weakened by the policies of past governments. They have insufficient infrastructure (storage and transport facilities) and working capital for the effective transfer of products from where they are produced to where they are consumed. Therefore, the government should encourage and give incentives (in the form of tax and licence fee exemptions) to private businesses to establish their businesses for marketing output and provision of agricultural inputs in remote rural areas. In particular, the government should facilitate credit provision for the development of infrastructure and for working capital. Third, the government should provide marketing information so that all market participants may be better informed about output and input prices and thereby better able to make informed decisions.

As discussed in Chapter 5, the coverage and quality of the research and extension services are not adequate and the linkage between them is too weak to bring about rapid technological change in Ethiopian agriculture. Therefore, there is a need to strengthen the

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research and extension systems in terms of finance, staff and facilities in order to accelerate the adoption of new technologies. In particular, adaptive research should be strengthened to ensure that the technologies which have already been generated are suited to the conditions under which farmers are operating. Thus, the links between research, extension and farmers need to be reinforced.

10.3. Areas of Future Research

The application of the duration analysis has greatly enhanced our understanding of the process of technology adoption over time and our ability to predict the effect of time-varying variables on adoption. It enabled us to view the probability of adoption for different groups of farmers and different technologies and relate this to internal (i.e. factors under the control of farmers) and external factors prevailing at different points in time. Nonetheless, this research has suffered from certain data limitations. Some of the variables which have been treated as time-invariant variables are in fact time-varying in nature; examples include farm size, labour, credit, farmers' perceptions of technology and extension information. The effects of these variables on duration of adoption can not be fully captured using cross-sectional data. Therefore, future research should focus on generating time-varying data and on predicting their effect on duration of adoption.

The effect of economic reform was significant in the case fertilizer adoption on tef. However, at the time when economic reform was launched, most farmers had already adopted fertilizer on tef, so diffusion had reached its later stages. Thus, the result we found might be attributed to the nature of the technology adoption stage. The effect of economic reform could, however, be judged by monitoring the rate of disadoption and declines in the rate of application. Because of data limitation this issue has not been examined in this study and is
Intensity (degree) of adoption has been analyzed using static models in Chapters 7 and 8. Farmers may use a certain amount of input over a period of time and move to the next level of input use depending on the economic environment in which they operate. Such movements create a sequence of states of input use that were occupied and the times at which movements between them occurred. The static models used in Chapters 7 and 8 can not capture the adjustment process farmers are making over time. Farm-level time series data on intensity of adoption are not available to analyze intensity of adoption over time. Given the possibility of multiple states and time series data on intensity of adoption, it may be possible to use duration models to analyze intensity of adoption over time although such models have not yet been developed. To carry out such analysis, there is a need to generate farm-level time series data through a multiple visit surveys which extends over many years.

Agricultural technologies such as fertilizer, herbicide, irrigation water etc. proved beyond doubt that they increase crop yield. In the study area, many farmers have already adopted fertilizer and herbicide. However, the rate, time and methods of application of these technologies differ between farmers. Most farmers do not follow recommended time, rate and method of applications. This can compromise the impact of technologies on productivity of a crop. This study as well as other studies, dealt with technology adoption, focused on the rate of adoption and factors affecting adoption and diffusion. The impact of the technologies under different farmers' agronomic practices have not been examined. Hence, future research should give attention to the efficiency of already adopted technologies. Evaluation of impact of these technologies requires data on yields. As observed during the field work for this study, farmers were reluctant to report yield. So there is a need to use a case study method which employs crop-cut techniques to estimate yield data.
### Table A1. Correlation matrix of explanatory variables.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Gender</th>
<th>Age</th>
<th>Education</th>
<th>Location</th>
<th>Distance to market</th>
<th>Labour</th>
<th>Farm size</th>
<th>Index of awareness</th>
<th>Credit</th>
<th>Oxen</th>
<th>Perception of price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>1</td>
<td>-0.041</td>
<td>0.295</td>
<td>0.076</td>
<td>-0.042</td>
<td>0.128</td>
<td>0.117</td>
<td>0.153</td>
<td>0.283</td>
<td>0.140</td>
<td>0.133</td>
</tr>
<tr>
<td>Age</td>
<td>1</td>
<td>-0.373</td>
<td>-0.097</td>
<td>0.141</td>
<td>0.324</td>
<td>0.266</td>
<td>0.025</td>
<td>0.001</td>
<td>0.062</td>
<td>0.073</td>
<td>0.058</td>
</tr>
<tr>
<td>Education</td>
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<td>0.034</td>
<td>-0.069</td>
<td>-0.130</td>
<td>-0.010</td>
<td>0.076</td>
<td>0.059</td>
<td>0.126</td>
<td></td>
<td>0.073</td>
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<tr>
<td>Location</td>
<td>1</td>
<td></td>
<td></td>
<td>-0.336</td>
<td>0.109</td>
<td>-0.372</td>
<td>-0.003</td>
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<td>Distance to market</td>
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<td></td>
<td></td>
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<td>0.292</td>
<td>0.001</td>
<td>-0.100</td>
<td>0.065</td>
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<td>0.114</td>
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<td>Labour</td>
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<td></td>
<td></td>
<td>0.275</td>
<td>0.097</td>
<td>0.114</td>
<td>0.241</td>
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<td>0.118</td>
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<tr>
<td>Farm size</td>
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<td></td>
<td></td>
<td>0.169</td>
<td>0.075</td>
<td>0.387</td>
<td>0.043</td>
<td></td>
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</tr>
<tr>
<td>Index of awareness</td>
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<td></td>
<td></td>
<td>1</td>
<td>0.125</td>
<td>-0.008</td>
<td>-0.153</td>
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<tr>
<td>Credit</td>
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<td></td>
<td></td>
<td>1</td>
<td>0.172</td>
<td>0.139</td>
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<tr>
<td>Oxen</td>
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<td></td>
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<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.107</td>
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<tr>
<td>Perception of price</td>
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<td></td>
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</table>
Table A2. Conversion factors used to estimate LU.

<table>
<thead>
<tr>
<th>Class/types of livestock</th>
<th>Livestock Unit (LU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxen</td>
<td>1.00</td>
</tr>
<tr>
<td>Horses</td>
<td>1.00</td>
</tr>
<tr>
<td>Cows</td>
<td>0.72</td>
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<tr>
<td>Donkey</td>
<td>0.72</td>
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<tr>
<td>Heifers</td>
<td>0.54</td>
</tr>
<tr>
<td>Bulls</td>
<td>0.54</td>
</tr>
<tr>
<td>Calf</td>
<td>0.34</td>
</tr>
<tr>
<td>Sheep</td>
<td>0.20</td>
</tr>
<tr>
<td>Goats</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Table A3. Conversion factor used to estimate Man-Adult-Equivalent.

<table>
<thead>
<tr>
<th>Age (in year)</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-60</td>
<td>1.0</td>
<td>0.75</td>
</tr>
<tr>
<td>&gt; 60</td>
<td>0.5</td>
<td>0.25</td>
</tr>
<tr>
<td>10-14</td>
<td>0.5</td>
<td>0.25</td>
</tr>
<tr>
<td>&lt;10</td>
<td>Ignored</td>
<td>Ignored</td>
</tr>
</tbody>
</table>


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