Improved production technology and efficiency of smallholder farmers in Ethiopia: Extended parametric and non-parametric approaches to production efficiency analysis

by

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Dedication

This work is dedicated to my mother Aynadis Ayichew.

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Abstract

The objective of this study was to assess the impact of improved production technologies and Ethiopia's New Extension Program on the production efficiency of smallholder farmers in eastern Ethiopia. It employed an extended stochastic efficiency decomposition technique to analyze the technical, allocative, and economic efficiencies of farmers in the dry land and wet highland agro-climatic zones. It also employed an extended interspatial total factor productivity analysis to investigate the resource use efficiency and productivity of alternative cropping systems and technologies in these zones.

Although the results indicated a positive impact of improved maize technology on maize production efficiency, the study found considerable inefficiencies of maize production under both traditional and improved technology. Production inefficiency in traditional maize production is attributed more to technical inefficiency, suggesting that improvements in technical efficiency provide a greater opportunity to increase maize production. For maize production under improved technology, the results showed that production inefficiency is equally attributed to both technical and allocative inefficiencies. The results thus suggest that both technical and allocative efficiencies must be raised to increase maize production under improved technology.

Despite the positive impact of new maize technologies, however, the study found no evidence of impact of Ethiopia's New Extension Program on the overall food production efficiency of smallholder farmers. In the wet highland zone, the results indicated that the participants in the

New Extension Program used a superior technology but both groups encountered similar levels of production inefficiencies. The participants and non-participants can, respectively, increase food production by an average 35 percent and 37 percent through improved technical and allocative efficiency. The results thus indicated that the New Extension Program has had no impact on overall production efficiency in the wet highland zone. In the dry land zone, the results showed that apart from using homogeneous production technologies, the two groups of farmers do not have significantly different technical and allocative efficiencies and thus have similar overall productive efficiencies. The participants and non-participants in the dry land zone can, respectively, increase food production by an average 46 percent and 43 percent through improved technical and allocative efficiency. The results thus indicated that the New Extension Program has had no positive impact on production efficiency of farmers in the dry land zone. Education, credit, previous participation in previous extension programs, greater security of tenure, the share of the leading cropping system in each zone, and off-farm income were generally found to have a positive impact on food production efficiency.

The study found considerable variation in resource use efficiency among cropping systems in the dry land as well as wet highland zones. In the wet highland zone, cropping systems involving maize and potatoes turned out to be more efficient. While cropping systems involving maize were also superior to sorghum in the dry land zone, sorghum systems were widely practiced. This could be due to sorghum's higher tolerance to drought under the prevailing unreliable weather conditions, confirming that farmers are actually forced to adopt cropping practices that are inefficient but ensure reliable food supply in the absence of appropriate technologies.

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Acronyms and Abbreviations

ADE	Adult Equivalent
ADLI	Agricultural Development Led Industrialization
AE	Allocative Efficiency
AISCO	Agricultural Inputs Supply Corporation
AMC	Agricultural Marketing Corporation
ARDU	Arsi Rural Development Program
CADU	Chilalo Agricultural Development Program
COLS	Corrected Ordinary Least Squares
CRTS	Constant Returns to Scale
CSA	Central Statistical Authority
DAP	Diammonium Phosphate
DEA	Data Envelopment Analysis
DRTS	Decreasing Returns to Scale
EE	Economic Efficiency
EMTP	Extension Management Training Plot
ESE	Ethiopian Seed Enterprise
GDP	Gross Domestic Product
ha	Hectare
IRTS	Increasing Returns to Scale
Kg	Kilogram
LGP	Length of Growing Period
LP	Linear Programming
LR	Likelihood Ratio
LU	Livestock Unit
masl	Meters Above Sea Level
MEDaC	Ministry of Economic Development and Cooperation
mm	Millimeter
ME	Man Equivalent
ML	Maximum Likelihood
MOA	Ministry of Agriculture

MPP	Minimum Package Project
NEP	The New Extension Program
NGO	Non-governmental Organization
NSIA	National Seed Industry Agency
NSIP	National Seed Industry Policy
OLS	Ordinary Least Squares
PA	Peasant Association
PADEP	Peasant Agricultural Development Program
SFPF	Stochastic Frontier Production Function
SG	Sasakawa-Global 2000
TGE	Transitional Government of Ethiopia
TE	Technical Efficiency
VRTS	Variable Returns to Scale

CHAPTER 1

INTRODUCTION

1.1 Background to the Study

By all accounts, agriculture is the mainstay of the Ethiopian economy. It generates over 45 percent of the GDP and 90 percent of the total export earnings and provides employment for about 85 percent of the labor force. Despite the importance of the agricultural sector in the overall development of the Ethiopian economy, its performance has been very poor as viewed from its frequent failure to provide food for a large segment of a fast-growing population. For instance, an estimated 50 percent of the Ethiopian population is food insecure (Befekadu and Berhanu, 1999; MEDaC, 1999) and a significant share of Ethiopia's food needs has been obtained in the form of aid over the last couple of decades. The annual volume of cereal food aid has grown from 2.3 to 23 percent of total domestic grain production over the period 1985-1996 (MEDaC, 1999). The growing gap between domestic food production and demand is attributed to the very low productivity of the agricultural sector. Accordingly, improving the productivity of the agricultural sector is believed to be the key to alleviating food insecurity and bringing about overall growth of the Ethiopian economy.

The current development strategy of the Ethiopian government focuses primarily on agricultural growth and food security. An economic reform program was initiated in 1992, which included the removal of taxation on agriculture, market liberalization and devaluation (Mulat, 1999). It is believed that food self-sufficiency can be attained through an increased use of improved agricultural production technologies following the liberalization of the input and product markets to allow private sector participation, deregulation of prices, and expansion of extension services (Techane and Mulat, 1999; Mulat, 1999). Within the framework of the agricultural development-led industrialization (ADLI) policy of the Ethiopian government, the new extension program (NEP) was launched in 1994/95 to demonstrate to farmers the benefits of a package of modern agricultural inputs, notably balanced and higher rates of fertilizer, improved seeds, pesticides, and better cultural practices.

Despite a relative increase in the consumption of fertilizer and improved seeds, however, the productivity of major cereal crops has been low. Quite often the failure to realize potential output is partly attributed to partial adoption and sub-optimal application of technology packages by farmers that is far below the research recommendations (Mulat, 1999). This may lead to inefficient use of improved technologies. Efficient technology utilization could be severely undermined by a wide range of economic, institutional, social, and cultural constraints. Efforts to increase productivity have also failed to explore opportunities within the farm to increase agricultural production through promotion of local innovative cropping practices (Mulat, 1999). Innovative farming practices could be identified, refined and promoted alongside improved technologies to help raise food production.

There is, however, little knowledge about the efficiency of farmers who have been using improved technologies and of the impact of NEP on efficiency of resource use among smallholders. Knowledge about the level of inefficiency of production under improved technology and of the underlying socio-economic and institutional factors causing that may help to assess the opportunities for increasing agricultural production and the strategies to enhance the effectiveness of NEP. This study thus aims to contribute towards a better understanding of the impact of improved production technologies in particular and that of NEP in general on the technical, allocative, and economic efficiency of smallholder farmers using extended efficiency and productivity measurement techniques.

1.2 Motivation and Nature of the Research Problem

The growing gap between food demand and supply in Ethiopia is mainly attributed to the very low productivity of the agricultural sector. Heavy reliance on obsolete farming techniques, poor complementary services such as extension, credit, marketing, infrastructure, and inappropriate agricultural policies are among the major factors that have greatly constrained the development of Ethiopia's agriculture. Despite its dominant share in the country's total agricultural output, and hence in the GDP, smallholder agricultural production lacked the necessary attention in the country's agricultural development efforts in the past and thus its productivity remained very low. One of the major policy shifts since the change of government in 1992 has been the substantial emphasis placed on improving the productivity of peasant agriculture through increased use of a package of improved agricultural technologies.

As part of the ADLI development strategy, the Ethiopian government introduced NEP based on the experiences of the Sasakawa-Global 2000 (SG) project which embarked upon the popularization of large-scale (usually half-hectare) on-farm demonstration plots for already available improved agricultural production technologies. In formulating NEP, attempts were made to screen out and preclude the shortcomings of past extension systems. First, extension services were erroneously organized by commodity rather than by function and were prescriptive in the sense that they only transmitted information without adequate or no supply of inputs. Second, they were limited only to high potential areas of the country, neglecting other agro-climatic zones. Third, demonstration sites were not widely distributed and they were rather undertaken in fences. Fourth, extension information was not effectively communicated through different methods and budgets, manpower, and means of transport were not adequately allocated for the extension service in addition to noted inefficiency in administration and management (TGE, 1994).

NEP was thus developed against the above background aiming to improve the productivity of smallholder farmers through better access to improved production technologies such as fertilizer, improved seeds, pesticides, and better cultural practices mainly for cereal crops such as maize, wheat, and tef. The program provides credit, inputs, and extension assistance to farmers willing to participate in the program by allocating their own land for technology demonstration and settling the down payments for improved inputs. It promotes integrated technology packages developed for different agro-climatic zones, including the highland mixed farming zone, highland degraded and low moisture zone, lowland agro-pastoralist zone, and lowland pastoralist zone (Befekadu and Berhanu, 1999). Its implementation was launched in 1995/96 cropping season as an expansion of the SG package approach, primarily through dissemination of crop technologies. In 1995/96, about 36,000 half-hectare on-farm demonstration plots were established and average yields for the major crops including, maize, wheat, tef, and sorghum have increased by 98 percent and the increment was more than double for maize and wheat (Takele, 1996). In 1996/97 and 1997/98, the number of government sponsored demonstration plots was 650, 000 and 2.9 million, respectively (Befekadu and Berhanu, 1999).

The rapid expansion of NEP has taken place at a time of major changes in markets, policies, and institutions affecting the agricultural sector: a new credit system launched in 1994, gradual liberalization of the fertilizer market from 1991 to 1997, and decentralization of the government. Despite considerable yield increments obtained from the demonstration plots of the SG project in the high potential agricultural areas, knowledge about the impact of NEP on the production efficiency of farmers is very scanty. The success of NEP is believed to depend upon how well the three roles of extension, credit and input delivery meet the particular needs of smallholders. This is a situation very different from that of the SG project, which was limited to specific high potential zones with relatively better functioning credit and input delivery services. For example, NEP's credit system is more complex: there are multiple actors (banks provide credit, regional governments guarantee credit, and extension agents approve participants and collect payments); interest is charged; and local administration follows strict enforcement rules. Further, NEP needs to deal with a fertilizer sector characterized by increasing retail prices due to subsidy removal and supply inefficiencies.

There are growing concerns over NEP's effectiveness in enhancing new technology utilization and in bringing about the desired improvements in productivity. First, extension agents, apart from their own little technical knowledge about new technologies, are involved in too many non-extension tasks: processing credit applications, dealing with input distributors, mobilizing farmers for public works, and collecting loans and taxes. Second, rapid expansion of NEP to less favorable and marginal areas required more supervision and credit, than less, due to the low literacy rates and poor asset endowments of the farmers in these areas. This is expected from an extension service with a rather limited number of extension agents and dwindling credit portfolios to regions. The overall impact of increased plots per extension agent and the extra tasks is a lower quality extension message (Mulat, 1999).

In fact, in a changing technological and policy environment, it is argued that farmers encounter considerable inefficiencies before the realization of the intended gains from technological progress. New technologies can yield better results only under better management of farm resources to efficiently use a package of modern inputs and agronomic practices. However, farmers lack information and managerial skills to be able to fully exploit the productivity potential of new technologies. New technologies demand a new set of skills and knowledge, integration into the input and product markets, and access to infrastructure, credit and educational services if their productivity-enhancing potentials are to be fully exploited. Neither the extension service is strong enough to provide adequate and timely technical advice on new methods and procedures and market information nor are there adequate credit and infrastructural facilities for farmers to have easy access to inputs and markets for optimal input use. Deviations of farmers' practices from technical recommendations coupled with sub-optimal input choices will ultimately lead to both technical and allocative inefficiencies.

Farmers thus experience greater production inefficiency and hence loss of potentially obtainable output from new technology due to lack of familiarity with the new technology, market information, and credit. Like in other developing countries, the technical efficiency of traditional food crop production has been researched in Ethiopia (e.g., Assefa, 1995; Assefa and Heidhues, 1996; Getu et al., 1998; Getachew, 1995). However, the efficiency of modern crop production has received little or no attention partly because of the wrong assumption that farmers' constraint is the choice of appropriate technology and not the efficient use of a technology. Further, previous studies dealt exclusively with technical efficiency of farmers. While physical productivity considerations are important, improvements in allocative efficiency could yield greater benefits to agricultural producers using improved technologies in Ethiopia. In view of the steady liberalization of the input and product markets since 1993, knowledge about farmers' production efficiency and the underlying constraints under improved technology is extremely valuable for policy makers. This will help enhance the effectiveness of the various support services and thus bring about the desired growth in agricultural productivity and food security in the country. This study thus attempts to address such a noticeable lack of knowledge about the efficiency and productivity impact of new technologies in particular and NEP in general.

1.3 Objectives of the Study

It is argued that there is a considerable lag between farmers' attempt to adjust their production decisions to keep pace with changes in the technological and economic environment and achieving the ultimate efficient use of their resources. Ali and Byerlee (1991) pointed out that agriculture in much of the third world has experienced profound changes and can no longer be classified as traditional. In this new situation, the scope for inefficiencies in resource use is much greater and hence development strategies may need to be re-examined. In Ethiopia, based on the encouraging SG project experiences of high cereal yields obtained from selected high potential agricultural areas, there was a growing optimism that new and improved agricultural technologies widely promoted through NEP would bring about substantial increases in food production. Unfortunately, cereal yields have not improved despite increased use of packages of improved technologies owing to concerted efforts made through NEP.

Whilst various incentive measures have been used to induce farmers to achieve a high rate of adoption of the chosen modern technologies (use of fertilizer, improved seeds, and chemical inputs), little effort has been made to ensure appropriate application and more efficient use of these technologies. This is partly attributed to the wrong hypothesis that farmers may not be able to select appropriate technologies but can nevertheless operate technology efficiently when chosen for them. This may have contributed to the poor field performance of the new technologies. Mulat (1999) indicated that the yield levels of major cereal crops remained too low to justify the substantial investments in the modern inputs used. Cereal yield increased by only 0.3 percent per annum between 1990 and 1997 and there is no indication that yields have significantly improved since 1994 despite the sharp increase in the use of fertilizer and other inputs.

The main objective of this study is thus to measure the impact of NEP on the technical, allocative, and economic efficiency of smallholder farmers and to identify the underlying factors in eastern Ethiopia. This is accomplished by pursuing the following specific objectives:

1. To measure the crop level technical, allocative, and economic efficiency of production under traditional and improved technology;

2. To measure the farm level technical, allocative, and economic efficiency of production under traditional and improved technology across agro-climatic zones;

3. To identify the major social, economic, and institutional factors influencing technical, allocative, and economic efficiency of smallholder farmers; and

4. To measure the total factor productivity and resource use efficiency of alternative cropping systems and technologies.

1.4 Significance of the Study for Policy, Research, and Extension Services

The capacity to develop and manage technology in a manner consistent with a nation's physical, human, and cultural endowments is the single most important variable accounting for differences in agricultural productivity among nations. The development of such capacity is dependent on the following factors. (1) The capacity to organize and sustain the institutions that generate and transmit scientific and technical knowledge. (2) The ability to embody new technology in equipment and materials. (3) The level of husbandry skill and the educational accomplishments of rural people. (4) The efficiency of input and product markets and the effectiveness of social and political institutions (Ruttan, 1988).

Although agriculture in developing economies has undergone considerable technological change since the Green Revolution, there have been evidences of substantial inefficiency in agricultural production due to farmers' high unfamiliarity with new technology, poor extension and education services, and poor infrastructure, among others (Ali and Chaudhry, 1990). An investigation of farm level productive inefficiencies and the underlying causes associated with the use of improved agricultural technologies greatly helps policy makers to take the necessary corrective measures for enhancing agricultural production through better and efficient use of these technologies alongside the limited farm resources. The study will help generate knowledge that will serve as the basis for making sound policy decisions as part of the economic reform and adjustment program with a view to enhancing the effectiveness of NEP in the realization of the intended food security and agricultural development objectives.

Knowledge about the extent of production inefficiency under improved technology and the associated responsible factors will greatly help policy makers to explore untapped potentials of new technology and increase food production with existing resources by addressing the identified constraints. It also enables the identification of those farmers who need the most support from the government and hence helps for better targeting and priority setting. Further, knowledge about production efficiency gaps between users and non-users of improved technology will inform policy makers of the impact of improved agricultural technologies and the extension program, which is very valuable for better design and implementation of intervention programs. Knowledge about agro-climatic variations in production efficiency and the respective inefficiency factors will also be extremely useful for decision makers in their endeavor to design appropriate strategies to solve farmers' problems in different agro-climatic zones. The study will also contribute to the literature on production efficiency in the context of a changing agriculture and the appropriate analytical methodologies to deal with the same.

1.5 Organization of the Thesis

In addressing its main objective of assessing the production efficiency of smallholders under the unfolding new economic environment in Ethiopia, this study addresses a wide range of issues in its various chapters. Chapter two provides an overview of the agricultural development policies and strategies pursued in the country with the aim of identifying their impacts on smallholder productivity as one important dimension of the performance of smallholder agriculture. Chapter three gives a detailed account of the theoretical and empirical issues relating to technical, allocative, and economic efficiency and establishes the framework for the intended analysis. Chapter four is devoted to the description of the study areas and selected socio-economic characteristics of the sample households. It examines the role of the various cropping strategies practiced by the smallholders and identifies those offering greater opportunities to the farmers in terms of efficiency of resource use in the face of decreasing farmland and adverse climatic conditions.

Results of the empirical investigation of the level and variability of smallholders' efficiency of production both at crop and farm levels are presented in chapters five and six, respectively. The last chapter brings together the major findings, draws conclusions and makes recommendations with a view to improving smallholder agricultural productivity and efficiency in the study areas. Based on the literature surveyed as well as the empirical results obtained, it also draws relevant generalizations that could help tackle stagnating cereal productivity in the country.

CHAPTER 2

DEVELOPMENT STRATEGIES AND THE PRODUCTIVITY OF SMALLHOLDER AGRICULTURE IN ETHIOPIA

2.1 Introduction

Government policies and strategies either encourage or discourage economic growth and hence development. Sound and prudent policies serve as a tool for development. On the contrary, ill-conceived and inflexible government policies generally lead to underdevelopment, which eventually lead to poverty. Macroeconomic and sectoral policies were among those affecting agricultural development in Ethiopia during the past regimes, coupled with recurrent droughts and other natural calamities. The said economic policies were inconsistent with the country's social and economic conditions. Allocation of productive manpower and other resources as well as the bulk of government budget were focused on the industrial and services sectors, neglecting the dominant agricultural sector (MEDaC, 1999).

An agricultural development strategy can generally be evaluated by its ability to promote overall economic growth, the capacity to bring about structural transformation and its positive interaction with the other economic sectors. Moreover, such a strategy is evaluated in terms of the measures designed to achieve broadly based improvement for the vast majority of the rural communities and by the capacity to bring about a favorable impact on attitudes and behavior of the rural population. Agricultural growth encompasses more than the provision of increased food supplies and raw materials. Increased rural demand for inputs and consumer goods can provide an important stimulus to domestic industry that is likely to promote the growth of local manufacturing and stimulate the peasant farmers to increase production.

Developing countries are faced with the challenge of devising agricultural development strategies that will help improve the lives of the rural communities and that promote overall economic development. Moreover, because farming is generally confronted with many risks, unless there are deliberate efforts to encourage its development, its productivity would decline from time to time. The constant challenge of weather, drought or floods, unstable market conditions, falling product prices, increasing prices of agricultural inputs, and threat of diseases and pests are only a few of the risk factors with which farmers must contend. Appropriate agricultural policies could help in reducing some of these uncertainties.

The agricultural sector being the basic source of food and raw material supply, engaging more than four-fifths of the population, contributing about half of the GDP and 90 percent of foreign exchange earnings, compels inescapable emphasis in any analysis of Ethiopia's socio-economic development. As a result, the performance of the overall economy depends very much on the progress made in this sector. The agricultural sector is not only an important branch because it is the main stay of the population, but also because a significant proportion of the economic surplus of the nation emanates from it. Thus development efforts in Ethiopia should primarily focus on developing the agricultural sector.

The development of the agricultural sector is reflected by its capacity to supply adequate amount of food for the population and raw materials for the industries; by its potentials to generate adequate foreign exchange; and by its capacity to provide market for industrial output. Judged on the basis of these criteria, the development of the sector has been unsatisfactory and it has not been able to generate surplus production to meet the growing demand for agricultural products. The country had no better alternative than to give top priority to the development of the agricultural sector since it is the dominant economic sector (Assefa, 1995).

The bulk of agricultural production comes from smallholders who cultivate small, scattered and fragmented plots. They are primarily subsistence farmers, employing mainly backward cultivation methods using very little or no improved farm inputs. Smallholders in Ethiopia also lack the necessary skill for management, are constrained by lack of transportation and storage facilities, and are victims of inappropriate, biased and inconsistent government policies on marketing, pricing, credit, taxation, and land tenure systems. Consequently the productivity of these farmers remained very low (Mulat, 1999; Assefa, 1995).

The poor performance of the agricultural sector has been attributed to several factors. The feudalistic land ownership system has often been cited as the major obstacle that hindered the development of the agricultural sector in feudalistic Ethiopia. This problem was solved when the land reform proclamation came into effect in 1975. Nevertheless, land reform is a necessary but not a sufficient condition for raising output levels and hence the expectations have not been met. Other necessary measures that promote agricultural development ought to have accompanied the land reform. Agricultural development policies pursued by the government could enhance or curtail the development momentum and in the absence of sound agricultural policies land reform alone will not bring about increased agricultural production and productivity.

The purpose of this chapter is to give a brief account of the agricultural development policies and strategies pursued in the country and their impact on the productivity of smallholder farmers. Particular emphasis is given to agricultural technology, policies, institutions, and the underlying constraints hindering the growth of agriculture. Two distinct time periods are identified to analyze the distinct policies and strategies adopted in the country over the last two and half decades. These are the **socialist period** (1975-1990) and the **current period** (after 1991).

2.2 Development Strategies During the Socialist Period (1975-1990)

2.2.1 Socialist Organization of Agricultural Production

Two strategies of rural development competed for the attention of Ethiopian policy makers during the socialist period. (1) The smallholder approach based on individual freehold, a strong private sector, and public sector expenditures in support of essential agricultural sector institutions and infrastructures. (2) The agrarian socialism approach based on collective ownership of the means of production, group farming, state farms, and government control of rural marketing. Although the smallholder strategy has been the preferred approach on several grounds, the socialist regime pursued agrarian socialism as its development strategy. Agrarian socialism was promoted through land tenure rules, producer and service cooperative promotion, state farm expánsion, villagization and resettlement initiatives, production input and output marketing regulations, and direct and indirect taxation practices (Cohen and Isacksson, 1988).

During the socialist period, the state emerged as a dominant economic agent in the economy. The rationale behind this state hegemony was that socialization of the production process would in the first place involve transferring ownership of the means of production to the public. This, it was alleged, could be achieved only when the state as the representative of the people and in the interest of the Ethiopian workers and the peasants, directly owns and controls natural resources, key industries and commercial and financial sectors of the economy. One factor that profoundly altered the agrarian structure was thus the radical land reform that made all rural lands the collective property of the Ethiopian people (Assefa, 1995; Dejene, 1996; Abebe, 2000). The landlord-tenant relationships were abolished and large-scale commercial farms were nationalized without compensation. Moreover, new and radically different types of production relations emerged in the rural areas after the land reform (Cohen and Isacksson, 1988).

Collectivization was seen by the government as the basis for transforming agriculture and ensuring socialist production relations in the rural areas. In this regard, the formation of producers' co-operatives has been given top priority by the government with the aim of creating large-scale production units, which may achieve better utilization of land, labor, and equipment through a three-stage collectivization process. The main objective of establishing producers' co-operatives was to organize the rural people into effective production units. They were also considered future centers of technological diffusion in agricultural production (Cohen and Isacksson, 1988). Despite the support producers' co-operatives received from the government the growth of these co-operatives was not satisfactory (Dejene, 1996). Therefore, the socialist transformation of agriculture has proved to be overall a very slow and difficult process.

Moreover, the rural land reform transformed previously privately owned and managed large-scale farms into government-managed and controlled state farms. All the large-scale commercial farms were nationalized and organized either as state farms or co-operative farms. The main objectives of the state farms were to alleviate the national food shortage problems, provide raw materials for the domestic industries, and produce for export to acquire foreign exchange. In addition, state farms were supposed to expand and establish agro-industries, create employment opportunities, and introduce new farming techniques. The state farms absorbed most of the government expenditure on agriculture. They received more than 80 percent of the chemical fertilizer, 95 percent of the improved seeds and 80 percent of the credit (Stroud and Mulugetta, 1992). But the contribution of state farms either to total output or cultivated area was very negligible compared with private smallholders (World Bank, 1990).

2.2.2 Agricultural Development Programs and Productivity of Smallholders

2.2.2.1 The Package Agricultural Development Program

Several agricultural development programs had been initiated before the land reform to promote the development of the agricultural sector. Some of these projects were modified to fit the conditions after the land reform and continued to be operational even after the reform. The Minimum Package Program (MPP), which was a national program in scope and was started before the land reform, continued to operate in a different phase after the reform with the aim of increasing food production by developing and providing improved crop production packages to the farmers. After the first phase of MPPI was completed in 1974, there was a plan to extend MPPI to its second phase under MPPII for the period 1978-1982. However, due to the political developments and due to the land reform since 1974 it was necessary to re-draft the proposals of the MPPII. It was launched in 1980/81 and was officially terminated in 1985 (Assefa, 1995).

The objectives of the MPPII included the promotion of co-operative development, expansion of applied research and demonstration and seed multiplication responsibilities. Because the 'model farmer' approach adopted under MPPI was criticized for its tendency to enrich those farmers serving as models and widening the income gap between them and the laggards, this approach was dropped under MPPII and the PAs were now used as the extension channels. The MPPII, like any other program in the country, followed the socialist path of development in agriculture. Thus the achievements of the program were severely restricted by this strategy and its contribution to increased productivity and food production had been minimal.

The overall achievements of the MPPII were unsatisfactory and the transfer of new technology had been constrained by lack of transport facilities, inadequate financial resources, lack of trained extension agents, weak linkage between research and extension and limited capacity to multiply research products to be distributed to farmers (Dejene, 1996). When the minimum package program terminated another program called the Peasant Agricultural Development program (PADEP) was initiated.

2.2.2.2 The Peasant Agricultural Development Program

The impact of MPPII was found to be minimal because of the difficulties mentioned above and its overall success was actually questionable. A revised program, initially labeled as MPPIII, was designed based upon the experiences gained from the previous MPPs. The new program acknowledged, for the first time, the existence of regional differences and emphasized the need for decentralization to bring services closer to the producers. As a result of these conscious efforts to formulate different programs for different agro-climatic regions, PADEP was conceived and launched after the MPPII was terminated. Location-specific and regionally demarcated projects were designed so that each project included areas with relatively homogeneous agro-climatic zones. PADEP had thus different characters in each zone and consisted of eight separate "zonal development projects", each project being based on the specific resource endowment, constraints and needs present in a particular zone.

PADEP emphasized increasing smallholder food production in selected high potential highland areas to reduce the prevailing food deficit and provide domestic industries with the necessary raw materials. Moreover, it was aimed to strengthen the organization and promotion of co-operatives as well as the institutional capability within the Ministry of Agriculture (MOA) and other institutions. The project gave more emphasis to the surplus-producing areas such that the Training and Visit system of extension could be implemented by assigning a development agent to work with 1300 households, whereas this ratio was as low as 1:2000 in non-surplus districts (Bezabih, 2000). The separate projects under the umbrella of PADEP adopted a strategy of decentralized agricultural development and all of them incorporated various components including agricultural development and extension, conservation-based developments, infrastructure development, and institution building.

Because of the delay in the implementation of the actual PADEP projects, however, other interim measures that were related to PADEP were undertaken. The surplus-producing districts' program was one such measure that was commenced around 1987 as an intermediate solution until all PADEP projects could be implemented and was to act as pilot project for the mobilization and implementation of the actual projects. The main aim of this program was to increase total grain production within the country in the shortest possible time to solve the food crisis facing the country. This was to be accomplished by ensuring the provision of agricultural inputs to farmers within the priority areas and by improving the extension and other support facilities (Solomon, 1990). However, this program did not last long and was soon discontinued.

2.2.2.3 Arsi Comprehensive Rural Development Program

After the land reform, the Chilalo Agricultural Development Unit (CADU), which was implemented during the imperial regime, was also transformed into a more comprehensive project in terms of its coverage. Other two districts in Arsi province were incorporated and it was then renamed as the Arsi Rural Development Unit (ARDU) to reflect the spatial coverage of the project. The objectives of ARDU were more or less similar with CADU. But the 'model farmer' approach, which was used as the extension channel in CADU, was dropped and replaced by PAs. The provision of agricultural services by the project had increased the production and marketable surplus of the farmers in the region (Dejene, 1996; Solomon, 1990).

The per capita income of Arsi farmers was also substantially higher than that of farmers in other regions. Cultivated area in Chilalo increased significantly over the years. In the case of barley and wheat, cultivated area increased two fold in 1980 (Assefa, 1995). The research unit of ARDU was particularly interested in identifying high-yielding varieties of wheat and barley. The growth in wheat and barley areas, which have been particularly profitable, was the result of such efforts. With regard to modern yield-increasing input distribution, the consumption of fertilizer, improved seeds, and complementary services had increased substantially. Fertilizer and improved seed distribution and the number of credit participants increased significantly between 1974/75 and 1980/81. The research output of ARDU had also important applications in other areas of the country. The major undesirable effect of the project was that the concentration of available funds only in one region had obviously led to inter-regional inequalities among smallholder farmers. Furthermore, owing to its huge budgetary requirements, the project had to be phased out (Solomon, 1990; Assefa, 1995).

2.2.3 Impediments to Smallholder Agricultural Productivity

Most west donors and experts argue that the key to the agricultural development of Ethiopia lies in its smallholder sector. They hold that the land reform of 1975 unfroze Ethiopia's agricultural potential and that smallholders are the engine of growth that could drive the economic development of the country. It is argued that with the right price incentives and the public support of research, extension, credit, and private marketing infrastructure, smallholders can dramatically raise their yields, marketed output, and incomes. The resulting rise in rural incomes should increase the quality of rural life and create jobs in the small towns and urban centers that sell goods and services to rural producers (Cohen and Isacksson, 1988). Arguments for the adoption of this strategy by Ethiopia were supported by the fact that the country's agricultural sector is dominated by smallholders.

Based on the proportion of the land they cultivate and by the proportion of total agricultural production they contribute, the smallholders had a dominant position in agriculture. The private sector accounted for over 90 percent of the cultivated land and agricultural production. Besides, the sector provides employment for about 80 percent of the country's labor force. Although the land reform stipulated that a rural household could possess up to a maximum of 10 hectares, the majority of peasants in many parts of the country cultivated tiny plots, the largest of which may not be bigger than one hectare. Insecurity of tenure, obsolete farming techniques, and poor support services were responsible for the low productivity of the sector. The distribution of fertilizers and improved seeds, the most important yield-increasing inputs in Ethiopia, had always been highly biased towards the socialized sector. These inputs were supplied to small farmers who were cultivating their land individually only after the demand of state farms and co-operatives had been satisfied. The effect of all this bias against smallholders meant declining agricultural production (Stroud and Mulugetta, 1992).

2.2.3.1 Pricing and Marketing of Agricultural Produce

The socialist government had increasingly expanded its control over the supply of agricultural inputs and the marketing of farm production. In addition to institutional changes discussed earlier, pricing and marketing policies had also significant impact on smallholders' production. After 1974, the important economic activities were brought under the control of the state and central planning was adopted as the main instrument of management, guidance and acceleration of the economy. The government started to control and command the economy through price control measures, trade restrictions and imposed quota delivery systems. Before 1974 there had been a relatively free, but poorly integrated, system of marketing in which only some merchants had often monopoly power.

The government established the Agricultural Marketing Corporation (AMC) in 1976 as the main instrument of state intervention to control the marketing activity and stabilize producers' and consumers' prices. The corporation was created, at least theoretically, to reduce marketing margins to the advantage of the producer, to ensure the timely and efficient supply of farm inputs, and to assure adequate supplies for the public distribution system. It was supposed to cover its operational costs, including depreciation and interest on capital from its own margins. The corporation offered arbitrary prices during the initial years of its operations. However, it gradually introduced planned purchases and quota delivery, fixed and uniform producer prices and restriction of movement of grains from one region to another.

The state farms and producers' co-operatives were required to deliver all of their marketed output to the AMC, at prices, of course, higher than those paid to the smallholders. The purchases from private smallholders were based on compulsory quota systems. Quotas were allocated to each region on the basis of the number of PA and traders in the respective region and the PAs in turn assigned these quotas to the individual members. The compulsory quota system made the function of prices irrelevant and eliminated price competition between AMC and the private traders. In this way the government was able to extract large amount of grain from the rural areas for urban consumption and for the army. The prices were basically set with the aim of keeping low the retail price in the urban areas. The purchase prices, which were set in 1980, remained unchanged until 1988. Such prices served as disincentives to farmers and seriously undermined agricultural production and productivity. Consequent to all these there were widespread dissatisfactions among the peasantry.

2.2.3.2 Credit, Extension Services, and Input Distribution

The policies pursued by the socialist government with respect to the distribution and supply of agricultural inputs to help farmers realize the gains of new technology had an important impact on smallholders' production and productivity. Limited availability, high input prices, and inadequate and untimely delivery of these inputs and complementary services had a detrimental effect on agriculture and food production. The price policy had an impact on the utilization of modern technology and on efforts to increase productivity or efficiency. Input marketing organizations usually fail to deliver the right type of input at the right time and quantity without government intervention. The information available to farmers concerning the nature of the technology, the application techniques, and the expected results of the inputs and the availability of credit for the purchase of these inputs were additional aspects that legalize government intervention.

The use of modern inputs by smallholder farmers in Ethiopia had been generally restricted due to a number of reasons. Fertilizer had often been unprofitable compared to the product price. Studies have shown that the benefit-cost ratio for fertilizer use, assuming AMC prices, was too low to provide adequate incentive to the farmer to use fertilizer (World Bank, 1990). While the price of crop output had been suppressed, the price of fertilizer was increasing over the years. In addition to being unprofitable because of the low product price relative to the price of fertilizer, the use of this input was also constrained by administrative difficulties and biases. Before 1984, the AMC was responsible for the procurement of inputs from abroad and the MOA was the distributing agency. However, since AMC was primarily concerned with grain purchase, it had concentrated its activities only on those regions producing surplus grain and gave little or no attention to other regions.

To improve this situation, the Agricultural Inputs Supply Corporation (AISCO) was established in October 1984 and was given the responsibility of the procurement and distribution of fertilizer and improved seeds to farmers. This organization was, however, unable to meet the growing demand for inputs by farmers. In general, the distribution of agricultural services was limited and inefficient in that most of the time it was not delivered timely. Lack of foreign exchange to import chemical fertilizer also worsened the scarcity of fertilizer and other inputs. As a result of these problems, the consumption of inorganic fertilizer in Ethiopia had been less than many other countries in the region (Cohen and Issacksson, 1988).

In the case of improved seed distribution, more than 90 percent of the seed was usually distributed to state farms and the rest provided to smallholders and producers' co-operatives. Smallholders had not been entitled to bank credit for seeds except some fertilizer credit. Priority had always been accorded to state farms in the disbursement of agricultural credit. In the case of service co-operatives, only registered co-operatives were entitled to bank credit. Agricultural credit, therefore, did not play any significant role in promoting the productivity of smallholder agriculture.

The MOA and other institutions undertook extension activities to serve smallholders and producers' co-operatives. Extension agents demonstrated new technology, distributed inputs, carried out soil and water conservation projects, and undertook other similar activities. The Training and Visit system of the World Bank was adopted in the country in 1987 in which extension agents would visit the farmer on fortnightly schedule. One development agent was supposed to serve a minimum of about 1600 households under this system. Nevertheless, the extension agents did not have the necessary technology that could be disseminated to the farmers nor did they have adequate technical knowledge and logistic support from the administration during the socialist regime that forced them to be stationed in the towns.

2.2.4 Agricultural Sector Performance

Aggregate economic performance and that of the agricultural sector deteriorated during this period compared to figures recorded during the imperial regime. Not only did growth rates decline, but also they fluctuated markedly. Annual growth of agricultural GDP plunged below zero in seven of the 16 years. Aggregate GDP for the period 1975 to 1990 grew by an average of 2 percent per annum. It too fell below zero in four of these years. Growth of average agricultural GDP per annum stagnated between 1975 and 1984, and registered a growth rate of 2 percent per annum between 1985 and 1990. On the whole, the post-1974 annual agricultural growth rate was much lower than the agricultural growth rate during the 1964-1974 period. Per capita GDP declined at the rate of 0.8 percent per annum during the same period. Agricultural stagnation was largely responsible for the situation. Since the 1979/80, for instance, harvest had fallen below the rate achieved during the imperial regime and had failed to keep up with the high population growth rates (Cohen and Isacksson, 1988; Abebe, 2000).

The preceding review demonstrates that the agricultural sector policies of the socialist regime were characterized by several unfavorable features including the following. (1) Nationalization of all private and commercial farms and prohibition of private investments in the agricultural sector. (2) Involuntary collectivization of peasants into producers' and service cooperatives. (3) Forced villagization, government control of agricultural markets, and forced food grain quota deliveries at predetermined low prices. Defective agricultural policies penalized the smallholders and prevented them from attaining increased food production and productivity. In addition to the biased and ill-conceived development strategy of the socialist regime, civil war, drought, and other natural calamities as well as the international economic relations had contributed to the problem. Up until the downfall of the regime in 1991, these ill-conceived government interventions largely contributed to the lack of success in the development of agriculture. Far-reaching macroeconomic policies have been adopted to rectify these policy constraints since the seizure of power by the Transitional Government of Ethiopia.

2.3 Current Development Strategies

The Ethiopian economy has had mixed fortunes. It exhibited a situation from one of respectable growth of 1960's to the stagnation and decline of the 1970s and 1980s. GDP grew only by 1.5 percent during 1974-1990. By the dawning of the 1990s, the economy showed severe macroeconomic imbalances, severe food deficit, growing indebtedness, and increased vulnerability. As such the social and economic problems of the country have cumulatively become severe and complex mirroring sharp contrast between considerable potential and widespread poverty. Thus, by the beginning of the transition period in 1991/92, it was clearly observable that Ethiopia faced daunting economic development challenges: breaking the poverty trap and putting the economy on the path of sustained development. To this end, a new economic policy was put in place which was translated into a series of concrete economic reform programs (Mekonnen, 1999).

Following the downfall of the socialist regime in 1991, a new economic policy was drawn up to re-orient the economy and take the country out of the economic and social crisis. Most of the past economic policies were dismantled and replaced with new economic policies. The TGE, like the previous governments, acknowledged the importance of the agricultural sector and indicated that it could play a leading role in the economic development of the country. The transitional economic policy had also underscored the need to encourage the peasant sub-sector since it occupies a dominant position in terms of agricultural production (TGE, 1991). According to the economic policy smallholders would be supported by all available means because they constitute the majority of the rural population. Previous policies on market restrictions and discriminatory provision of agricultural support and extension services were abolished and replaced either with the norms of free markets, or smallholder farmers were given priority. Price controls have been lifted and the smallholders are allowed to sell their output at any place at market prices. It has also been stated that the transitional government would allocate more resources to expand and improve their productivity especially through improved agricultural production technologies.

2.3.1 Agricultural Development-led Industrialization Strategy

The present agricultural development strategy evolved from the new economic policy of the TGE and this has been operationalized through an economic reform program (Mekonnen, 1994). In essence, the present development strategy revolves around productivity enhancement of smallholder agriculture and industrialization based on utilization of domestic raw materials with labor intensive technology This strategy is popularly known in the economic literature as agricultural development-led industrialization, tailored to fit the Ethiopian context (Mekonnen, 1999). The strategy visualizes export-led growth as a propeller for an interdependent agricultural and industrial development. By and large, the strategy of ADLI in the context of Ethiopia focuses primarily on agricultural development. This is to be attained through improved smallholder agricultural productivity (MEDaC, 1999).

Within the strategy of ADLI, the development of smallholder agriculture was envisaged to proceed in three stages. Stage one involves the improvement of agricultural practices including animal husbandry and the utilization of better seeds. Stage two consists of the development of agricultural infrastructure, such as small-scale irrigation, and the introduction of modern inputs including fertilizers and agrochemicals. Stage three relates to increasing farm size that would take place alongside the shifting of population from agriculture to non-agricultural activities. Broadly, the aim is to attain food self-sufficiency, to reverse ecological degradation, and to raise the competitive advantage of Ethiopia's agriculture. The first stage has been actively implemented mainly through agricultural extension programs: SG and NEP.

2.3.1.1 The Sasakawa-Global 2000 Project

The SG agricultural project, started in Sub-Saharan Africa in 1986, was established by two humanitarian non-governmental organizations - the Sasakawa Africa Association and Global 2000 of the Carter Center. The primary goal of the SG project was to develop programs for technology demonstration in cooperation with national extension services; that is improving the capacity of national extension services to transfer seed-fertilizer technology to achieve food security among small scale farmers and the country at large (Takele, 1996). The SG project in Ethiopia was initiated in 1993 in collaboration with the national extension service and has developed a simple, and yet effective, approach to transfer agricultural production technologies. The centerpiece of this approach is the farmer-managed Extension Management Training Plot (EMTP). This is an on-farm demonstration plot that usually is half a hectare in size so that participating farmers can clearly assess the labor and other input requirements of the recommended technology. The focus of the project is on the regions and districts of high production potential where success in raising yields would have a major impact on national food supplies.

The EMTPs introduce improved technologies for the most important food crops of an area, including maize, wheat, tef, and sorghum for which proven and markedly superior technologies are available. The recommended technology packages include planting improved varieties at optimum densities, moderate and appropriate use of fertilizers and improved cultural practices that better control weeds, insects, and diseases as well as application of chemicals when necessary.

The distinctive feature that the SG technology transfer program manifested is simply filling the major gaps that had existed in the various extension systems of the past. These include access to technologies that are developed by the National Agricultural Research Systems, and other inputs and making them physically available through the provision of credit. Intensive practical training of extension workers from the central staff down to the development agents and the improvement of mobility of extension workers through provision of vehicles, motorcycles, and bicycles have greatly facilitated the success of the program (Dejene, 1996). It is through these approaches that the project proved that, if available technologies are properly packaged and utilized, they would considerably increase the productivity of major cereals grown in the country, under normal climatic conditions.

2.3.1.2 The New Extension Program

In order to enhance the implementation of the agricultural development-led industrialization development strategy, the government sponsored a task force that comprehensively assessed the agricultural extension system of the country. The task force issued a guideline on what it called Participatory Demonstration and Training Extension System in November 1994 (TGE,

1994) and has been actively implemented since 1994/95 as a new agricultural extension program in the country. It was synthesized from the experiences of SG project, which embarked upon the popularization of large-scale (usually half-hectare) on-farm technology demonstration plots.

In formulating NEP, attempts were made to screen out and preclude shortcomings of past extension systems. Accordingly the shortcomings of the previous extension systems were outlined as follows. (1) Extension service was erroneously organized by commodity rather than by function. (2) Extension service was rather prescriptive in the sense that it only transmitted information without adequate or no supply of inputs. Hence, input and credit supplying institutions were not well organized and oriented. (3) Extension service was limited only to high potential areas of the country, neglecting other agro-climatic zones. (4) Demonstration sites/plots were not widely distributed rather they were undertaken in fences. (5) Extension service was not participatory. Farmers were not participating in identification, planning, implementation, monitoring and evaluation of technologies. (6) Governmental and non-governmental agricultural development projects and programs were not well coordinated and freed from replication of efforts. (7) Extension information was not effectively communicated through different methods (demonstration, publications, and radio). (8) Budgets, manpower, and means of transport were not adequately allocated for the extension service. (9) Inefficiency in administration and management (TGE, 1994).

NEP was developed against these backgrounds aiming to improve smallholder agricultural production and productivity through better access to technologies. It promotes an integrated and science-based packages developed for different agro-climatic zones (highland mixed farming system zone, highland degraded and low moisture zone, lowland agro-pastoralist zone, and lowland pastoralist zone) and is aimed at sustainable intensification of agriculture and use of natural resources. It tries to merge the extension management principles of the World Bank's Training and Visit extension system with the technology diffusion experience of the SG project. The major elements of the extension package are fertilizer, improved seeds, pesticides and better cultural practices mainly for cereal crops (tef, maize, barley, sorghum and millet). Under the program, the district offices of agriculture provide participating farmers with a package of inputs. Participants agree to allocate 0.25 to 0.50 hectares of land for the demonstration plot and pay a 25-50 percent down payment on the input package at the time of planting with the balance due after harvest. The plots are managed by the farmers under the supervision of the extension agents. Its implementation started in 1994/95 cropping season primarily through dissemination of crop technologies. In 1997/98, it incorporated the transfer of livestock technologies. During its first year of implementation, about 3, 200 half-hectare on-farm demonstration plots were established and average yields for the major crops, including maize, wheat, tef, and sorghum increased by 98 percent and the increment was more than double for maize and wheat. About 360,000 and 650,000 demonstration plots were implemented in the second and third years, respectively, although assessment of the results has not been made (Takele, 1996).

NEP has expanded to areas that were previously neglected by the extension service. This expansion has taken place at a time of major changes in agricultural policies. NEP has put increasing demands on the quality and amount of extension, credit, and input supply services, which are critical for its successful implementation. However, these services have been far from being adequate and are poorly integrated. First, extension agents have very poor technical knowledge about new technologies and are also involved in too many non-extension tasks, including processing credit applications, dealing with input distributors, mobilizing farmers for public works, and collecting loans and taxes. Second, the rapid expansion of NEP to less favorable and marginal areas required more supervision and credit due to the low literacy rates and poor asset endowments of the farmers in these areas. Third, due to very poor infrastructural facilities especially in the marginal areas, adequate and timely distribution of inputs to farmers has been a major constraint facing NEP. It is not well known, however, to what extent the intended productivity gains from improved agricultural production technologies have been realized through NEP. Therefore, it is of interest in this study to assess the impact of NEP on the production efficiency of smallholder farmers.

2.3.2 The Current State of Ethiopian Agriculture

Like in many other developing countries, Ethiopian agriculture continues to make the greatest contribution to the GDP although it has played a limited role as an engine of economic growth. Its average share was 68 percent of GDP during the imperial regime. The share declined to 55 percent during the socialist regime and presently it stands at 50 percent of GDP (Table 2.1). Agriculture's continued dominance is also implied by its strong correlation with GDP. The share of the service sector has increased from 25 percent during the imperial regime to 34 percent during the socialist regime and 39 percent at present. The contribution of the manufacturing sector remained within the range of 9-11 percent over the same period. The fact that agriculture has accounted for the lion's share in GDP for the past 40 years signifies that the Ethiopian economy has not yet undergone structural transformation and therefore that production constraints similar to those in the 1960s are exerting similar influence on today's overall GDP growth. The performance of the overall economy and agriculture's role in GDP changes could be inferred from GDP growth rates. GDP growth rate declined by 1.82 percent during the socialist regime compared to the imperial regime and grew by 3.09 percent after 1991 compared to its level during the socialist regime.

Table 2.1: Average growth rates and sectoral shares in GDP

Year	Agriculture		Manufacturing		Services		GDP
	Growth rate	Share	Growth rate	Share	Growth rate	Share	Growth rate
1963-1974	0.9	68	7	5	7	25	3.5
1975-1991	1.3	55	1.2	6.5	2.6	34	1.7
1992-1998	2	50	7	6.4	8	39	4.8

Source: Zerihun, 2002.

This is attributed to increased performance in the manufacturing and service sectors than the agricultural sector. Improved availability of inputs and spare parts to the highly incapacitated manufacturing sector were the major factors behind the profound growth registered in the industrial sector (MEDaC, 1999). This implies that GDP growth has mostly been the outcome of improved performance in the non-agricultural sector. Growth in the agricultural sector has not been stable compared to the manufacturing and service sectors. It has been extremely vulnerable to climatic variations. In the major drought years of 1973/74, 1983/1984, 1993/1994, and 1997/1998, agricultural production declined by 1.2, 17, 4, and 10 percent, respectively.

Severe drought was also reported in the year 2000 but its impact on agriculture is not yet made public. Good rain years such as 1982, 1986, 1992, and 1995, on the other hand, brought about a 13, 19, 6, and 15 percent growth in value added in agriculture, respectively. Most of the remaining years, which exhibited positive growth rates were years of recovery (Zerihun, 2002). Since 1995/96 cropping season, when NEP became operational in all regional states and agro-climatic zones of the country, fertilizer and improved seeds have witnessed widespread and increasing rates of adoption. This is attributed to the growing number of farming households embraced in NEP. In 1998/99, for example, an estimated 3.7 million farming households participated in the program and agricultural credit rose from 8.1 million to 153.2 million Birr[1] (Befekadu and Berhanu, 1999).

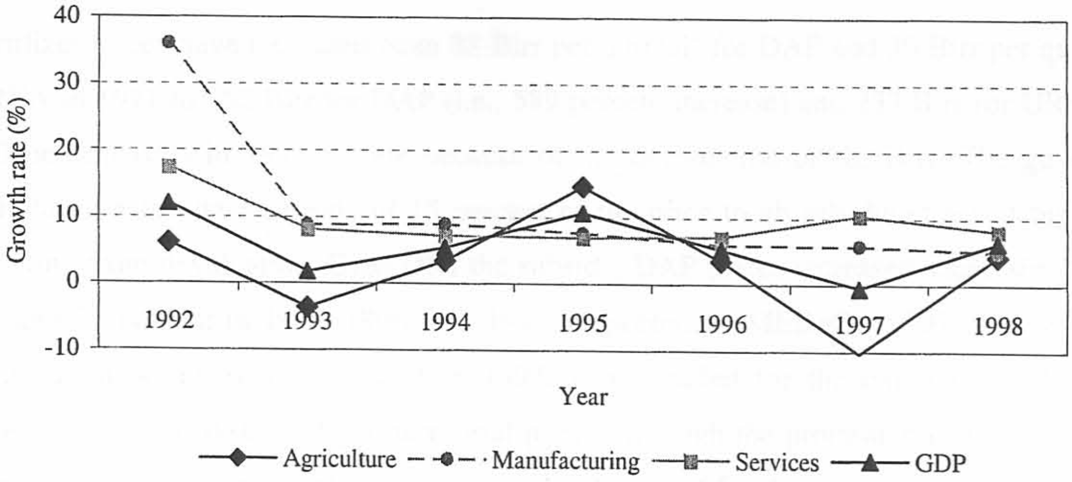

Figure 2.1: Sectoral growth rates.

Source: Own computation using data from MEDaC, 1999.

2.3.2.1 Trends in Fertilizer Utilization

Consistent with the new economic policy, the government designed the new marketing for fertilizer in 1992 with the main objective of the fertilizer market and creating a multi-channel distribution system. Average national fertilizer application per hectare remained negligible through the mid 1980s ranging from 0.1 kg in 1971 to 4 kg per hectare in 1985/86. Beginning in 1986, it started to grow steadily and fall back in 1993 as a result of devaluation (Figure 2.2). Fertilizer application grew from 22.1 kg per hectare in 1991/92 to 34.5 kg per hectare in 1999/2000. Although this is below recommended application rates, the trend is very promising. Fertilizer consumption increased from 145,709 tons in 1990 to 206, 294 tons in 1997 showing an annual average growth rate of 5 percent over the period. The share of fertilizer used by smallholders has increased from 73 percent during 1987-1990 to 94 percent in 1997. Of the total fertilizer used, DAP accounted for 78 percent while UREA accounted for the remaining 22 percent (MEDaC, 1999). Because of the gradual liberalization of the fertilizer market, however, fertilizer prices have increased considerably over the years and this

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[1] Birr is the currency of Ethiopia. As of January 2003, 1 US$=8.58 Birr.

has proved to be a major constraint to greater fertilizer technology utilization as shown by a declining trend of total fertilizer use in Figure 2.2 after 1996.

2.3.2.2 Trends in Fertilizer Prices

Fertilizer prices have increased from 38 Birr per quintal[2] for DAP and 30 Birr per quintal for UREA in 1971 to 262 Birr for DAP (i.e., 589 percent increase) and 237 Birr for UREA (i.e., 690 percent rise) in 1997 mainly because of the devaluation of the Birr. The government introduced a fertilizer subsidy of 15 percent of the price to absorb the effect of high prices resulting from devaluation. Even after the subsidy, DAP prices increased successively by 19, 33, and 75 percent in 1995, 1996, and 1997, respectively (MEDaC, 1999). A new fertilizer distribution policy was introduced in 1997, which called for the elimination of fertilizer subsidies and the system of pan-territorial pricing through the promotion of the involvement of private sectors in importation, distribution, and sales of fertilizer.

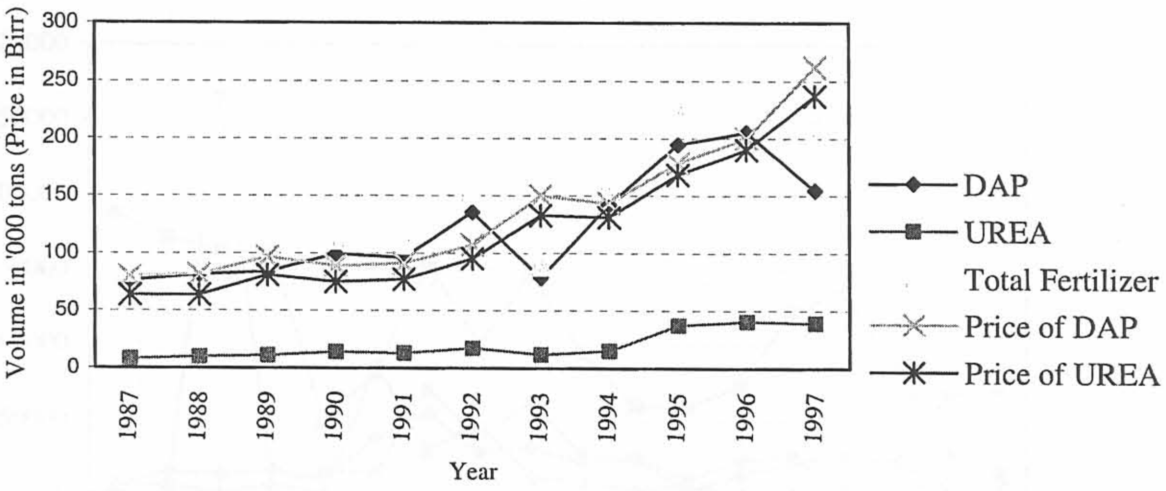

Figure 2.2: Trends in smallholder fertilizer use and prices.
Source: Own computation using data from MEDaC, 1999.

In compliance with the workings of a market economy, the government has been looking for a phased removal of fertilizer price controls and subsidies. Accordingly, the government deregulated the retail price of fertilizer on 31 January 1997 immediately after the removal of fertilizer subsidies by the end of 1996. Wholesale prices were deregulated at the end of 1997

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[2] One quintal is equivalent to 100 kilograms.

and in February 1998, the government completely liberalized the fertilizer market including the distribution system (MEDaC, 1999).

2.3.2.3 Trends in Improved Seed Utilization

In October 1992, TGE issued a National Seed Industry Policy (NSIP) with the objective of laying the ground for the development of a healthy seed industry in which private seed enterprises would be encouraged to actively participate in the production and distribution of improved seeds. To properly implement the policy, the TGE established the National Seed Industry Agency (NSIA) entrusted with the task of guiding and monitoring the National Seed Industry along sound lines. While seed certification is the sole responsibility of the NSIA, the role of the Ethiopian Seed Enterprise (ESE) is to obtain breeder seeds from research institutions, multiply breeder seeds into basic and pre-basic seeds, and multiply basic seeds into commercial seeds (MEDaC, 1999).

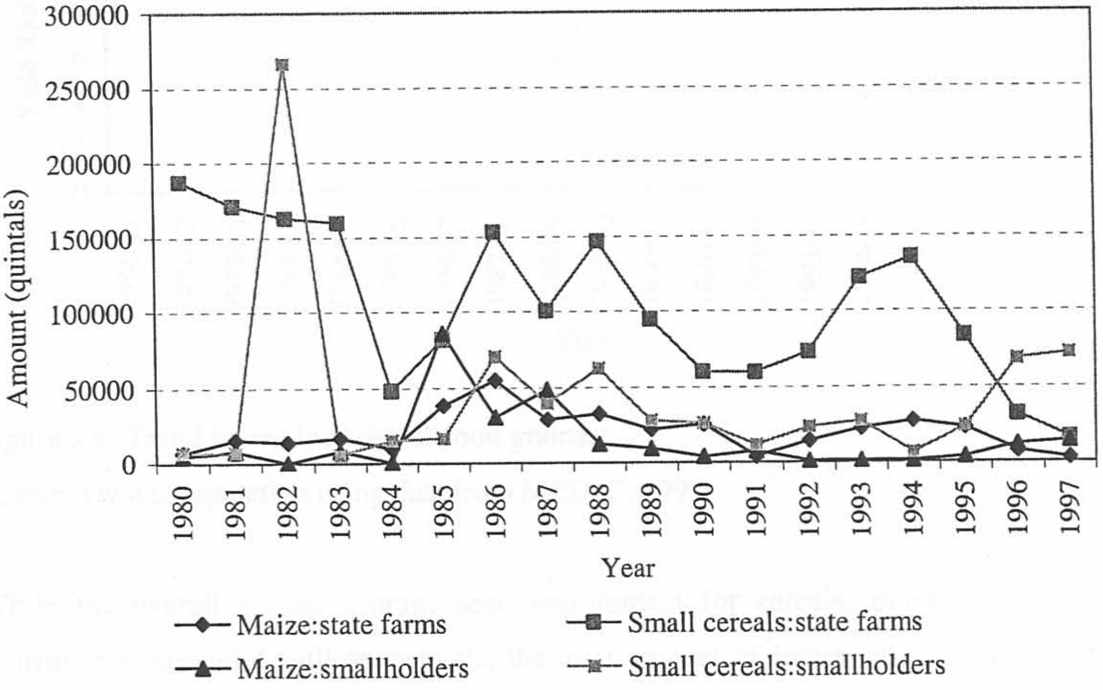

Figure 2.3: Trends in improved seed utilization by major crop and sector.
Source: Own computation using data from ESE, 1997 and MEDaC, 1999.

2.3.2.4 The State of Food Production, Productivity, and Food Security

The production of major food grains in the past few decades has been characterized by wide fluctuations in total output and a very slow growth. Performance throughout the 1980s was low with cereal production increasing at a rate of 1.7 percent annually compared to a population growth rate of 2.9 percent. During the 1990s the performance of the crop sub-sector showed an improvement over the 1980s. Estimates of food grain production grew from a longer-term annual average of 60 million quintals in 1980/81 to 103.27 million quintals in 1995/96 and 104.3 million quintals in 1996/97 (CSA, 1997). The increase in production in 1995/96 and 1996/97 was mainly due to very good weather and expansion of cultivated area. But the contribution of increased use of improved agricultural technologies was argued to have been minimal mainly because yields of most cereals remained stagnant (Mulat, 1999).

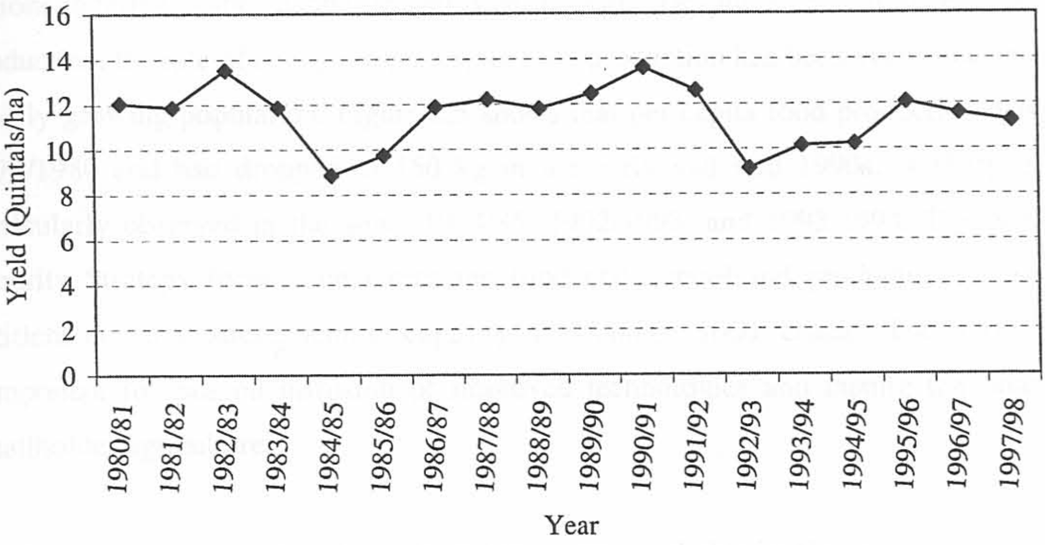

Figure 2.4: Trend in productivity of food grains.

Source: Own computation using data from MEDaC, 1999.

While the overall annual average seed requirement for cereals, pulses and oil seeds is estimated at around 4 million quintals, the total amount of improved seed sold to different users has not exceeded 45 percent of the requirement. Improved seeds distributed so far include different varieties of maize, sorghum, pulses, small cereals (wheat, barley, and tef), and oil crops. As shown in Figure 2.3, the largest quantity of improved seeds distributed so far is the small cereals followed by maize. Wheat constitutes about 90 percent of the seeds of small cereals distributed. In general, however, lack of adequate supply of improved seed varieties has been one of the critical constraints hindering effective extension work in the country (Bezabih, 2000). There was not a consistent supply of improved seeds as shown by the fluctuation of the quantity distributed over the past many years. It showed an increasing tendency during the years before 1983/84 and declined thereon until it turned up starting the 1991/92 cropping year. The trend of improved seeds distributed during the recent years shows an increasing tendency for the peasant farms while it declines for the state farms.

With the exception of the good performance of maize yields of up to 20 quintals per hectare in 1995/96, grain yields per hectare for total grains have remained between 9 and 14 quintals per hectare (Figure 2.4). This suggests that increased production has come about through intensive cultivation only in the case of maize (Tadesse, 2002). Further, because these trends are national averages, they mask potentially significant differences between different growing regions in terms of the changes in yields per hectare. Despite a general increase in total grain production, the rate of change in per capita food production has been very slow because of the rapidly growing population. Figure 2.5 shows that per capita food production was 200 kg in 1979/1980 and had dropped to 150 kg in the early and mid 1990s. A sharp decline was particularly observed in the years 1984/85, 1992/1993, and 1993/1994. The National Food Security Strategy focuses on increasing food and agricultural production, improving food entitlement, and strengthening capacity to manage food crises. The food production component focuses on diffusion of improved technologies and raising the productivity of smallholder agriculture.

Food security focuses on eliminating long term food deprivation and averting short term stresses in the capacity of commanding enough food. It was initially conceptualized as a problem of food supply against the level of consumption needs. This view, however, failed to be practical when there was an increase in the size of famine, hunger and malnutrition irrespective of the increase in the volume of food supply. This has made a shift of thinking from food availability consideration to a food entitlement approach. Food insecurity can be of two types depending on its intensity: chronic food insecurity and transitory food insecurity. The former is a sign of poverty and often caused by a constant failure to acquire enough food while the latter is caused by short term fluctuation in production or prices of food. It also takes a form of famine requiring an urgent and coordinated effort to withstand its shocks (MEDaC, 1999; Bezabih, 2000). The size of the food insecure people in Ethiopia has varied between 40 and 50 percent over the last decade (MEDaC, 1999). This food insecurity problem is generally highly correlated with the decline in food production. Although an increase in food production has been observed in some of the post-reform years, there is still an increasing food deficit in Ethiopia (Devereux, 2000).

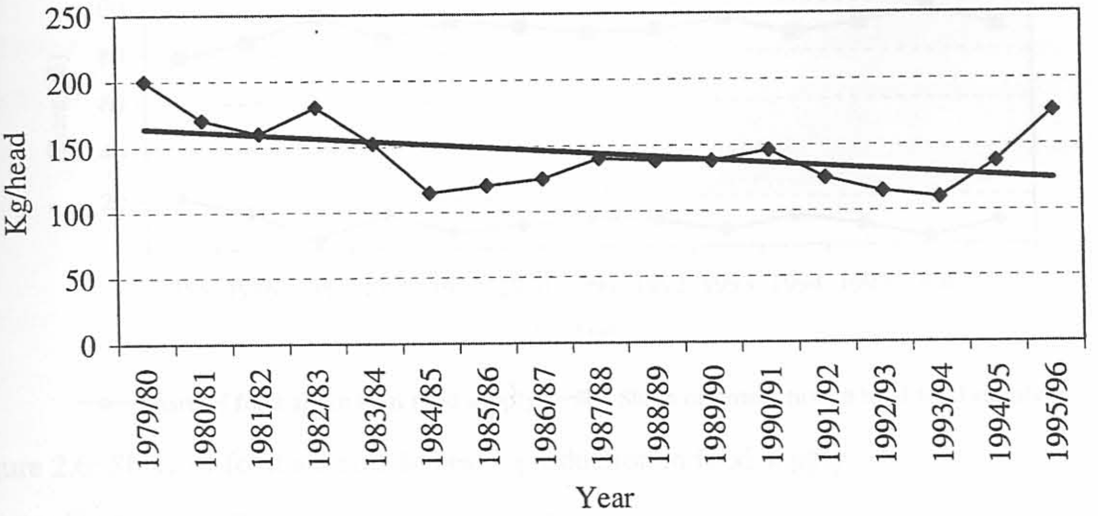

Figure 2.5: Trend in per capita food production.
Source: Adapted from MEDaC, 1999 and Befekadu and Berhanu, 1999.

For decades, the gap created by domestic production shortfalls has been largely met through external food aid. The annual volume of cereal food aid has ranged from 2.3 percent to 26 percent of the total grain production over the period 1985-1996 (MEDaC, 1999). Food aid has thus been the most important guarantee of household food security in rural Ethiopia. Although food aid is a standard response to transitory food insecurity (e.g., drought emergencies), it has become an institutionalized response to chronic food insecurity as well (Devereux, 2000). Annual food aid deliveries since 1980 have varied from 200, 000 to 1, 200, 000 metric tones. The number of needy people ranged from 2.5 million in 1987 and 7.85 million in 1992 to 7.7 million in 2000. Food aid deliveries averaged 11 percent of national cereals production or 12 kg per capita between 1985 and 1996, peaking at 26 percent in famine years (Clay et al., 1999).

Figure 2.6 shows that in the famine years such as 1985, food aid's share in total food supply was 21 percent implying that domestic food grain production contributed only 79 percent of the country's food supply. Although a slight improvement in food grain production has been observed in the period since 1991 compared with that during the socialist regime, food aid has continued to be an important source of food supply to the nation. Since 1996, for example, the share of food aid in total food supply has been increasing in view of the country's inability to achieve food self sufficiency.

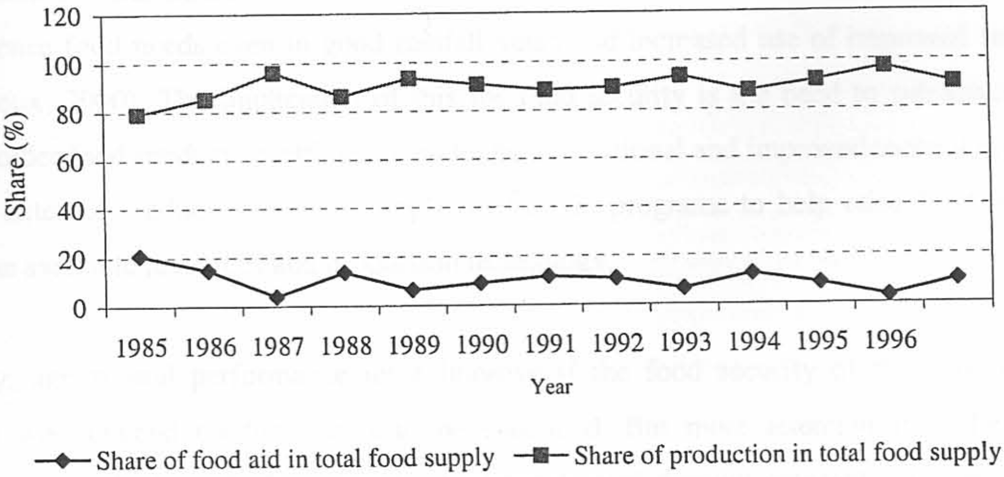

Figure 2.6: Share of food aid and domestic production in food supply.
Source: Own computation.

Current conventional wisdom on food insecurity in Ethiopia asserts that the problem can be simply conceptualized as follows (Devereux, 2000). (1) Landholdings are too small to allow most farming households to achieve food self-sufficiency. (2) Population pressure reduces landholdings further and places intolerable stress on an already fragile natural resource base. (3) Soil fertility is declining due to intensive cultivation and limited application of yield-enhancing inputs. (4) Recurrent droughts add food production shocks to abnormally low yields. (5) Limited off-farm employment opportunities restrict diversification and migration options, leaving people trapped in increasingly unviable agriculture. The poor performance of smallholder agriculture is certainly a large part of the explanation. The implication for food security in the longer term is that a structural transformation of agriculture is urgently needed to considerably raise food production and productivity mainly through increased and efficient use of improved agricultural production technologies.

The low level of smallholder agricultural productivity and food production efficiency, despite increased use of improved technology since the NEP initiative, is reflected in the continued food deficit facing the country even in good rainfall years such as 1995/96. Befekadu and Berhanu (1999), for example, reported that the food gap rose from 0.75 million tons in 1979/80 to 5 million tons in 1993/94, falling to 2.6 million tons in 1995/96 despite a record harvest. During the late 1980s, 52 percent of Ethiopia's population consumed less than the recommended daily allowance of 2100 kilocalories, and even in the record harvest year of 1995/96, this population fell only to 43 percent (Clay et al., 1999). This figure approximates the 40 percent of rural households who farm less than 0.5 hectares, which is inadequate to meet subsistence food needs even in good rainfall years and increased use of improved technology (Devereux, 2000). The implication of this for food security is the need to substantially raise smallholder food production efficiency under both traditional and improved technology through strong extension, education, input supply, and credit programs to help raise food production with the available resources and production technology.

Clearly, agricultural performance must improve if the food security of the majority of the people who depend on farming is to be enhanced. But more attention must be given to stabilizing yields through, for example, dissemination of drought-resistant varieties to farmers in marginal areas, rather than high-yielding but riskier varieties. More attention also needs to be given to the landless and effectively landless- farmers on tiny 'starvation plots'- for whom agricultural-based livelihoods are less sustainable from year to year. These people are chronically food insecure and will require recurrent relief until viable alternative livelihood options open up for them.

The foregoing analysis of the current agricultural development strategy and food security demonstrates that while the efforts underway to raise smallholder productivity and bring about sustained agricultural growth, mainly through increased use of improved technology, are encouraging, there remain critical constraints and problems facing smallholder agriculture that need utmost attention. Although there has been fluctuation in production and consumption of agricultural inputs and outputs, agricultural production has generally showed positive growth since NEP was launched as part of the current development strategy. In spite of the complete removal of subsidies, utilization of fertilizer has generally increased. The consumption of improved seeds and amount of input credit distributed to smallholders has also increased. However, smallholder agricultural production has failed to keep pace with population growth. A stagnation of agricultural productivity, reflected in low cereal yields despite the increased use of improved technologies of major cereal crops (Figures 2.2 and 2.3), provides most of the explanation. The intended benefits in terms of increased yields of major food crops, as demonstrated by the SG project in high potential areas following the increased use of input packages, have not been realized.

CHAPTER 3

PRODUCTION EFFICIENCY: CONCEPTS, APPROACHES TO MEASUREMENT, AND EMPIRICAL APPLICATIONS

3.1 Introduction

Efficiency is considered to be one of the most important issues in the production process. Efficiency is measured by comparing the actually attained or realized value of the objective function against what is attainable at the frontier. The resource constraint makes increasing efficiency one of the important goals of any individual and society since efficiency improvement is one of the important sources of growth. Thus, efficiency has policy implications both at the micro and macro economic levels.

The analysis of production and resource use in the farming sector has started to occupy an important place in agricultural policy frameworks that seek to increase domestic production by encouraging optimal resource utilization. Increasing technical and allocative efficiency is an important factor of productivity growth and is more appropriate in developing countries like Ethiopia where resources are scarce and raising production through improved efficiency does not generally require increasing the resource base or developing new technology. The importance of measuring and analyzing the level of efficiency of firms cannot thus be overemphasized. The analysis of technical and allocative efficiency under current technological change in agriculture will help policy makers to formulate adequate and appropriate extension services, pricing, marketing, credit, input distribution and land distribution policies.

3.2 Components of Production Efficiency

In microeconomic theory of the firm, production (or economic) efficiency is decomposed into technical and allocative efficiency. A producer is said to be technically efficient if production occurs on the boundary of the producer's production possibilities set, and technically inefficient if production occurs on the interior of the production possibilities set. That is, technical efficiency is the extent to which the maximum possible output is achieved from a given combination of inputs (Ellis, 1988). On the other hand, a producer is said to be allocatively efficient if production occurs in a region of the production possibilities set that satisfies the producer's behavioral objective.

Farrell (1957) distinguished between technical and allocative efficiency in production through the use of a frontier production function. Technical efficiency is the ability to produce a given level of output with a minimum quantity of inputs under certain technology. Allocative efficiency refers to the ability of using inputs in optimal proportions for given factor prices (i.e., where the ratio of marginal products for each pair of inputs is equal to the ratio of market prices). Economic efficiency is the product of technical and allocative efficiency. An economically efficient input-output combination would be on both the frontier function and the expansion path. Alternatively, economic efficiency can be defined as the ability of a production organization or any other entity to produce a given output at minimum cost. If a firm has achieved both technically efficient and allocatively efficient levels of production, it is economically efficient and new investment streams may be critical for any new development.

3.3 Production Technology and Sources of Output Growth

The specification of a production technology forms the basis for the conceptualization and measurement of efficiency. The determination of a benchmark for efficiency analysis depends on certain assumptions to be made about the behavior of the firm. The behavior of the production entity or the firm can be described either by the production function, cost function, profit function, or demand and supply functions. A rational decision maker will always attempt to maximize the gains or minimize the losses, which are defined by the respective maximization or minimization functions. There are different alternative economic theories of peasant household behavior, which assume that peasant households maximize one or more household objectives. In this study the behavior of the smallholders will be analyzed in terms of the production function approach.

The production technology that transforms inputs $X \in \mathrm{R}^n$ into net outputs $Y \in \mathrm{R}^m$ is modeled by the production function $Y = f(X)$, where $f(X)$ specifies the maximum output obtainable from the input vector X. This function represents the maximum attainable output for a given set of inputs. In other words, it represents a locus of efficient input-output combinations. The production technology is thus a mathematical relation on *f*, which transforms inputs into outputs and it gives the set of all technologically feasible input-output vectors. Production economics focuses not only on how resources are allocated but also on developing an efficient method of allocating resources to attain growth or economic development. Hence the analysis of economic development can also be approached through the theory of production economics.

Production in general may be increased in different ways. First, production may be increased through increased use of inputs, termed as horizontal expansion. In order for producers to use more inputs, either output prices must increase or the input prices must fall or both. This source of economic growth has little applicability in the present economic and social environment in Ethiopia, which is faced with resource limitations. Output can also be increased by improving efficiency usually referred to as the improvement approach. This approach requires the improvement of conditions or the removal of some existing institutional constraints to increase output using the existing technology. The other major source of growth is the transformation approach, which is characterized by a shift or an improvement in farm technology such as the use of technical packages, including improved seeds, fertilizers, credit, and chemicals that shift the production function outwards. Output per unit of input will be increased by changing the parameters of the production function. When new types of inputs of production are introduced into the production process, the production surface or the production horizon is changed.

3.4 The Efficiency Hypothesis

In the economic literature on efficiency, an important and often controversial subject is what is called the efficiency hypothesis. The notion that traditional farmers are 'poor but efficient' in their static environment has often been a view that drew the attention of several economists. The efficiency hypothesis, which was advanced by Schultz (1964) states that farm families in the developing countries are 'poor but efficient'. He explicitly stated that there are comparatively few significant inefficiencies in the allocation of the factors of production in traditional agriculture.

According to this hypothesis, since peasants are efficient within the constraints of existing technology, then only a change in the technology will bring about an increase in output. This hypothesis had influenced the perception of economists for a long time and its policy implications had remained to be of central importance in resource allocation. Accordingly, new investments and technological inputs from outside have been increasingly emphasized rather than extension and education efforts. Even in situations where the efficiency hypothesis did not apply, development policy makers have been overlooking opportunities for relatively inexpensive gains in production and concentrating only on expensive options such as investment in developing new technologies.

Conceptually the 'poor but efficient' hypothesis is related to a situation where external conditions are steady and not to situations which leave the farmer in a continuous disequilibrium. But farmers' environment is in a continuous motion, which necessitates an alteration in the technological, economic, and ecological conditions. The ever-growing degradation of tropical soils as well as the high man-land ratios under population pressure are best indicators for the disturbances of traditional farming systems. Different measures adopted by farmers to adjust to the rapidly changing environment create possibilities for substantial differences in efficiency. Farmers also find themselves in disequilibrium because of the continuously generated and diffused new technological innovations as well as by the continuous changes in input and output prices (Ali and Chaudhry, 1990). Accordingly, Schultz (1964) excluded very explicitly those who experienced a significant alteration of technological, economic or ecological conditions to which they had no time to fully adjust. Yet such alterations have meanwhile become typical for a great number of agricultural locations. With the rapidly changing environment, farmers attempt, more or less deliberately, to adjust their land use system, agronomic practices (such as soil preparation, planting date, plant density, fertilization, number of weeding, cultivation, and sowing date) and even the household economy and off-farm activities. Such adjustments require skills, awareness of risks and evaluation of current gains against fulfillment of future expectations and resource protection. This opens up possibilities for substantial inter-farm differences with respect to the path chosen and the technical efficiency of factor reallocation.

In addition to the conceptual arguments, the 'poor but efficient' hypothesis has also been a subject for a number of empirical investigations. For instance, after reviewing previous studies, Shapiro (1983) rejected this hypothesis and did his own empirical investigation of

Tanzanian cotton farmers and showed that output could be increased by 51 percent. This could be brought about if all farmers achieved those levels of technical efficiency that were in fact achieved by the best farmers in the sample using the inputs and technologies that the less efficient ones used. Studies conducted in the Philippines also showed that there were 25 to 50 percent inefficiencies in rice production (Lingrad, Castillo and Jayasuriya, 1983; Dawson and Lingrad, 1989). Ali and Flinn (1989) also found that the profit of rice farmers in Pakistan could be increased by 28 percent by improving their efficiency. A study in Punjab indicated that the income of farmers could be raised by 13 to 30 percent using the current technology (Ali and Chaudhry, 1990).

So the universal validity of this hypothesis is questionable in an environment that is no longer static and is characterized by substantial changes of technology, economy, and environment. It is also virtually impossible to meet the assumptions of facing the same production technology and prices for inputs and outputs and accept the profit-maximizing behavior of peasants. Rejecting the ‘poor but efficient’ hypothesis does not, however, necessarily imply that the theory does not have any contribution. At least it has been successful in placing peasant economics rationality on the agenda.

The Schultzian hypothesis was the point of departure for taking much more seriously the logic of peasant farm systems in order to discover the underlying logic of peasant farm practices instead of dismissing them as backward, lazy and irrational. The theory of profit maximization, which was the basis for the ‘poor but efficient’ hypothesis, is only one of the theories advanced to explain peasant household behavior. Several other alternative economic theories of peasant household behavior have been presented in the literature. The risk-averse peasant model (Ellis, 1988), the Chayanov model of utility maximization (Chayanov, 1966) and the new household models (Singh et al., 1986) are other major peasant household models frequently discussed in the literature.

The profit maximizing theory assumes that peasants are profit maximizing economic agents and are thus efficient producers. On the other hand, the risk-averse peasant theory argues that poor small farmers are necessarily risk-averse and they attempt to increase family security rather than maximize profit. The Chayanovian peasant model sets up a theory of the peasant household, which contains both consumption and production components and is based upon two basic assumptions: the absence of labor market and the flexible access to land. The new household economic models, which are similar to the Chayanovian model, relax some of the assumptions while at the same time maintain the integration between consumption and production. They drop the non-existence of the labor market and the unlimited supply of land assumptions.

No theory can be said to fully explain all aspects of peasant production systems and each may have relevance in explaining different aspects of the peasant economy. On the other hand, the theories are not distinct in all respects and none of the peasant household models make the study of technical efficiency inappropriate. Ellis (1988) pointed out that none of the theories assume or predict that peasant farmers are uniformly technically efficient in the sense that they all operate on the same 'best' production function. The simple conclusion to draw from this is that varying technical efficiency amongst peasant farms is always worth investigating irrespective of the microeconomic theory of the farm household.

3.5 Efficiency under New Technology

Because modern agricultural technology is recognized to be an important tool for increasing agricultural production, policy makers have paid attention mainly to the choice of technology, and to the adoption of such chosen technology by farmers (Kalirajan, 1991; Ali and Chaudhry, 1990). Following the neoclassical Hirschman's model of economic development, policy makers in developing countries have followed the method of providing various incentive measures to induce farmers to achieve a high rate of adoption of the chosen modern technology. Contrary to the expectation, the field-level performances of many new technologies have been shown not to be as suggested by the Hirschman's model of development. In this context, Schumpeterian theory of development provides an explanation. It stresses the fact that technological progress depends not only on the choice of technology but also on the appropriate application of any technology (Kalirajan, 1991).

With the introduction of a new input (e.g., a new variety), farmers may experience initial inefficiency as they learn about the new input. This inefficiency may include technical inefficiency as farmers acquire skills in applying the input and allocative errors as they adjust the level of use of the new input to their own specific circumstances (Ghatak and Ingersent, 1984; Ali and Byerlee, 1991; Xu and Jeffrey, 1998). This is especially true if the environmental variables have strong interaction with the new inputs. If the introduction of a new input is a one-time change to the system, farmers will eventually adjust to a reasonably efficient use of the input through learning by doing. In practice, agriculture in developing countries has undergone profound changes in both the technical and economic environments. Changes in the technical environment are often accompanied by changes in the economic environment. The development of better transportation and marketing infrastructure encourages crop specialization. At the same time, input-output price relationships are subject to sharp changes, especially with the policy reforms in many developing countries, which have gradually eliminated subsidies on critical inputs such as fertilizers. The combination of an evolving technical and economic environment means that the equilibrium required for economic efficiency is a constantly moving target (Ali and Byerlee, 1991).

The complexity of decision making in a dynamic environment is compounded by several other sources of complexity in a modernizing agriculture. These sources of complexity are caused by the following factors. (1) A wide array of purchased inputs which can potentially be applied. (2) Strong interaction between some purchased inputs and environmental variables (e.g., between fertilizer and soil type or rainfall). (3) Interaction between the purchased inputs and the time and method of application of the inputs leading to high variability in output. (4) Interaction between management of preceding and succeeding crops in a multiple cropping sequence (Ghatak and Ingersent, 1984; Ali and Byerlee, 1991; Ellis, 1988). In a dynamic agriculture where decision making is a complex process, it is hypothesized that in the short run the managerial skills and information available to farmers may be more important in causing inefficiencies than other institutional factors.

3.6 Causes of Economic Inefficiency

The early interest in economic efficiency centered on the question of whether small farmers of the Third World were economically rational and price responsive. This question is no longer seriously debated. Rather, economic efficiency should be viewed only as a standard by which to judge resource productivity against its potential. As such, interest now centers on *system inefficiencies* that cause resource productivity to fall below its potential. Technical inefficiency due to inappropriate timing and method of using an input is likely to reflect inadequate information and technical skills on the part of farmers. However, factors external to farmers such as untimely input supply may also be important in some cases (Ellis, 1988; Ghatak and Ingersent, 1984; Ali and Byerlee, 1991).

Allocative errors may also reflect inadequate information and skills, but other factors such as risk aversion, capital constraints, and institutional constraints (e.g., tenancy) influence allocative efficiency. Moreover, interdependence of production and consumption decisions in farm households and failures in input markets are also expected to play an important role especially in determining optimum use of resources. Many of these factors, such as input market failures, are exogenous to the farmer. Even the failure to use the most efficient technique of production due to inadequate information suggests that the cost to the individual farmer of acquiring better information is greater than the benefits because of failure in information markets (Ellis, 1988; Ali and Byerlee, 1991). Therefore, the presence of inefficiency in resource use at the farm level is not inconsistent with the rationality of small farmers.

3.7 Approaches to Efficiency Measurement

The measurement of production efficiency has been highly recognized as an important exercise in view of its relevance for policy makers in showing whether it is possible to increase output by simply increasing the efficiency of the firm without substantial additional resources. The methodologies for examining the production efficiency of farmers can generally be grouped into four different broad categories: the average factor productivity estimates; the linear programming approach; the production function approach; and the profit function methodology. The simplest measure of efficiency is the partial or average productivity index. This approach is an unsatisfactory measure since it ignores the presence of other factors, which affect average or marginal productivity and considers only one input at a time.

A simple comparison of total factor productivity is not a satisfactory efficiency indicator because farm households differ with respect to factor proportions, subsistence needs, and off-farm income opportunities, all of which have an impact on the revenue obtainable from a given resource endowment (de Haen and Runge-Metzger, 1989). The attempts to overcome this shortcoming led to the development of total factor productivity indexes in which a weighted average of inputs was compared with average output. The profit function approach is also seriously criticized because of its assumption of profit maximization as the given objective in the allocation process (Ellis, 1988). Farmers' objectives may not necessarily be that of profit maximization. Utility maximization or minimizing risk could be important factors influencing farmers' decision making.

The conventional production function approach is the most widely used measure in the analysis of production efficiency of farmers. The traditional approach is to estimate an average production function by a statistical technique such as least squares. Average production functions have received far more attention for the simple statistical reason that the mean of the error terms is zero. This is, however, not consistent with the definition of the production function.

Thus finding a measure of technical efficiency that is consistent with the definition of production function has been a major concern for many researchers. The production technology is represented by the transformation (production) function that defines the maximum attainable outputs from different combinations of inputs. Alternately, if considered from an input orientation side, it describes the minimum amount of inputs required to achieve a given output level. In other words, the production function describes a boundary or a frontier.

Given the definition of a production function, interest has then centered more on specifying and locating the production frontier. Alternative production models have often been proposed and the frontier model is one of these models and there seems to be a consensus in the recent literature on production function estimation that the production frontier rather than the average production function corresponds to the theoretical notions of the production function. Farrell (1957) had been the pioneer who introduced the frontier measure of efficiency, which reflects actual firm performances, and can include all relevant factors of production and is consistent with the textbook definition of the production function.

The frontier production function approach has some obvious advantages over the traditional methodologies and its use has therefore become widespread. The primary advantage of the method is that it is more closely related to the theoretical definition of a production function, which relates to the maximum output attainable from a given set of inputs. The second advantage of the method lies in the fact that estimates of technical efficiency of a firm in the sample may be obtained by comparing the observed output with the predicted (or attainable) output. Deviations from the frontier have acceptable interpretations as measures of the inefficiency of economic units. This approach provides a benchmark against which one can measure the relative efficiency of a firm. The production frontier is, however, unknown and it has to be empirically constructed from observed data in order to compare the position of a firm or a farm relative to the frontier. Several methods have been developed for the empirical measurement of frontier models. The different methods that are developed to estimate the frontier production function can be categorized based on certain major criteria (Assefa, 1995). First, based on the way the frontier is specified, the frontier may be specified as a parametric function or as a non-parametric function. Second, based on the way the frontier is estimated, the frontier may be estimated either through programming techniques or through the explicit use of statistical procedures. Third, based on the way the deviations from the frontier are interpreted, deviations may be interpreted simply as inefficiencies or they could be treated as mixtures of inefficiency and statistical noise.

3.7.1 Deterministic Frontiers

3.7.1.1 Non-parametric Programming

Farrell's (1957) original work formed the basis of the non-parametric programming method with subsequent extensions of his work by Charnes et al. (1978) and Färe et al. (1985) giving rise to what is often referred to as Data Envelopment Analysis (DEA). In this approach, technical efficiency is defined as the minimum input for any particular combination of outputs. Farrell's original approach of computing the efficiency frontier as a convex hull in the input coefficient space was generalized to multiple outputs. This was reformulated into calculating the individual input saving efficiency measures by solving a linear programming (LP) problem for each unit by Charnes et al. (1978) under the constant returns to scale assumption. Färe et al. (1985), Banker et al. (1984), and Byrnes et al. (1984) extended this approach to the case of variable returns to scale and developed corresponding efficiency measures.

DEA is a nonparametric approach to distance function estimation (Färe et al., 1994). The method involves the use of linear programming to construct a piecewise linear envelopment frontier over the data points such that all observed points lie on or below the production frontier. Let X be a $K \times N$ matrix of inputs, which is constructed by placing the input vectors, x_i, of all N firms side by side, and Y denotes the $M \times N$ output matrix which is formed in an analogous manner.

The output oriented variable returns to scale DEA frontier is defined by the solution to N linear programs of the form

$$\begin{aligned} &\min_{\theta,\lambda} \quad \theta \\ &\text{subject to} \quad -y_i/\theta + Y\lambda \geq 0 \\ &\qquad x_i + X\lambda \geq 0 \\ &\qquad N1'\lambda = 1 \\ &\qquad \lambda \geq 0, \end{aligned} \tag{3.1}$$

where $N1$ is an $N \times 1$ vector of 1s, λ is an $N \times 1$ vector of weights, and θ is the output distance measure. We note that $0 \leq \theta \leq 1$ and that $1/\theta$ is the proportional expansion in outputs that could be achieved the ith firm, with input quantities held constant.

In a similar manner, the input-orientated variable returns to scale DEA frontier is defined by the solution to N linear programs of the form

$$\begin{aligned} &\max_{\rho,\lambda} \rho \\ &\text{subject to} \quad -y_i + Y\lambda \geq 0 \\ &\qquad x_i/\rho - X\lambda \geq 0 \\ &\qquad N1'\lambda = 1 \\ &\qquad \lambda \geq 0, \end{aligned} \tag{3.2}$$

where ρ is the input distance measure. We note that $1 \leq \rho \leq \infty$ and that $1/\rho$ is the proportional reduction in inputs that could be achieved by the ith firm, with output quantities held constant.

The technical efficiency measure under constant returns to scale, also called the 'overall' technical efficiency measure, is obtained by solving N linear programs of the form

$$\begin{aligned} &\min_{\theta_i^{\mathrm{CRS}}} \theta_i^{\mathrm{CRS}} \\ &\text{subject to } -Y\lambda + y_i \leq 0 \\ &\qquad\qquad \theta_i^{\mathrm{CRS}} x_i - X\lambda \geq 0 \\ &\qquad\qquad \lambda \geq 0 \end{aligned} \tag{3.3}$$

where θ_i^{CRS} is a technical efficiency measure of the ith firm under constant returns to scale and $0 \leq \theta_i^{\mathrm{CRS}} \leq 1$. The output and input oriented models will estimate exactly the same frontier surface and, therefore, by definition, identify the same set of firms as being efficient. The efficiency measures may, however, differ between the input and output orientations. Under the assumption of constant returns to scale, the estimated frontier and the efficiency measures remain unaffected by the choice of orientation (Coelli and Perelman, 1999).

Farrell (1957) used an input-oriented approach to illustrate the measurement of efficiency. He used a simple example involving firms which use two inputs, X_1 and X_2, to produce a single output Y, under the assumption of constant returns to scale. The constant returns to scale assumption allows representing the technology using a unit isoquant. Farrell discussed the extension of his method so as to accommodate more than two inputs. Knowledge of the unit isoquant of the fully efficient firm, represented by TT′ in Figure 3.1, permits the measurement of technical efficiency. If a given firm uses quantities of inputs, defined by the point K, to produce a unit of output, the technical inefficiency of that firm could be represented by the distance YK, which is the amount by which all inputs could be proportionally reduced without a reduction in output. This is usually expressed in percentage terms by the ratio YK/OK, which represents the percentage by which all inputs could be reduced.

The technical efficiency (TE) of a firm operating at K is measured by the ratio TEk = OY/OK, which is equal to one minus YK/OK. TEk will take a value between zero and one, and hence provides an indicator of the degree of technical inefficiency of the firm. A value of one indicates the firm is fully technically efficient. For example, the point Y is technically efficient because it lies on the efficient isoquant.

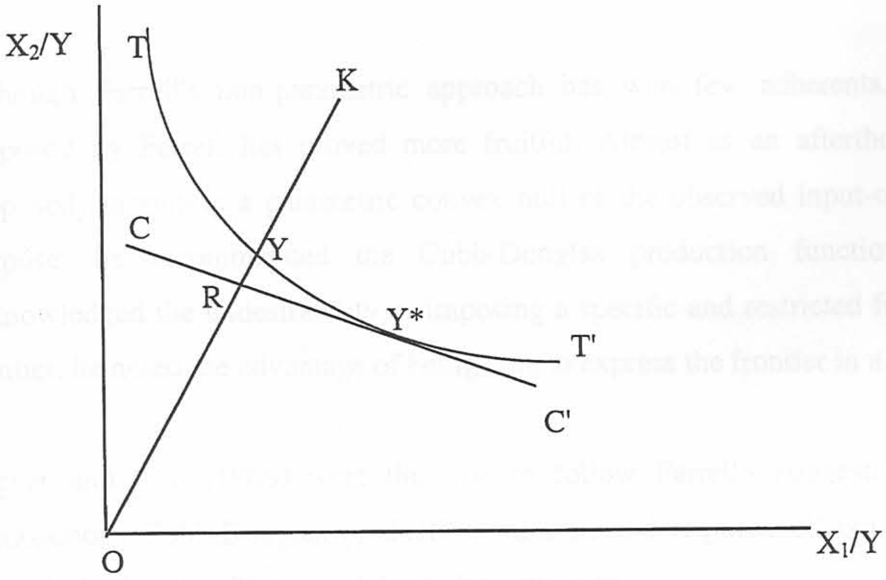

Figure 3.1: Farrell's Measure of Technical and Allocative Efficiencies

Farrell has also demonstrated that the unit isoquant provides a set of standards for measuring allocative efficiency. The isocost line CC′ gives the minimum cost of producing one unit of output given relative input prices. The allocative efficiency (AE) of the firm operating at K is defined to be the ratio, AEk = OR/OY, since the distance RY represents the reduction in production costs that would occur if production were to occur at the allocatively (and technically) efficient point Y*, instead of at the technically efficient but allocatively inefficient point Y. The total economic efficiency (EE) is defined to be the ratio, EEk = OR/OK, where the distance RK can also be interpreted in terms of a cost reduction. Thus, the product of technical and allocative efficiency provides the overall economic efficiency measure.

On the whole, the principal advantage of the non-parametric approach to technical efficiency measurement is that no functional form is imposed on the data. The principal disadvantage is that the frontier is computed from a supporting subset of observations from the sample and is therefore particularly susceptible to extreme observations and measurement errors. A second disadvantage of the approach is that the process of resource allocation to achieve better output is never explicitly used in the model. A third disadvantage of the approach is that estimated functions have no statistical properties, and hence the estimated production frontier has no statistical properties to be evaluated upon.

3.7.1.2 Parametric Programming

Although Farrell's non-parametric approach has won few adherents, a second approach proposed by Farrell has proved more fruitful. Almost as an afterthought, Farrell (1957) proposed computing a parametric convex hull of the observed input-output ratios. For this purpose, he recommended the Cobb-Douglas production function. Although Farrell acknowledged the undesirability of imposing a specific and restricted functional form on the frontier, he noted the advantage of being able to express the frontier in a mathematical form.

Aigner and Chu (1968) were the first to follow Farrell's suggestion. They specified a homogenous Cobb-Douglas production frontier, and required all observations to be on or beneath the frontier. Their model may be written as

$$\ln Y_i = \ln f(X_i;\beta) - u_i , \tag{3.4}$$

where Y_i is the output of the i^{th} firm, X_i is the input of the i^{th} firm and u_i is a one-sided disturbance term. The one-sided error term forces $Y \leq f(X)$. The elements of the parameter vector β may be estimated either by linear programming (i.e., minimizing the sum of the absolute values of the residuals, subject to the constraint that each residual be non-positive) or by quadratic programming (i.e., minimizing the sum of squared residuals, subject to the same constraint). The authors suggested that minimization of the sum of absolute deviations, $\sum_{i=1}^{n} |Y_i - f(X_i;\beta)|$, subject to $Y \leq f(X_i;\beta)$, which is a linear programming problem if $f(X_i;\beta)$ is linear in β. This is equivalent to minimization of the one-sided error term, u_i. Alternatively, they suggested minimization of the sum of squared deviations, $\sum_{i=1}^{n} [Y_i - f(X_i;\beta)]^2$, subject to the same constraint, which is a quadratic programming problem if $f(X_i;\beta)$ is linear in β. Although Aigner and Chu (1968) did not do so, the technical efficiency of each observation can be computed directly from the vector of residuals, since u_i represents technical inefficiency.

The principal advantage of the parametric deterministic approach vis-à-vis the non-parametric approach is the ability to characterize frontier technology in a simple mathematical form. However, the mathematical form may be too simple. The parametric approach imposes a structure on the frontier that may be unwarranted. The restrictive homogenous Cobb-Douglas specification has been relaxed by Forsund and Jansen (1977) and Forsund and Hajlmarsson (1979), among others. The parametric approach often imposes limitations on the number of observations that can be technically efficient. In the homogenous Cobb-Douglas case, for example, when the linear programming algorithm is used, there will, in general, be only as many technically efficient observations as there are parameters to be estimated. As was the case with the non-parametric frontier, the estimated frontier is supported by a subset of the data and is therefore extremely sensitive to outliers. One possibility suggested by Aigner and Chu (1968) and implemented by Timmer (1971) was essential just to discard a few observations. This has led to the development of the so-called probabilistic frontiers, which are estimated by the type of mathematical programming techniques discussed above, except that some specified proportion of the observations is allowed to lie above the frontier. The selection of this proportion is essentially arbitrary, lacking any explicit economic or statistical justification. If the rate of change of the estimates with respect to succeeding deletions of observations diminishes rapidly, this suggestion will be useful.

A final problem with this approach is that the estimates which it produces have no statistical properties. That is, mathematical programming procedures produce estimates without standard errors, *t*-ratios, and so forth. Basically this is because no assumptions are made about the regressors or the disturbance term in equation (3.4), and without some statistical assumptions inferential results cannot be obtained.

3.7.1.3 Statistical Frontier

The shortcomings of the programming approaches have led to the further development of the deterministic statistical frontiers. The statistical frontier models are similar to the deterministic programming frontier model. The deterministic statistical model involves statistical techniques and assumptions to be made about statistical properties.

The model of the previous section can be made amenable to statistical analysis by introducing some assumptions. Note that the model in equation (3.4) can be written as

$$Y = f(X)e^{-u} \tag{3.5}$$

or

$$\ln Y = \ln f(X) - u, \tag{3.6}$$

where $u \geq 0$ and thus $0 \leq e^{-u} \leq 1$, and where ln *f*(*X*) is linear in the Cobb-Douglas case presented in equation (3.4). The question that must be asked is what to assume about *X* and u. The answer that has been given most often is to assume that the observations on u are independently and identically distributed, and that *X* is exogenous. Any number of distributions for u could be specified. Aigner and Chu (1968) did not explicitly assume such a model, though it seems clear that it was assumed implicitly. Afriat (1972) was the first to explicitly propose this model. He proposed a two-parameter beta distribution for $\exp(-u)$, and proposed that the model to be estimated by the maximum likelihood method. This amounts to a gamma distribution for u, as considered further by Richmond (1974). On the other hand, Schmidt (1976) has shown that if u is exponential, then Aigner and Chu's linear programming procedure is maximum likelihood, while their quadratic programming procedure is maximum likelihood if u is half-normal. It should be stressed that the choice of a distribution for u is important because the maximum likelihood estimates depend on it in a fundamental way - different assumed distributions lead to different estimates. This is a problem because there do not appear to be good a priori arguments for any particular distribution.

A further problem with maximum likelihood in the frontier setting is that the range of the dependent variable (output) depends on the parameters to be estimated, as pointed out by Schmidt (1976). This is because Y ≤ *f*(*X*) and *f*(*X*) involve the parameters to be estimated. This violates one of the regularity conditions invoked to prove the general theorem that maximum likelihood estimators are consistent and asymptotically efficient. As a result, the statistical properties of the maximum likelihood estimators needed to be reconsidered. This is done by Greene (1980) who showed that the usual desirable asymptotic properties of maximum likelihood estimators still hold if the density of u is zero at $u = 0$ and the derivative of the density of u with respect to its parameters approaches zero as u approaches zero. As noted by Greene (1980), the gamma density satisfies this criterion and is thus potentially useful here. However, it is a little troubling that one's assumption about the distribution of technical inefficiency should be governed by statistical convenience.

There is also an alternative method of estimation, first noted by Richmond (1974), based on the ordinary least squares results, which is called corrected OLS (COLS). Suppose equation (3.6) is linear (Cobb-Douglas). Then, in the first step, OLS is used to obtain consistent and unbiased estimates of the slope parameters and a consistent but biased estimate of the intercept parameter. In the second step the biased OLS intercept $\hat{\beta}_0$ is shifted up ("corrected") to ensure that the estimated frontier bounds the data from above. The COLS intercept is estimated consistently by

$$\hat{\beta}_0^* = \hat{\beta}_0 + \max(\hat{u}_i), \tag{3.7}$$

where the $\hat{u}_i$ are the OLS residuals. The OLS residuals are corrected in the opposite direction, and so

$$-\hat{u}_i^* = \hat{u}_i - \max(\hat{u}_i). \tag{3.8}$$

The COLS residuals $\hat{u}_i^*$ are nonnegative, with at least one being zero, and can be used to provide consistent estimates of the technical efficiency of each producer by means of $\mathrm{TE}_i = Exp(-\hat{u}_i^*)$.

The COLS technique is easy to implement, and generates an estimated production frontier that lies on or above the data. However, this simplicity comes at a cost: The estimated production frontier is parallel to (in natural logarithms of the variables) to the OLS regression, since only the OLS intercept is corrected. This implies that the structure of "best practice" production technology is the same as the structure of the "central tendency" production technology (Kumbhakar and Lovell, 2000). This is an undesirably restrictive property of the COLS procedure, since the structure of best practice production technology ought to be permitted to differ from that of production technology down in the middle of the data, where producers are less efficient than best practice producers.

3.7.2 The Stochastic Frontier Production Function

The stochastic frontier production model represents an improvement over the traditional average production function and over the deterministic functions, which use mathematical programming to construct production frontiers. The notion of a deterministic frontier shared by all firms ignores the possibility that a firm's performance may be affected by factors entirely outside its control such as bad weather and input supply breakdowns as well as by factors under its control (i.e., technical inefficiency). To lump up the effects of exogenous shocks, both favorable and unfavorable, together with the effects of measurement errors and inefficiency into a single one-sided error term, and to label the mixture inefficiency is a problem with the deterministic frontiers.

According to Forsund et al. (1980) this conclusion is reinforced if one considers also the statistical noise that every empirical relationship contains. The standard interpretation is that, first, there may be measurement errors on the dependent variables. Second, the equation may not be completely specified, with the omitted variables individually unimportant. Both of these arguments hold just as well for production functions as for any other kind of equation, and it is dubious at best not to distinguish this noise from inefficiency, or to assume that noise is one-sided. These agreements lie behind the stochastic frontier (also called composed error) model developed independently by Aigner et al. (1977) and Meeusen and van den Broeck (1977). The essential idea behind the stochastic frontier model is that the error term is composed of two parts. A symmetric component permits random variation of the frontier across firms, and captures the effects of measurement error, other statistical noise, and random shocks outside the firm's control. A one-sided component captures the effects of inefficiency relative to the stochastic frontier.

The stochastic production function considered is defined as (Battese, 1992)

$$Y_i = f(X_i;\beta)\exp(\varepsilon_i), \tag{3.9}$$

where Y_i is total output of the i^{th} firm; $f(X_i;\beta)$ is a suitable function of the inputs vector X_i; β is a vector of unknown parameters; and ε_i is a random variable whose distributional properties are defined below.

The residual random variable, ε_i, in the production function of equation (3.9) is defined by

$$\varepsilon_i = v_i - u_i, \tag{3.10}$$

where v_i's are assumed to be independently and identically distributed as a normal random variable with mean zero and variance σ^2_v [i.e., $v_i \sim N(0, \sigma^2_v)$], and independent of the u_i's, which are assumed to be non-negative truncations of the normal distribution with mean, μ, and variance, σ_u^2 , [i.e., $u_i \sim N|(\mu, \sigma_u^2)|$], and μ, σ_u^2 and σ^2_v are unknown parameters to be estimated. The variance of ε is given by $\sigma^2 = \sigma_u^2+\sigma^2_v$. The decomposition of the residual random variable, ε_i, in the production function (3.9), as specified in equation (3.10), is the decisive property which defines the stochastic frontier production function. The first term, v_i, is a random error which is assumed to be involved in the traditional linear regression allowing for the random variation of production across farms, and captures the effects of statistical noise, measurement errors, and the exogenous shocks beyond the control of the producing unit. The mean of this random error term is zero. The second term, u_i, is a non-negative firm effect variable, which is assumed to account for the existence of technical inefficiency of production of the i^{th} firm. The mean of the firm effect term is zero for a half-normally truncated distribution. If u_i=0, production lies on the stochastic frontier and is technically efficient; if u_i>0, production lies below the frontier and is inefficient. If the firm effect random term u_i is absent from the model, equation (3.9) becomes an average production function used in most econometric studies. Alternatively, if the random disturbance v_i is absent from equation (3.9), the model reduces to a deterministic frontier often estimated by linear programming techniques.

The economic logic behind equation (3.9) is that the production process is subject to two economically distinguishable random disturbances, with different characteristics. The non-negative firm effect u_i reflects the fact that each firm's output lies on or below its frontier. Any such deviation is the result of factors under the firm's control, such as technical and economic inefficiency, the will and effort of the producer and employees. The condition that $u_i \geq 0$ forces that all observations lie on or beneath the stochastic production frontier. The economic meaning of the one sided u_i component is that each firm's production must lie either on or below the production frontier. Any downward deviation from the frontier is due to technical inefficiency for the firm. If these inefficiencies could be eliminated, the firm would produce on the frontier. The error term u_i then represents technical inefficiency in the production process. But the frontier itself can vary randomly across firms, or over time for the same firm. According to this interpretation the frontier is stochastic, with random disturbance $-\infty \leq v_i \leq \infty$ being the result of favorable as well as unfavorable external events such as luck, climate, and topography.

The other important issue in stochastic frontier models is the assumption about u_i. Any number of one-sided distributions exist, which could plausibly be assumed to represent the distribution of the shortfall of output from the frontier. Aigner et al. (1977) considered half-normal and exponential distributions, while Meeusen and van den Broeck (1977) considered exponential ones. Other possibilities include gamma (Richmond, 1974) and lognormal (Greene, 1980). In most empirical research, however, the error term u_i is usually assumed to follow one of the following three distributions (Lee, 1983; Schmidt and Lin, 1984; Bauer, 1990): (1) half-normal $u_i \sim |N(0, \sigma_u^2)|$; (2) truncated normal at zero (μ, σ_u^2); (3) exponential EXP (μ, σ_u^2), where EXP indicates exponential distribution. Exponential is identical to the half-normal case, except that the technical inefficiency term u_i is assumed to follow the one-parameter exponential distribution. The result is similar to that for the half-normal (Jondrow et al., 1982). Greene (1990), however, also offered a two-parameter gamma distribution model.

Because of the ease of estimation and interpretation and the fact that technical efficiencies are in most cases similar for each distribution, there is a tendency by researchers to use the half-normal and truncated normal distributions. In addition, standard tests for distribution selection are not available. According to Lee (1983) since there are no a priori arguments for the choice of a particular distribution, one needs to base the choice and evaluation on statistical means. Lee (1983) proposed a Lagrange-Multiplier test to assess different distributions for the inefficiency term.

With the specifications (3.9) and (3.10), a measure of each firm's technical efficiency can be defined as

$$\mathrm{TE}_i = \frac{Y_i}{f(X_i; \beta)\exp(v_i)}, \tag{3.11}$$

where TE_i is technical efficiency for the i^{th} firm. As v_i is unobservable, (3.11) is not estimable. In other words, measurement of firm-specific technical efficiency requires first the estimation of the non-negative error u_i, that is the decomposition of ε_i into two individual components, u_i and v_i. Jondrow et al. (1982) suggested a technique for this decomposition using the conditional distribution of u_i given the total disturbance ε_i.

Following Jondrow et al. (1982) and adopting Battese and Corra's (1977) parameterization, the firm specific technical efficiency estimate can be derived from the conditional distribution of u_i given ε_i. The technical efficiency of the i^{th} firm is then given by

$$\mathrm{E}(u_i/\varepsilon_i) = \frac{\sigma_u\sigma_v}{\sigma}\left[\frac{f(.)}{1-F(.)} - \frac{\varepsilon_i}{\sigma}\left(\frac{\gamma}{1-\gamma}\right)^{1/2}\right] \tag{3.12}$$

where ε_i are estimated residuals for each farmer and $f(.)$ and F(.) are the values of the standard normal density function and standard normal distribution function, respectively, evaluated at $\frac{\varepsilon_i}{\sigma}\left(\frac{\gamma}{1-\gamma}\right)^{1/2}$. The maximum likelihood estimation of equation (3.9) yields estimators for β and γ where $\gamma = \frac{\sigma_u^2}{\sigma^2}$ and $\sigma^2 = \sigma_u^2 + \sigma_v^2$. γ explains the total variation of output from the frontier which can be attributed to technical inefficiency and lies between zero and one. The estimates of u_i and v_i can be obtained after replacing ε_i, σ and γ by their estimates. Hence, individual technical efficiency can be measured as $\mathrm{TE}_i = \exp(-\mathrm{E}(u_i/\varepsilon_i))$ which represents the level of technical efficiency of the i^{th} firm relative to the frontier firm.

More recent developments in frontier methodology include multi-equation models based on production, cost or profit function specifications. Coelli (1995) provides a review of these and other recent extensions of the stochastic frontier approach that take advantage of panel data structures. A major advantage of panel data models is that there is no longer need to assume that inefficiency is independent of the regressors. In addition, these models do not restrict the efficiency term to follow a specific distribution for the inefficiency term while making these restrictions testable propositions.

3.7.3 Stochastic Frontier Efficiency Decomposition

All the models discussed so far are only appropriate for measuring technical efficiency per se. The measurement of technical, allocative, and economic efficiency can only be handled, in a stochastic frontier framework, through the efficiency decomposition technique. The stochastic efficiency decomposition methodology was proposed by Bravo-Ureta and Rieger (1991), which was an extension of the model introduced by Kopp and Diewert (1982) to decompose cost efficiency into technical and allocative efficiency measures. Stochastic efficiency decomposition is generally based on the duality between production and cost functions.

Bravo-Ureta and Rieger (1991) utilize the level of output of each firm adjusted for statistical noise, observed input ratios, and the parameters of the stochastic frontier production function (SFPF) to decompose overall efficiency into technical and allocative efficiency. The parameters of the SFPF are actually used to derive the parameters of the dual cost function. Let the SFPF be redefined in its original form (e.g., Aigner et al., 1977) as

$$Y_i = f\left(X_i;\beta\right) + v_i - u_i . \qquad (3.13)$$

If v_i is now subtracted from both sides of equation (3.13), we obtain

$$Y_i^* = f\left(X_i;\beta\right) - u_i = Y_i - v_i , \qquad (3.14)$$

where Y_i^* is the i^{th} firm's observed output adjusted for the statistical noise captured by v_i, $f(\cdot)$ is the deterministic frontier output, and u and v are, respectively, the inefficiency and random components of overall deviations from the frontier. Adjusted output Y^* is used to derive the technically efficient input vector, X^t. The technically efficient input vector for the i^{th} firm, X_i^t, is derived by simultaneously solving equation (3.14) and the observed input ratios $\frac{x_1}{x_i} = k_i (i > 1)$ where k_i is equal to the observed ratio of the two inputs in the production of Y_i^*. The technically efficient input vectors form the basis for deriving the technical efficiency measures by taking ratios of the vector norms of the efficient and observed input quantities while the adjusted output is used to derive allocative and economic efficiencies employing the dual cost frontier function that is analytically derived from the SFPF.

Assuming that the production function in equation (3.9) is self-dual (e.g., Cobb-Douglas), the dual cost frontier can be derived algebraically and written in a general form as

$$C_i = h(W_i, Y_i^*; \delta), \tag{3.15}$$

where C_i is the minimum cost of the k^{th} firm associated with output Y_i^*, W_i is a vector of input prices for the i^{th} firm, and δ is a vector of parameters to be estimated. The economically efficient input vector for the i^{th} firm, X_i^e, is derived by applying Shephard's Lemma and substituting the firm's input prices and adjusted output level into the resulting system of input demand equations

$$\frac{\partial C_i}{\partial W_n} = X_n^e(W_i, Y_i^*; \theta), \tag{3.16}$$

where θ is a vector of parameters, $n = 1, 2, \ldots\ldots, N$ inputs. The observed, technically efficient, and economically efficient costs of production of the i^{th} firm are equal to $W_i'X_i$, $W_i'X_i^t$, $W_i'X_i^e$, respectively. These cost measures are used to compute technical (TE) and economic efficiency (EE) indices for the i^{th} firm as

$$\mathrm{TE}_i = \frac{W_i' X_i^t}{W_i' X_i} \tag{3.17}$$

and

$$\mathrm{EE}_i = \frac{W_i' X_i^e}{W_i' X_i}. \tag{3.18}$$

Following Farrell (1957), the allocative efficiency (AE) index can be derived from equations (3.17) and (3.18) as

$$AE_i = \frac{W_i' X_i^e}{W_i' X_i^t}. \tag{3.19}$$

3.8 Empirical Applications of Production Frontiers

Frontier production function models have been applied in a considerable number of empirical studies both in agriculture and non-agricultural sectors since the pioneering work of Farrell (1957). Farrell's notion of an efficient unit isoquant provided a standard based on best results in practice, from which to gauge the efficiency of any sample observation. Recently, there have been increasing concerns about assessing the relative technical efficiency/inefficiency of firms, or the ability of firms to produce maximum output with a given set of inputs and technology.

A number of empirical works since Farrell's (1957) seminal paper used deterministic frontier production functions to analyze technical efficiency (e.g., Timmer, 1971; Russell and Young, 1983; Shapiro, 1983; Mijindadi and Norman, 1984; de Haen and Runge-Metzger, 1989; Ekayanake and Jayasuriya, 1987; Ali and Chaudhry, 1990; Saito, 1994; Getachew, 1995; Llewelyn and Williams, 1996). While the results of most of these studies indicated the existence of substantial inefficiencies of production, some of these studies actually found no evidence of significant inefficiencies among farmers and suggested that opportunities for inexpensive production gains through efficiency improvement are minimal. Analyses of technical efficiency of farmers in Tanzania (Shapiro, 1983), Punjab (Ali and Chaudhry, 1990), Ghana (de Haen and Runge-Metzger, 1989), Ethiopia (Getachew, 1995), Nigeria (Mijindadi and Norman, 1983), Kenya (Saito, 1994), England (Russell and Young, 1983), and Sri Lanka (Ekayanake and Jayasuriya, 1987) showed existence of considerable inefficiency ranging from 15 percent in Pakistan to 50 percent in Sri Lanka. On the other hand, studies of technical efficiency of US agriculture (Timmer, 1971) and East Java of Indonesia (Llewelyn and Williams, 1996) indicated very low levels of inefficiency, suggesting that the welfare losses are small and thus the expansion of agricultural output through improving production efficiency are limited.

Since the introduction of the stochastic frontier models (Aigner et al., 1977; Meeusen and van den Broeck, 1977), considerable applications of the stochastic frontier production, cost, and profit function models to both agricultural and non-agricultural production have been documented (e.g., Kalirajan and Shand, 1988; Parikh and Shah, 1994; Kumbhakar, 1994; Assefa, 1995; Parikh et al., 1995; Kumbhakar and Heshmati, 1995; Sharif and Dar, 1996; Ali, 1996; Getu et al., 1998; Seyoum et al., 1998). While only Parikh and Shah (1994) obtained insignificant technical inefficiencies, on average, of 4 percent among farmers in the North-West province of Pakistan, the rest of the studies obtained high levels of inefficiencies and hence proved the existence of considerable opportunities for output growth through efficiency improvement in other developing countries. Parikh and Shah (1994) identified lack of education, restricted credit and fragmented holdings as the causes of technical inefficiency and recommended policies which consolidate holdings, provide credit or educate farmers as these factors would tend to improve efficiency.

Kumbhakar (1994) estimated the technical efficiency of farms in West Bengal in India and obtained a mean technical inefficiency of 24 percent. While Kumbhakar and Heshmati (1995) analyzed the technical efficiency of Swedish dairy farms and found a mean technical inefficiency of 15 percent, Ali (1996) analyzed the technical efficiency of farmers in Nepal and obtained an average resource-use inefficiency of 25 percent. Ali (1996) also found poor land preparation, crop disease, off-farm work, and plot distance to have a negative impact on technical efficiency of wheat farmers. Assefa (1995) and Getu et al. (1998) used the Cobb-Douglas stochastic frontier model to analyze the technical efficiency of smallholder agriculture in central and eastern Ethiopia, respectively. While Getu et al. (1998) obtained higher average technical inefficiency of 32 percent, Assefa (1995) obtained average technical inefficiencies of 12 percent, confirming the regional variation in farmers' efficiency of production and also the higher technical efficiency among farmers in the relatively modern agricultural areas such as the central highlands. Assefa (1995) found that education, number of oxen, time of fertilizer delivery, farming experience, credit availability, distance from market center, farm size, and extension contact are important factors influencing technical efficiency.

Applications of the stochastic frontier models included that of comparison of the efficiencies of farmers across crop varieties. Sharif and Dar (1996), for example, studied the technical efficiency of farmers in the cultivation of traditional and high-yielding varieties of rice. They found that the overall yield variability in high-yielding varieties cultivation was due to technical inefficiency, while the opposite was true for traditional crops where random factors accounted for much of yield variability. Sharif and Dar (1996) also found that household characteristics such as educational level, growing experience, and farm size are associated with the technical efficiency differentials. Kalirajan and Shand (1988) analyzed the level and causes of technical efficiency of farmers in Southern India operating under rain-fed cultivation and obtained average inefficiencies of 35, 28, and 32 percent in the production of rice-1, corn, and rice-2, respectively. Kalirajan and Shand, in addition, examined the sources of technical efficiency differentials and found that while rice production efficiency is influenced by farming experience and extension officials' visits, corn production, on the other hand, appeared to be highly dependent on financial availability. On the basis of the analysis, Kalirajan and Shand concluded that a mere choice of high-yielding technology is not sufficient to increase the production of rice. What is important is the proper use or application of the technology.

The frontier models have also been used to evaluate the performance of different development programs. The effectiveness of a world bank-sponsored agricultural credit program as a tool for improving the agricultural productivity and income of the traditional farmers in Brazil was examined by assessing the technical and allocative efficiency of farmers who participated in the credit program vis-à-vis a comparable group of non participating farmers by Taylor et al. (1986). Since there was no significant difference between the technical and allocative efficiency of the two groups, the authors concluded that the agricultural credit program did not bring any significant impact on the efficiencies of the participating farmers. Seyoum et al. (1998) also investigated the technical efficiency of two samples of maize producers in eastern Ethiopia, one involving farmers within the SG project and the other involving farmers outside this program. The study used the Cobb-Douglas stochastic frontier production function in which the technical inefficiency effects are assumed to be functions of age, education, and extension. They found that farmers within the SG project are more technically efficient than farmers outside the project, relative to their respective technologies. Moreover, for farmers within the project, extension and education were found to have a positive and significant effect on technical efficiency while age has a negative influence. For farmers outside the project, extension and age were found to have a negative influence while education had no influence at all.

The stochastic efficiency decomposition technique has also been applied by a couple of authors to estimate the technical, allocative, and economic efficiency of farmers. For instance, Xu and Jeffrey (1998) obtained significantly lower technical, allocative, and economic efficiency indices for hybrid rice production in China as compared with conventional rice production across all the three regions studied. Singh et al. (2000) obtained lower technical, allocative, and economic efficiency for newly established Indian dairy processing plants after liberalization of the dairy industry compared to the old plants as they needed time to reach full operation, the right choice of products and other managerial skills required for higher performance.

Ali and Chaudhry (1990) estimated the mean technical, allocative, and economic efficiency measures for crop production in Pakistan at 84, 61, and 51 percent, respectively, while the corresponding measures for dairy farms in the USA were 83, 85, and 70 percent (Bravo-Ureta and Rieger, 1991). The average technical, allocative, and economic efficiency measures for crop-livestock farmers in Brazil were 17, 74, and 13 percent, respectively (Taylor et al., 1986), while the corresponding estimates for swine producers in Hawaii were 75.9, 80.3, and 60.3 percent, respectively (Sharma et al., 1999). Bravo-Ureta and Evenson (1994) obtained the three measures for cotton and cassava production. The average technical, allocative, and economic efficiency measures for cotton production were 58, 70, and 40 percent, respectively, while the corresponding figures for cassava were 59, 88, and 52 percent, respectively. Singh et al. (2000) also obtained average technical, allocative, and economic efficiency measures, respectively, of 86.7, 84.4, and 72 percent for Indian private dairy processing plants while the corresponding figures for the cooperative dairy processing plants were 87.4, 90.4, and 78.8 percent, showing that the new private dairy processing plants were less efficient than the old cooperative plants. All these studies indicated the existence of considerable potential within the farms to increase production through improved technical, allocative, and economic efficiency.

This study employs an extended stochastic frontier efficiency decomposition technique that accounts for scale effects that are a source of substantial bias in efficiency measures obtained from the Bravo-Ureta and Rieger method. The stochastic efficiency decomposition technique allows us to estimate the technical, allocative, and economic efficiencies of farmers using our cross-sectional data. The details of the analytical framework are given in Chapter 5 where it is applied to smallholder farmers in Eastern Ethiopia.

CHAPTER 4

CASE STUDY AREA, SURVEY DESIGN, AND SELECTED SOCIO-ECONOMIC CHARACTERISTICS OF THE SAMPLE HOUSEHOLDS

4.1 Introduction

This study was conducted in Meta and Babile districts in East Hararghe Zone of Oromia Regional State in the eastern Ethiopian highlands. These districts were chosen for the study mainly based on availability of strong intervention (research and extension) programs embracing smallholder food grains producers and representativeness of distinct (wet highland and dry land) agro-climatic zones typical of most smallholder farming conditions in eastern Ethiopia. Meta and Babile districts adequately represent distinct agro-climatic zones for the analysis of efficiency of food production across agro-climatic zones. The New Extension Program is actively implemented in view of the importance of food grains production in these districts as opposed to many other districts where cash crop production especially khat[3] cultivation dominates, and competes with, the production of food crops.

In this chapter, an overview of the nature of the farming systems in the Hararghe highlands in general and in the case study areas in particular is given. The survey design, including sampling, sample size determination, data collection, and selected household and farm characteristics of the sample households are also presented and discussed.

4.2 The Hararghe Highlands

The Hararghe area is situated in the eastern part of Ethiopia, 200 to 400 kilometers (km) east of the capital city Addis Ababa, some 300 km south of Djibouti and 250 km west of Hargeisa towns. In the sub-regional context (Djibouti, Northwest Somalia, & East Ethiopia), Hararghe is the only highland area with adequate climatic conditions for rain-fed agriculture and a reasonably well developed transportation network by road, rail, and air. Hararghe thus enjoys

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[3] Khat (*Catha edulis*) is a perennial bush the leaves of which are chewed as stimulants. It is also the leading cash crop in East and West Hararghe (Storck et al., 1991, 1997).

a privileged position for food and cash crop production and marketing, with the trading potential still exceeding the actual production capacity.

The agro-climatic range includes lowland (*kolla*, 30-40 percent), midland (*weyna dega*, 35-45 percent) and highland areas (*dega*, 15-20 percent), with lowest elevations at around 1,000 meters above sea level (masl), culminating at 3,405 meters (m), at the top of Gara Muleta mountain. There are two rainy seasons and these are the short (*belg)* and the main (*meher)* seasons. Production during the *belg* season is limited within the *dega* zone and part of the wetter *weyna dega*, but *belg* rains are widely used for land preparation and seeding of long-cycle *meher* crops (sorghum & maize). Annual rainfall averages range from below 700 millimeters (mm) for the lower *kolla* to nearly 1,200 mm for the higher elevations of *weyna dega* and *dega* zones. The variability of rainfall from year to year and its uneven distribution during the growing seasons causes a wide range of climatic hazards which farmers have to deal with.

The main food staples include sorghum, maize, and sweet potatoes. Sweet potatoes are extensively cultivated during bad years to improve food security. Other food crops include barley, wheat, tef, and pulses. Cash crops like khat (a popular mild narcotic) and coffee have a long-standing tradition, complemented by Irish potatoes, onions/shallots and some other vegetables. They are mainly cultivated in the *weyna dega* zone, with some extension into the lower *dega* and exceptionally into *kolla* zones. The eastern lowlands such as Babile and to some extent the southern lowlands grow groundnut as a cash crop. Some twenty years ago, the lowlands of Mieso produced sesame, but their cultivation has stopped for climatic (and eventually economic) reasons, even though sesame is more tolerant to aridity than groundnuts. Climatic hazards are increasingly frequent in Hararghe, with pest infestations and crop diseases additionally hampering crop production

Increasing population density coupled with the lack of alternative employment opportunities leads to progressive land pressure and subsequent shrinking of individual landholdings. Likewise, arable land has to be used intensively, leaving practically no room for fallowing (Storck et al., 1997). Under actual conditions, crop rotation and fallow are no longer practiced and are rather dictated by climatic hazards. During a bad year, fallow will increase, especially in the lowlands, whereas the crops to be planted on individual plots will have to be chosen according to moisture availability and expected length of growing period. In this context, short cycle crops increasingly gain importance.

According to CSA (1997), 44 percent of farmers have landholdings not exceeding 0.5 hectares (ha) and 82 percent of farmers with landholdings less than 1 ha. Even if the accuracy of available data is questionable, they nevertheless reveal the actual trend where farmers' main capital besides labor and arable land is reaching a critical stage of fragmentation. The prevalence of extreme land pressure has already resulted in vast deforestation and the cultivation of unsuitable slopes in the highlands and midlands, causing severe environmental damage. In addition, considering the fact that with a population growth rate of around 3 percent, farm units are expected to double approximately every 20 years, future prospects in agriculture look very bleak.

The situation is further complicated by the multitude of very diverse farming systems, as practically every farmer follows his/her individual farm management strategy in terms of physical and human inputs and crop varieties. As a common trend, especially in *weyna dega* zones, taking advantage of the specific geographical situation, farmers respond to the worsening situation by progressively increasing their cash crop production in order to improve the performance of their farms in terms of cash value. The subsequent progressive shortage of staple food is made up for by the supply of cereals originating from neighboring surplus-producing areas of Arsi, Bale, and to a lesser extent East Shoa.

Farming systems in the eastern highlands consist of a number of interdependent cropping and livestock activities and they are strongly influenced by the respective natural and economic environment. They are to be described in terms of resource endowment, market orientation, major activities and location. Resource endowment is indicated by size and factor relations (intensity); major activities concern cropping pattern and crop rotations as well as animal husbandry; market orientation relates to the share of production for subsistence and cash; and location is determined by agro-climatic conditions, distance to markets and other indicators of the socio-economic environment (Storck et al., 1991).

Moreover, the farming systems in the eastern highlands of Ethiopia constitute complex production units involving a diversity of mixed crops and livestock in order to meet the multiple objectives of the household (Bezabih and Storck, 1992). The main features of the farming systems in the eastern highlands are summarized in Table 4.1. It is observed that land scarcity prevails in the region with land-labor ratios decreasing with altitude. Cropping patterns change with altitude though large cereals generally play an important role and intercropping is widely practiced. As the focus of this study is on food crops, the large cereals zones were selected. These included areas with altitudes ranging from 1300-2600 masl.

Table 4.1: Indicators of the farming systems in East Hararghe Zone

Altitude range (masl)	Land/labor (ha/ME*)	Livestock Unit (LU)	Share of cultivated area (percent)				Intercropping index (percent)
			Coffee	Large cereals	Pulse	Oil crops	
1301-1700	1.36	3.64	0.8	68	0	9.8	37
1701-2200	0.8	2.73	1.4	67	1	0.3	45
2201-2600	0.56	1.47	0.3	50	0	0.5	25
Total	0.94	2.92	1.1	66	1	3.1	41

Note: ME = man equivalents

Source: Bezabih and Storck (1992).

4.3 Description of the Case Study Areas

The study areas, Babile and Meta districts, are located in East Hararghe Zone (Map 4C) in the eastern Highlands of Ethiopia. Oromia is one of the Regional States of Ethiopia (Map 4A) and East Hararghe is one of its administrative zones (Map 4B). Meta is located in eastern Oromia at about 435 km from Addis Ababa and 90 km west of Alemaya University. The average altitude is about 2000 masl and the length of growing period (LGP) lies between 240 and 300 days (Storck et al., 1991). Babile is located in eastern Oromia at about 555 km east of Addis Ababa and 50 km east of Alemaya University. The average altitude is about 1650 masl with small variations among the PAs in the district and the LGP lies between 150 and 210 days. The area is mainly characterized by an erratic rainfall pattern, which fluctuates heavily from year to year making cropping vulnerable to drought. The average annual rainfall in Babile ranges between 500 mm and 875 mm with much variation among different years (Figure 4.1).

The average amount falls below the national average rainfall, which varies roughly between 600 mm and 1000 mm per year (Storck et al., 1997; Bezabih, 2000). Figure 4.1 shows that, over the last four years, annual rainfall has been steadily decreasing in Babile. Rainfall being the single most important factor dictating food production in the area, this could largely explain the growing food shortages in the area over the last couple of years. Meta district, on the other hand, receives relatively higher amount of annual rainfall ranging between 900 mm and 1200 mm. Meta, as opposed to Babile, is thus considered a high potential food crop production zone and NEP is widely implemented to enhance the production of cereals, including maize, wheat, and barley.

Therefore, the two districts were purposely selected for this study to represent widely differing agricultural production conditions where Babile is highly fragile and some intervention programs are underway to revert the situation, and Meta represents a high potential production zone but with high population pressure causing excessive fragmentation of farmland. In the study areas, cultivation of annual and perennial crops and rearing of livestock are the common farming activities. The major crops grown in Babile include sorghum, maize, and groundnut while maize, wheat, and barley are the dominant crops in Meta.

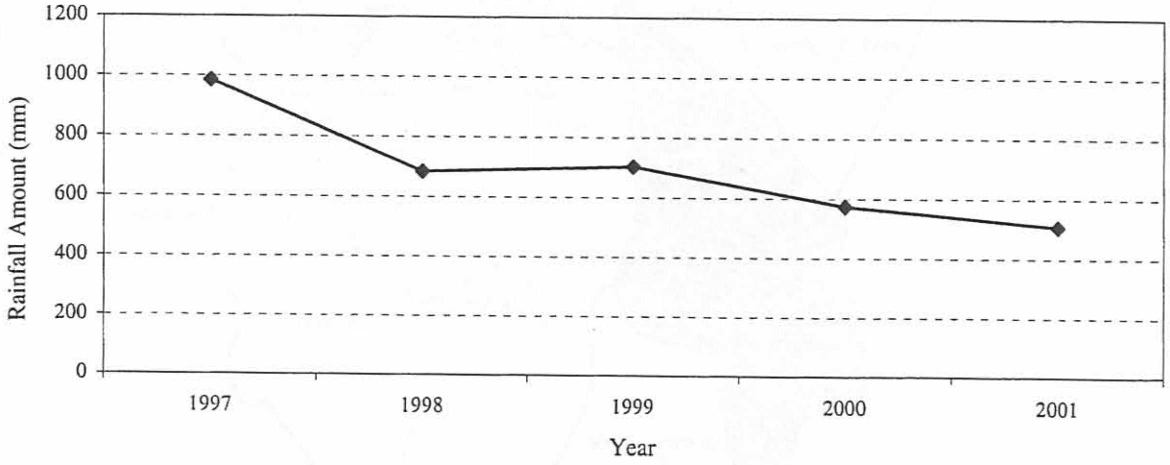

Figure 4.2: Amount of annual rainfall in Babile.

Source: Computed from Babile Weather Station data, Alemaya University.

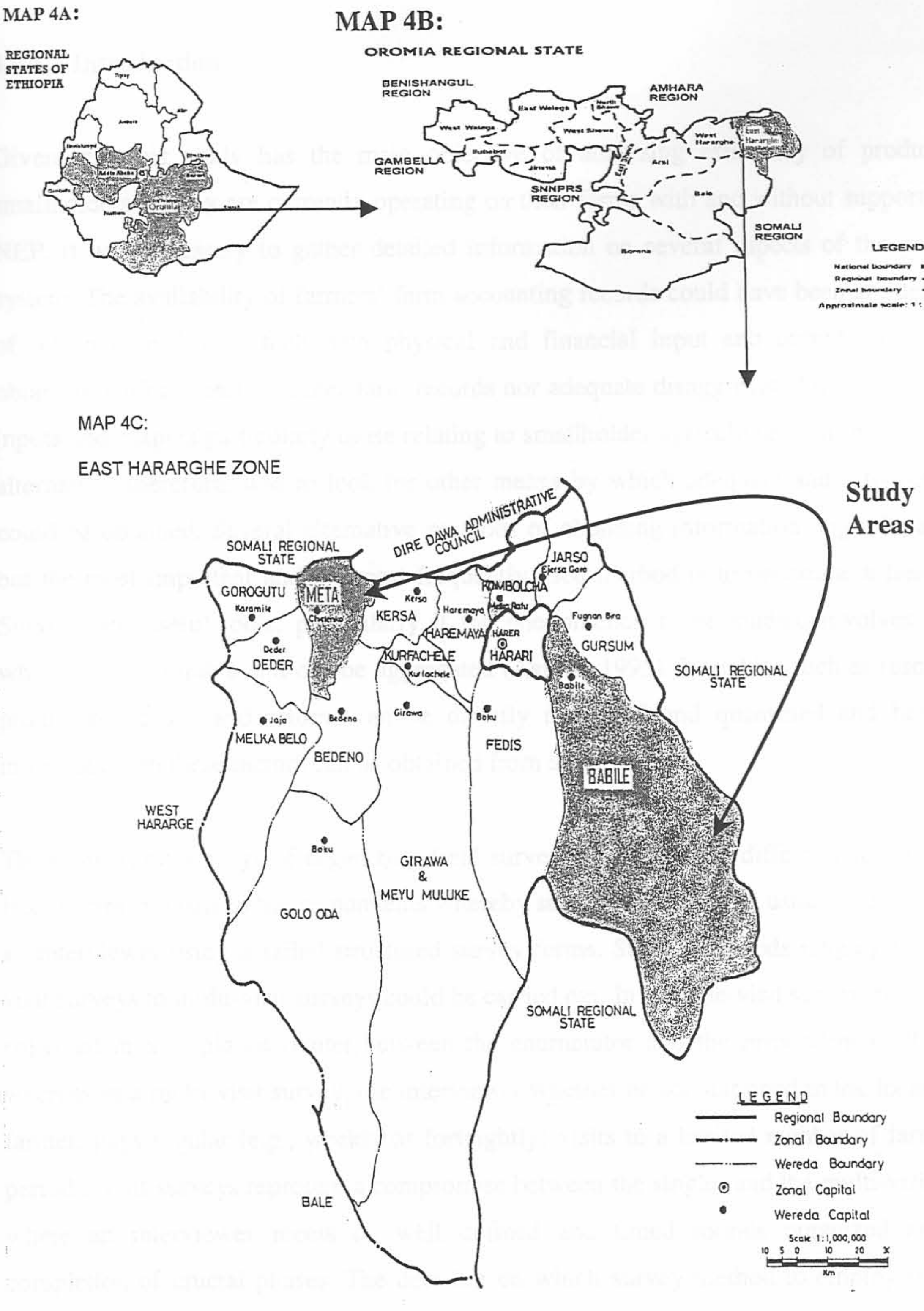

Figure 4.1: Maps of Oromia region and East Hararghe Zone.

4.4 Sample Design and Data Collection

4.4.1 Introduction

Given that this study has the main objective of analyzing efficiency of production of smallholders as they are currently operating on their farms with and without support through NEP, it was necessary to gather detailed information on several aspects of the production system. The availability of farmers' farm accounting records could have been an ideal source of information from which both physical and financial input and output data could be obtained. Unfortunately, neither farm records nor adequate disaggregated time series data on inputs and outputs particularly those relating to smallholder agriculture exist in Ethiopia. The alternative, therefore, was to look for other means by which adequate and satisfactory data could be obtained. Several alternative methods of obtaining information might be available, but the most important and the most frequently used method is to undertake a field survey. Surveys are useful tools, particularly if the phenomenon to be studied involves variables which are measurable and can be aggregated (Assefa, 1995). Variables such as resource use, production, costs, and returns can be directly measured and quantified and hence basic information on these factors can be obtained from a field survey.

There are various ways of organizing field surveys, each method differentiated by different frequencies in visits to the respondents whereby sets of questions are usually administered by an interviewer using detailed structured survey forms. Survey methods ranging from single-visit surveys to multi-visit surveys could be carried out. In a single-visit survey, information is collected in a single encounter between the enumerator and the respondent or the farmer, whereas in a multi visit survey, the interviewer whether or not stationed in the locality of the farmer, pays regular (e.g., weekly or fortnightly) visits to a limited number of farmers. The periodic visit surveys represent a compromise between the single- and the multi-visit surveys, where an interviewer meets on well defined and timed rounds organized around the completion of crucial phases. The decision on which survey method to employ is made by considering the trade-offs between quality of data needed and the costs of the information needed. In this particular study, the multi-period or periodic visit field survey has been used to generate the necessary information for the intended analysis.

4.4.2 Sampling and Sample Size Determination

Given the general scarcity of resources, conducting a census in which every individual farmer is directly approached is not possible and this forces us to employ sample surveys. In order to draw valid inferences from the sample and to ascertain the degree of accuracy of the results, the sample need to be drawn following the laws of probability. The appropriateness of a sampling method thus depends on how it will successfully meet study objectives. This study followed a multi-stage sampling procedure in selecting farmers to be surveyed throughout the agricultural year.

The first stage involved a purposeful selection of East Hararghe Zone from eastern Ethiopian highlands based on availability of strong intervention (research and extension) programs embracing smallholder food grains producers and availability of distinct (wet highland and dry land) agro-climatic zones representing most smallholder farming conditions in eastern Ethiopia. The second stage involved purposeful selection of the two study areas, Babile and Meta districts, based on their adequate representation of distinct agro-climatic zones for the analysis of efficiency of food production across agro-climatic zones. Moreover, NEP is well underway in view of the importance of food grains production in these districts as opposed to many other districts where cash crop production especially khat cultivation dominates, and competes with, the production of food crops.

Meta district was selected to represent a typical highland (2500 masl) where there is very high population pressure on land and receives relatively better rainfall amount and distribution ranging between 900 and 1200 mm per annum. Meta is a high potential production zone and NEP is widely implemented to enhance the production of food grains and to promote soil conservation practices. On the other hand, Babile district was selected to represent a low moisture zone receiving an annual rainfall between 500 and 875 mm and has got an average altitude of 1650 masl. Babile is an important target of NEP and several non-governmental organizations (NGOs) in view of widespread food insecurity in the area. Dry land technologies generated by Alemaya University and other research centers are mainly tested and promoted in Babile. Technologies include short-cycle, drought-tolerant, and better-yielding varieties of maize and sorghum along with the appropriate fertilizer recommendations and agronomic practices.

Farmers in the study area are organized into PAs, the lowest administrative units consisting of 80 to 300 farm households residing in villages adjacent to one another (Storck et al., 1991). In this study, because of the need to adequately control for the influence of environmental factors, that cannot be captured through surveys, on the efficiency of farmers, not only did this require homogenous PAs to be selected but also their number had to be limited to minimize heterogeneity. Therefore, three homogenous PAs were selected from each district and the farm households in each PA were stratified into participants and non-participants based on whether a household was participating in NEP during the 2001/2002 cropping season or not. The list of PAs in each district was obtained from the district agricultural offices and the list of PA members was obtained from the district finance offices. Based on the list of the PA members in the three selected PAs, the agricultural offices in the respective districts prepared two sampling frames, one each for participants and non-participants in NEP.

Sample size determination as appropriate for a particular study is usually a difficult exercise in any research work. Theoretically, the sample size is determined by the pre-assigned level of accuracy of the estimates of the mean of the parameters. This, however, requires knowledge about the degree of variability of a large number of parameters, all having different degrees of variability. This knowledge rarely exists prior to the study. In practice, therefore, sample size is most often determined by considerations of financial constraints and availability and adequacy of other resources such as trained manpower and time (Assefa, 1995). Because of the complexity of data requirements and financial and time constraints, sample sizes are usually small and cannot be expected to produce highly reliable estimates for all parameters. Nevertheless, it is possible to improve this situation by stratifying the population into many sub-populations based on one or more classification variables.

Taking these issues into consideration, a total of 100 farm households were selected from each district. Based on the sampling frames prepared for each PA, a total of 50 farm households were randomly selected from each group of participants and non-participants, proportional to PA size, to represent the respective agricultural technologies, making the sample in each district 100 farm households (Table 4.2). However, 3 farmers in Meta who were originally non-participants later joined the program and this increased the sample of participants in Meta to 53 and decreased the sample of non-participants to 47.

Table 4.2: Sample farm households by district and PA

PA	Meta			Babile		
	Participants	Non-participants	Total sample	Participants	Non-participants	Total sample
Burqa Jalala	26	20	46	-	-	-
Caffee Aneni	13	13	26	-	-	-
Utuba Muti	14	14	28	-	-	-
Kito	-	-	-	19	19	38
Sirbaa	-	-	-	14	14	28
Wayuu	-	-	-	17	17	34
TOTAL	50	50	100	53	47	100

Source: Own survey.

4.4.3 Data Collection

Development of a structured and detailed questionnaire was an important step in data collection. The questionnaire was designed based on three major farm operations in the area: land preparation and planting, weeding, and harvesting. Therefore, separate questionnaires pertaining to each agricultural operation were designed and pre-tested through a pilot survey to ensure clarity, adequacy, and sequencing of the questions. The questionnaires were designed in such a way that they provide adequate input-output data which would enable assessment of the production efficiency of smallholder farmers. Based on the results of the pilot survey, the questionnaire sets were revised and finalized. Actual data collection was also preceded by selection of appropriate enumerators for the year-round survey (February 2001 – January 2003) who were already living and working with the farmers. The selected enumerators received an intensive training on the objectives, contents, and methods of the survey.

Data collection took place during the 2001/2002 agricultural year through frequent visits to the sample households to carry out interviews using the structured questionnaires relating to resource use and management and productivity of the various enterprises. Farmers' crop fields were also regularly visited to take plot level measurements and observations throughout the cropping season. Input data were collected on a fortnight basis by asking the farmer to recall his/her activities during the past two weeks. Data included the quantities of seed and fertilizer used, labor time disaggregated by source, gender, age, and field operation and other miscellaneous inputs. The prices of all purchased inputs were also collected during this time. Output data on all the quantities of cereals, pulses, and oil crops harvested were also collected. A separate survey was conducted to collect output price information from Muti, Chelenko, and Babile markets during planting and harvesting times of the major crops. Data on the farm households' socio-economic characteristics were also collected during the survey.

There were three major data collection phases depending on the major farm operations in the study areas. The first round was soon after land preparation and planting of major crops in the respective districts. The second and third rounds were conducted after weeding and harvesting of major crops, respectively. The existence of two rainy seasons in Meta and the consequent need for repeating the three phases in both seasons for the respective crops was a daunting task. Although land preparation and planting of maize and sorghum takes place following the onset of the short (or *belg*) rains in March/April, the other farm operations such as weeding and harvesting are extended over their long growing season until they are harvested in January/February. On the other hand, there are also the so-called *belg* crops such as potatoes and barley which have to be planted following the short rains in April and harvested before the onset of the long rains starting June/July to release land for the long-rain (or *meher*) crops such as wheat, barley, and tef. Data collection thus required six rounds of surveys in Meta as opposed to 3 rounds in Babile in view of the prevalence of two cropping seasons in Meta.

4.5 Household and Farm Characteristics in the Study Areas

4.5.1 Family Size and Age Structure

In view of the extended family system in Ethiopia, several members of a family live together and take part in the social and economic activities of the household. Table 4.3 depicts family structure and labor force in the study areas. In Meta, family size ranges from 1 to 11 persons with an average of 5 persons per household.

In Babile, on the other hand, this ranges from 1 to 14 persons with an average of 6 persons per household. Owing to polygamous marriage and lack of family planning, farm households in the study areas have a large number of children who are less than 14 years and cannot significantly contribute to the family labor. This is clearly demonstrated by the lower man equivalent (ME), that proxies family labor supply, than the corresponding adult equivalent (ADE), that takes the subsistence requirements into account, both in Babile and Meta (see Appendix A4.1 and A4.2 for the conversion factors used to compute ME and ADE, respectively).

Table 4.3: Family structure and labor force of the sample farmers (mean)

Characteristics	Meta			Babile		
	Participants	Non-participants	All sample	Participants	Non-participants	All sample
Family size	6	5	5	6.5	6	6
Age	38	40	40	37	38	38
Adult equivalent	3	2.86	3	3.50	3.27	3.39
Labor force	1.58	1.39	1.49	1.57	1.45	1.50

Source: Own survey.

Table 4.3 shows that only 1.49 out of the 3 ADE in Meta can provide labor force in ME and actively engage in an economic activity, indicating that 50 percent of the family members depend on this active labor force for subsistence. This dependency is relatively higher in the case of non-participants (52 percent) than that of participants (47 percent), indicating the availability of higher supply of labor among participants. In Babile, only 1.5 out of the 3.39 ADE can provide labor force and actively engage in an economic activity, indicating that 56 percent of the family members depend on this active labor force for subsistence. This shows that there is higher dependency in Babile compared with that in Meta. Unlike in Meta, this dependency is similar among participant and non-participant farm households (56 percent), indicating comparable supply of labor across the farm groups. Moreover, in both areas, participant farmers have higher family size.

4.5.2 Education

Education is considered an important factor determining the efficiency with which farmers use their available resources and technology. Low level of education is typical in developing countries such as Ethiopia. Table 4.4 presents the education status of sample farmers in the study areas. Table 4.4 shows that 28 percent of the sample farmers in Meta and 46.5 percent of the sample farmers in Babile are illiterate, indicating relatively better educational status in Meta. Alternatively, 72 percent and 53.5 percent of the sample farmers in Meta and Babile, respectively, can at least read and write. It is also shown that there is a big difference between participant and non-participant farmers in terms of educational status. Table 4.4 shows 22.6 percent and 34 percent of the participant and non-participant farmers in Meta, respectively, are illiterates. In Babile, on the other hand, 34 percent and 59 percent of the participant and non-participant farmers, respectively, are illiterates. Alternatively, while about 78 percent of the participants in Meta can at least read and write, only 66 percent of the non-participants can read and write. In Babile, while 66 percent of the participants can at least read and write, only 40 percent of the non-participants can read and write. In both areas, this indicates higher educational status among farmers participating in NEP.

Table 4.4: Education status of the sample farmers (percent)

	Meta			Babile		
Characteristics	Participants	Non-participants	All sample	Participants	Non-participants	All sample
Illiterate	22.6	34.0	28.0	34.0	59.2	46.5
Read and write	45.3	48.9	47.0	30.0	24.5	27.3
Primary education	22.6	12.8	18.0	34.0	14.3	24.2
Secondary education	9.4	4.3	7.0	2.0	2.0	2.0

Source: Own survey.

4.5.3 Land Resources

Availability of productive land is a means of survival for the vast majority of the rural population. In rural areas of Ethiopia, land and labor account for the largest share of agricultural inputs. Capital inputs such as farm implements, oxen power, seeds and fertilizer are essential but constitute a marginal share of the total cost of production. Thus, the amount of land available for a household may determine the amount of production and hence its livelihood. The survey revealed that farm size ranges from 0.19 to 1.69 ha with an average of

0.69 ha in Meta and from 0.15 to 4.13 ha with an average of 1.57 ha per household in Babile (Table 4.5).

In the study areas, participants are better endowed with land compared with the non-participant farmers. In Meta, participants cultivated relatively larger area (0.73 ha) than the non-participants (0.65 ha). In Babile, participants also cultivated larger area (1.70 ha) than the non-participants (1.45 ha), where 32 percent of the participants cultivated more than 2 hectares of land. Generally, in view of the growing population pressure, availability of farmland per household seems to have dwindled over the years. For example, average cultivated land in Babile was 2.40 ha in 1993/1994 (Storck et al., 1997) and this decreased to 1.87 ha in 1996/97 (Bezabih, 2000) and is again reduced to 1.57 ha in 2001/2002 as revealed in this study.

Table 4.5: Distribution of the sample farmers by farm size (percent)

	Meta			Babile		
Farm size (ha)	Participants	Non-participants	All sample	Participants	Non-participants	All sample
<0.5	26.4	43.5	34.3	-	-	-
0.5 - 0.99	56.6	43.5	50.5	12.0	20.0	16.0
1 - 1.49	9.4	13.0	11.1	30.0	38.0	34.0
1.5 - 1.99	7.5	100.0	4.0	26.0	24.0	25.0
≥2	-	-	-	32.0	18.0	25.0
Average (ha)	0.73	0.65	0.69	1.70	1.45	1.57

Source: Own survey.

Land shortage seems to be more serious in the wet highland zone (Meta) than in the dry land zone (Babile). About 34 percent of the sample households in Meta and no sample household in Babile cultivated less than 0.5 ha. By farm groups, about 43.5 percent of the non-participant farmers and 26.4 percent of the participants in Meta cultivated less than half a hectare, indicating that a considerable proportion of the non-participant farmers were highly constrained with land. Farmers with serious land shortages have not benefited much from extension services in Ethiopia mainly due to their inability and unwillingness to allocate a portion of their land to 'experiment' with new technologies out of their already small and economically unviable plots.

In fact, the SG project in the past required a farmer to allocate half a hectare plot for demonstration of new varieties, fertilizer, improved cultural practices, and other technologies which means many of the sample farmers in this study would not qualify. This may still be a constraint under NEP in some of the regions although it has been relaxed in others with a view to reaching as many small farmers as possible. For example, the fact that about 26.4 percent of the participant sample farmers cultivated less than half a hectare clearly confirms that the size of demonstration plots has been further reduced from half a hectare. Actually, a farmer in Meta is required to allocate a quarter of a hectare of land for the application of improved technologies such as improved seeds and fertilizer and this plot is known as an extension plot.

4.5.4 Livestock Ownership

Livestock constitute an important component of the farming systems both in the highlands and lowlands of Ethiopia. Livestock production provides home consumable or saleable products like meat, milk, egg, manure, and fuel. Livestock products are also an integral part of the diet of the farm households. In addition to this, an important contribution of livestock particularly that of oxen is the provision of draught power for the cultivation, threshing, and transportation of grains and crop residues. Farmers also regard livestock to be a more reliable capital investment and store of wealth. They can be easily transformed into liquid assets in areas where no institutional credit facilities exist. However, the productivity of cattle in Ethiopia in terms of milk and meat output has been very low because of low genetic potential and inadequate nutrition. The seasonal variability in the quality and quantity of animal feed gives rise to an annual cyclical pattern of live weight gains and losses. In any case, the Ethiopian farmer would like to own some livestock in spite of the low productivity. In fact, farmers try to have more but less productive livestock than few but more productive livestock showing their primary interest in herd size as opposed to productivity.

In the study areas, the sample farmers rear different kinds of animals in order to produce animal products and also to generate income both enhancing the household's access to food. The animals include cattle, sheep, goats, donkeys, camels, and chicken. Small ruminants and chicken are reared, respectively, for meat and egg production both for consumption and for sale. In the event of serious food shortage, small ruminants and chicken are the first to be sold to meet the household's food demand. Based on Storck et al. (1991, p.188), the herd size was converted into Livestock Units (see Appendix A4.3 for conversion rules) to make comparison of livestock ownership across the farm household groups possible. Table 4.6 presents livestock ownership by farm household groups.

There is a noticeable variation across the study areas and between the farm groups. In view of the growing pressure on land in Meta and the consequent conversion of previously grazing lands into farmland for crop production, livestock production seems to have declined. For example, 4.5 percent and 35 percent of the sample households in Meta and Babile, respectively, have more than 5 LU. While no household owns more than 10 LU in Meta, 7.2 percent of the sample households in Babile own livestock in excess of 10 LU. On average, the sample households in Meta own 2.3 LU while the sample households in Babile have an average livestock holding size of 4.78.

Analysis of livestock holding by farm groups reveals that participant farmers in both study areas have greater holdings. Participant farmers in Meta have a higher average livestock holding (2.52 LU) than the non-participants (2.04 LU). Similarly, participants in Babile have higher average livestock holding (5.67 LU) than the non-participant farmers (3.9 LU). Further, none of the non-participant households and 7.7 percent of the participant households own livestock higher than 5 LU.

Table 4.6: Livestock holding of the sample households

	Meta			Babile		
LU range	Participants	Non-participants	All sample	Participants	Non-participants	All sample
<2	42.3	51.4	46.1	12.5	18.4	15.5
2.01 - 4.99	50.0	48.6	49.4	39.6	59.2	49.5
5 - 9.99	7.7	-	4.5	37.5	18.4	27.8
>10	-	-	-	10.4	4.1	7.2
Average	2.52	2.04	2.30	5.67	3.9	4.78

Source: Own survey.

The availability of animal draught power is an important factor in crop production in the Ethiopian highlands. The number of oxen owned by a farmer determines the area cultivated, influences the cropping pattern and has a serious impact on total production. In the study areas, smallholder farming systems are traditional and managed with simple production technology. Land preparation is done by traditional rudimentary farm implements like oxen-drawn ploughs, hoe, *Akkafa* (traditional spade), and *Dongora* (an iron tipped stick with stone at the top end). Farm machinery are absent in the area. As oxen shortage is severe, manual labor supply is very important for land preparation and subsequent cultivation during the cropping season. Significant delays in timely and proper land preparation and sowing are heavily influenced by oxen shortage. Conventionally, land preparation is done with the help of a pair of oxen. The survey revealed that in Meta 11 percent of the farmers have no working oxen, 64 percent have one ox, 23 percent have two oxen, and 2 percent have four or more oxen (Table 4.7).

In Babile, on the other hand, only 3 percent of the farmers have no working oxen, 13 percent have one ox, 56 percent have two oxen, 15 percent have three oxen and 13 percent have four or more oxen. This confirms the serious shortage of oxen power in the wet highland zones such as Meta producing large cereals (maize and sorghum) and small cereals (wheat, barley, and tef) compared with the dry land zones such as Babile producing largely sorghum and groundnuts.

Table 4.7: Distribution of oxen among the sample households

	Meta			Babile		
Status	Participants	Non-participants	All sample	Participants	Non-participants	All sample
No oxen	11.0	21.3	11.0	4.0	2.0	3.0
One ox	64.0	61.7	64.0	8.0	18.0	13.0
Two oxen	23.0	14.9	23.0	50.0	62.0	56.0
Three oxen	-	-	-	16.0	14.0	15.0
four oxen or more	2.0	2.1	2.0	22.0	4.0	13.0

Source: Own survey.

In both study areas, the non-participant farmers seem to be more constrained with draught power than the participants. In Meta, for example, 75 percent and 83 percent of the participants and non-participants, respectively, have only a single ox or no oxen at all.

Similarly, in Babile, 12 percent and 20 percent of the participants and non-participants, respectively, have only a single ox or no oxen at all. Farmers with only one ox or without an ox for draught power sometimes share with friends or relatives. Availability and capacity of oxen influences the cropping system especially in the wet highland zone of Meta. Farmers with less than a pair of oxen usually prefer to cultivate pulses such as beans rather than small cereals such as wheat and tef since the latter demand high oxen power for land preparation.

Unfortunately, the prevalence of small cereals production in the wet highland zone that require high draught power does not mean farmers have higher oxen holdings compared with the farmers in the dry land zone. Because of the fact that crop production and livestock production are highly competitive in the wet highland zone due to the growing shortage of grazing lands, the farmers in the wet highland zone keep a rather smaller number of livestock including oxen. In fact, because land is greatly diminishing over the years due to growing population pressure, farmers may have little or no reason to keep more oxen for draught power purposes if they have adequate labor force for hoe cultivation.

However, the shortage of both oxen power and labor force and the consequent delays in farm operations may pose problems for farmers to make use of the existing inadequate and uneven distribution of rainfall with the result that yields are substantially reduced. Therefore, farmers without oxen and relatively low labor supply have to reduce the number of plowing rounds before sowing crops. The undesirable consequences of a reduced number of plowing rounds on yield are obvious as this reduces water penetration into the soils and increases weed infestation. Farmers in the study areas turn over soils with *Dongora* during the dry season to overcome the labor shortage and facilitate a breakdown of soil particles. Cultivation is done 2 to 4 times per cropping season depending upon the availability of labor and rainfall conditions. In fact, cultivation goes together with weeding and thinning. The major cultivation activities to be undertaken are two: *Hagayii* (first cultivation) and *Ka'abaa* (second cultivation). The first cultivation is aimed at reduction of plant density (or thinning) and weed infestation control. First cultivation for sorghum and maize is sometimes done with oxen plough in seasons with relatively favorable rainfall and known as *Baq-baqaa*. The second cultivation is accomplished using traditional spade (*Akkafa)* aiming at root system development of the crops by heaping soils to the root and stem of the plant.

4.5.5 Labor Utilization

The smallholder farmers in the eastern highlands, like in any other subsistence oriented farming system, rely heavily on household labor supply to carry out the domestic social, economic and other activities. Labor use in a rain-fed agricultural system is usually characterized by seasonality. The work schedule is dictated by the calendar of farm operations in the year. Consequently, during peak production seasons particularly during harvesting and weeding seasons there exist labor shortages and non-family labor or extra labor has to be used. Labor shortages during peak periods constitute one of the major constraints to agricultural production in Ethiopia.

In the study areas, the family constitutes one of the main sources of labor supply for farming. Hired labor is less common. Exchange labor (or *Guzza)*, however, constitutes another source of labor in the study areas. This is a practice where a farmer requests a group of farmers (friends and/or relatives) to come together and work for him/her in the event of peak labor requirements. The farmer is, however, required to prepare *hodja* (boiled coffee with or without milk) and khat for that day. Family and exchange labor are thus the major sources of human labor in the study areas. The proportion of hired labor in the total human labor input was only 7 percent in Meta and 11 percent in Babile. About 65 percent and 28 percent of the labor force requirements for crop production in Meta were met, respectively, from family and exchange labor (Table 4.8). Similarly, about 68 percent and 21 percent of the labor demands in Babile were met, respectively, through family and exchange labor arrangements.

A comparison of farm household groups in Table 4.8 clearly shows that participant farmers in both districts applied more labor input than the non-participants probably due to their relatively higher cultivated land as presented in Table 4.4. Participants in Meta used a greater proportion of family labor (79 percent) and hired labor (11 percent) compared with the non-participants who used 49 percent family labor and only 3 percent hired labor. However, non-participants in Meta also used higher proportion of exchange labor (38 percent) than the participants who used only 20 percent exchange labor, showing the dependence of non-participant farmers on exchange labor in addition to own family labor. In Babile, on the other hand, participant farmers used a greater proportion of family labor (74 percent) but less exchange labor (18 percent) and hired labor (8 percent) compared with the non-participants who used 60 percent family labor, 25 percent exchange labor and 15 percent hired labor. This also shows the dependence of non-participant farmers on external labor (i.e., both exchange and hired labor) in addition to own family labor.

Another important aspect of labor utilization is the allocation of total labor inputs for the various crops and cropping systems characterizing the farming systems in the study areas. Labor input applied to most of the cropping operations benefit the whole plot in a cropping system. As far as sole cropping is concerned, labor input can be attributed to the requirement of the crop grown. But in the case of intercropping, most of the operations favor the whole system and the input cannot be broken down by crop components of the system. Harvesting labor input is applied for individual crops in a cropping system and this information is therefore related to one specific crop.

Table 4.8: Distribution of labor use by source (man-days)

Source	Meta			Babile		
	Participants	Non-participants	All sample	Participants	Non-participants	All sample
Family labor	1981.5 (79)	995.5 (49)	2977 (65)	3574.2 (74)	2253.4 (60)	5827.6 (68)
Exchange labor	502.8 (20)	779.6 (38)	1282.4 (28)	869.4 (18)	930.3 (25)	1799.7 (21)
Hired labor	260.7 (11)	59.9 (3)	320.6 (7)	386.4 (8)	556.3 (15)	942.7 (11)
Total	2510 (100)	2070 (100)	4580 (100)	4830 (100)	3740 (100)	8570 (100)

Note: Figures in parentheses are percentages.

Source: Own survey.

Table 4.9 presents the total labor input per hectare for the major cropping systems in the study areas. It is shown that labor input varies across cropping systems and locations. Labor inputs per hectare of the major cropping systems were generally lower in Babile than in Meta. This does not mean, however, that total labor inputs were lower in Babile. Rather, because the cultivated area of land allocated to each of these cropping systems in Meta was generally less than half a hectare, a per hectare labor input calculation could be misleading in that it overestimates actual labor inputs. Therefore, this at best shows how congested labor use is in Meta in view of the extremely small plots cultivated by the sample farm households coupled with the high supply of family and exchange labor in the absence of alternative employment opportunities. Nevertheless, it is also important to note that the crop growing period in the wet highland zone is so long compared with the dry land zone that it could have considerable implications for labor use and could thus provide part of the explanation. Further, because Meta receives better amount of annual rainfall than Babile, such cropping operations as weeding and cultivation require more labor due to more vigorous weed growth and infestation. Total labor input has been broken down by the three major cropping operations, including land preparation and planting, weeding and cultivation, and harvesting according to which the data were collected during the survey. Cropping systems including groundnuts, which are found only in Babile, do not require much more labor than cereals but the labor input for harvesting was quite substantial. Average labor input for each cropping operation is generally different and the differences are less consistent.

In Babile, while the system with haricot beans and large cereals such as maize and sorghum requires the highest per hectare labor input (78 man-days/ha), the system with groundnut requires the least (36 man-days/ha). Improved maize grown as a sole crop in Babile also requires high labor inputs (77 man-days/ha) the greatest share of which is needed for weeding and cultivation (34 man-days/ha). In Meta, while the system with maize and potatoes requires the highest amount of labor input (89-105 man-days/ha), most of which is required for weeding and cultivation, the system with local maize and local sorghum requires the least amount of labor (49 man-days/ha). Moreover, small cereals such as wheat, tef, and barley also require modest amounts of labor input (81-87 man-days/ha) but higher than the requirements of pulses and the system with khat and local large cereals.

Table 4.9: Per hectare labor input for the major cropping systems (man-days/ha)

Cropping system	Meta				Babile			
	Land preparation and planting	Weeding and Cultivation	Harvesting	Total	Land preparation and planting	Weeding and Cultivation	Harvesting	Total
Groundnut	-	-	-	-	13	16	39	68
Groundnut/Local Sorghum	-	-	-	-	9	12	15	36
Local maize/Local sorghum	13	21	15	49	11	16	12	39
Local sorghum	28	29	18	75	21	24	19	64
Local maize	26	30	28	84	19	27	22	68
Improved maize	31	38	23	92	22	34	21	77
Khat/local maize	20	32	10	62	19	28	8	45
Haricot beans/Local maize/Local sorghum	24	29	32	85	19	23	36	78
Barley	31	20	28	81	-	-	-	-
Tef	36	30	21	87	-	-	-	-
Potatoes	37	39	23	99	-	-	-	-
Beans	22	18	17	57	-	-	-	-
Wheat	30	28	27	85	-	-	-	-
Improved maize/Potatoes	34	38	33	105	-	-	-	-
Khat/Local maize/Potatoes	32	35	29	96	-	-	-	-
Local maize/Potatoes	29	32	28	89	-	-	-	-

Source: Own survey.

CHAPTER 5

EMPIRICAL ANALYSIS OF PRODUCTION EFFICIENCY UNDER TRADITIONAL AND IMPROVED TECHNOLOGY IN EASTERN ETHIOPIA

5.1 Introduction

Many developing countries including Ethiopia have made substantial investments in agricultural research and extension to increase agricultural production through new technologies. Despite considerable technological change since the Green Revolution, however, agricultural production in these countries continued to encounter substantial inefficiencies due to farmers' high unfamiliarity with new technology, poor extension and education services, and poor infrastructure, among others (Ali and Byerlee, 1991; Ghatak and Ingersent, 1984; Xu and Jeffrey, 1998). While there are a considerable number of studies dealing with technical efficiency of farmers in developing countries, very few studies have addressed both technical, allocative and economic efficiencies (Taylor et al., 1986; Bravo-Ureta and Rieger, 1991; Bravo-Ureta and Evenson, 1994; Sharma et al., 1999) employing the stochastic efficiency decomposition technique proposed by Bravo-Ureta and Rieger (1991) which was an extension of the model originally introduced by Kopp and Diewert (1982). However, due to scale biases arising from imposing an input-orientated framework on the output-orientated stochastic production frontier results, the efficiency estimates obtained based on Bravo-Ureta and Rieger's (1991) decomposition methodology either overestimate or underestimate the true measures depending on the returns to scale associated with the production technology and are thus inconsistent. Although a couple of authors (e.g., Singh et al., 2000) recognized the limitation of the conventional efficiency decomposition, no attempt has been made to improve upon the technique. This study, therefore, extends the Bravo-Ureta and Rieger's (1991) efficiency decomposition methodology to account for scale effects.

This chapter analyses the production efficiency of smallholder farmers in eastern Ethiopia. The study employed a robust efficiency decomposition technique, which accounts for scale effects, to analyze the technical, allocative, and economic efficiencies of smallholder farmers under traditional and improved production technologies. Specifically, the extended efficiency decomposition approach is employed to assess the impact of improved maize technologies on the efficiency of maize production in Meta district and the impact of NEP on farmers' overall technical, allocative, and economic efficiency in Babile and Meta districts. Socio-economic and institutional factors influencing farmer efficiency are also analyzed. The next section presents the analytical framework employed to conduct the intended production efficiency analyses. Results of the empirical application of the framework to maize production in Meta are discussed in section 5.3. Empirical analysis of overall farm level production efficiency is presented in section 5.4, and the final section distills conclusions and implications.

5.2 The Analytical Framework

While technical efficiency is the ability to produce a given level of output with a minimum quantity of inputs under certain technology, allocative efficiency refers to the ability of choosing optimal input levels for given factor prices. Productive (or economic) efficiency is the product of technical and allocative efficiency. Since Farrell's seminal paper, there has been a growing interest in methodologies and their applications to efficiency measurement. While early methodologies were based on deterministic models that attribute all deviations from maximum production to inefficiency, the introduction of the stochastic frontier production function has made it possible to separately account for factors beyond and under the control of firms (Aigner et al., 1977; Meeusen and van den Broeck, 1977). The production technology of a firm is represented by a stochastic frontier production function (SFPF) as follows

$$Y_i = f(X_i;\beta) + v_i - u_i, \tag{5.1}$$

where Y_i measures the quantity of agricultural output of the i^{th} firm, X_i is a vector of the input quantities, β is a vector of parameters, and $f(X_i;\beta)$ is the production function; v_i s are assumed to be independently and identically distributed $N(0,\sigma^2{}_v)$ random errors, independent of the u_i s; and the u_i s are non-negative random variables, associated with technical inefficiency in production, and are assumed to be independently and identically distributed as half-normal, $u \sim |N(0,\sigma^2 u)|$. The maximum likelihood estimation of equation (5.1) yields estimators for β and λ where $\lambda = \frac{\sigma_u}{\sigma_v} \geq 0$ and $\sigma^2 = \sigma^2 u + \sigma^2 v$. The assumptions made on the statistical distributions of v and u, mentioned above, make it possible to calculate the conditional mean of u_i given $\varepsilon_i = v_i - u_i$ as

$$E(u_i / \varepsilon_i) = \frac{\sigma_u \sigma_v}{\sigma} \left[\frac{f^*(\varepsilon_i \lambda / \sigma)}{1 - F^*(\varepsilon_i \lambda / \sigma)} - \frac{\varepsilon_i \lambda}{\sigma} \right], \qquad (5.2)$$

where F^* and f^* are, respectively, the standard distribution and the standard normal density functions, evaluated at $e_i \lambda / \sigma$. Therefore, equations (5.1) and (5.2) provide estimates of u and v after replacing ε, σ, and λ by their estimates.

5.2.1 The Stochastic Efficiency Decomposition Methodology

Bravo-Ureta and Rieger (BUR) utilized the level of output of each firm adjusted for statistical noise, observed input ratios, and the parameters of the stochastic frontier production function (SFPF) to decompose overall efficiency into technical and allocative efficiency. The parameters of the SFPF are actually used to derive the parameters of the dual cost function. For example, if v_i is now subtracted from both sides of equation (5.1), we obtain

$$Y_i^* = f(X_i; \beta) - u_i = Y_i - v_i, \qquad (5.3)$$

where Y_i^* is the i^{th} firm's observed output adjusted for the statistical noise captured by v_i, $f(\cdot)$ is the deterministic frontier output, and u and v are, respectively, the inefficiency and random components of overall deviations from the frontier. Adjusted output Y^* is used to derive the technically efficient input vector, X^t. The technically efficient input vector for the i^{th} firm, X_i^t, is derived by simultaneously solving equation (5.1) and the observed input ratios $\frac{x_1}{x_i} = k_i (i > 1)$ where k_i is equal to the observed ratio of the two inputs in the production of Y_i^*. The technically efficient input vectors form the basis for deriving the technical efficiency measures by taking ratios of the vector norms of the efficient and observed input quantities while the adjusted output is used to derive allocative and economic efficiencies employing the dual cost frontier function that is analytically derived from the SFPF.

In the BUR method, the parameters of the frontier function are estimated using an output-orientated approach but technical efficiency is derived by imposing an input-orientated approach implied by the simultaneous solution of adjusted outputs and the observed input ratios to yield the technically efficient input vectors. This is clearly inconsistent and will give technical efficiency estimates that are very different from those obtained from the maximum-likelihood estimation of the SFPF in equation (5.1) which is output-orientated unless the firms are operating under constant returns to scale (CRTS). Even if the hypothesis of constant returns to scale is not rejected, consistent estimates cannot be obtained as long as the function coefficient is numerically different from unity. A positive scale effect indicates operation in an irrational zone of production (i.e., IRTS) whereas a negative scale effect implies a rational production zone (i.e., DRTS).

A variable returns to scale technology (VRTS) will generally give different estimates of technical, allocative, and economic efficiency when the output and input-orientated approaches are used. Under decreasing returns to scale (DRTS), the BUR method underestimates technical, allocative, and economic efficiency (e.g., Bravo-Ureta and Rieger, 1991 for dairy farms in USA; Bravo-Ureta and Evenson, 1994 for cotton production in Paraguay) while it overestimates the corresponding efficiencies under increasing returns to scale (IRTS) (e.g., Bravo-Ureta and Evenson, 1994 for cassava production in Paraguay; Sharma et al., 1999 for swine production in USA).

5.2.2 A Consistent Approach to Efficiency Decomposition

Adopting an input orientation for efficiency decomposition when original specifications have an output orientation requires that observed output be adjusted for statistical noise as well as scale effects. This is accomplished by first defining a scale factor as the deviation from CRTS as

$$\eta_i = \psi - 1, \tag{5.4}$$

where η_i is the scale factor for the i^{th} firm and ψ is the function coefficient of the production technology. The output-orientated technical inefficiency effect of the i^{th} firm in the composed error structure in equation (5.1) is denoted by u_i. Imposing an input-orientated approach on the SFPF will produce an input-orientated technical inefficiency effect, denoted as u_i^i, that is actually composed of the pure technical inefficiency effect , u_i , and a scale effect, ζ_i, such that

$$u_i^i = u_i + \zeta_i . \tag{5.5}$$

However, consistency requires that $u_i^i = u_i$. To the extent that there is a non-zero scale effect, the conventional decomposition methodology gives inconsistent efficiency estimates. From this it follows that the observed output must be adjusted not only for statistical noise but also for scale effects while employing the input-orientated approach to decompose overall efficiency into technical and allocative efficiency measures based on the (output-orientated) estimates of the SFPF. The scale effect is a proportion of the output-orientated technical inefficiency effect, the factor of proportionality being the scale factor η. Therefore, the scale effect of the i^{th} firm can be given by

$$\zeta_i = \eta_i u_i . \tag{5.6}$$

From equations (5.5) and (5.6), the input-orientated adjusted output of the i^{th} firm is derived and given as

$$Y_i^{i*} \equiv f(X_i;\beta) - u_i^i = Y_i - v_i - \eta_i u_i , \tag{5.7}$$

where Y_i^{i*} is the observed (or actual) output adjusted for statistical noise and scale effects.

Figure 5.1 illustrates the difference between observed and adjusted output in the input and output orientation in the SFPF framework. The technically efficient input quantities obtained by projecting the output-orientated adjusted outputs, Y_k^{o*} and Y_l^{o*}, on the deterministic frontier are typically BUR efficient quantities and are denoted as X_k^B and X_l^B for the k^{th} and l^{th} firms, respectively.

On the other hand, the technically efficient quantities for the k^{th} and l^{th} firms obtained by projecting the input-orientated adjusted outputs, Y_k^{i*} and Y_l^{i*} , on the deterministic frontier are the consistent input vectors, X_k^t and X_l^t, respectively, used in this study as given in equation (5.7). For firm k, operating under DRTS, X_k is the vector of actual input use and Y_k is the actual output. Given the level of input use, the stochastic frontier output is represented by Y_k^s. The total deviation from the deterministic frontier output for this firm (v - u) is the distance $Y_k^d Y_k$. This distance may be decomposed into the random component ($v = Y_k^s Y_k^d$) and the inefficiency component ($u = Y_k^s Y_k$) (Jondrow et al., 1982). As indicated by equation (5.7), u_k (i.e., distance $Y_k^s Y_k$) is subtracted from the deterministic frontier output to obtain the output-orientated adjusted output for firm k, Y_k^{o*}. The input-orientated adjusted output for this firm, Y_k^{i*}, that rationalizes the consistent technically efficient input vector X_k^t, is obtained by making an upward scale adjustment equivalent to the distance Y_k^{i*} Y_k^{o*} to the output orientated adjusted output, Y_k^{o*}, that rationalizes BUR technically efficient input vector X_k^B.

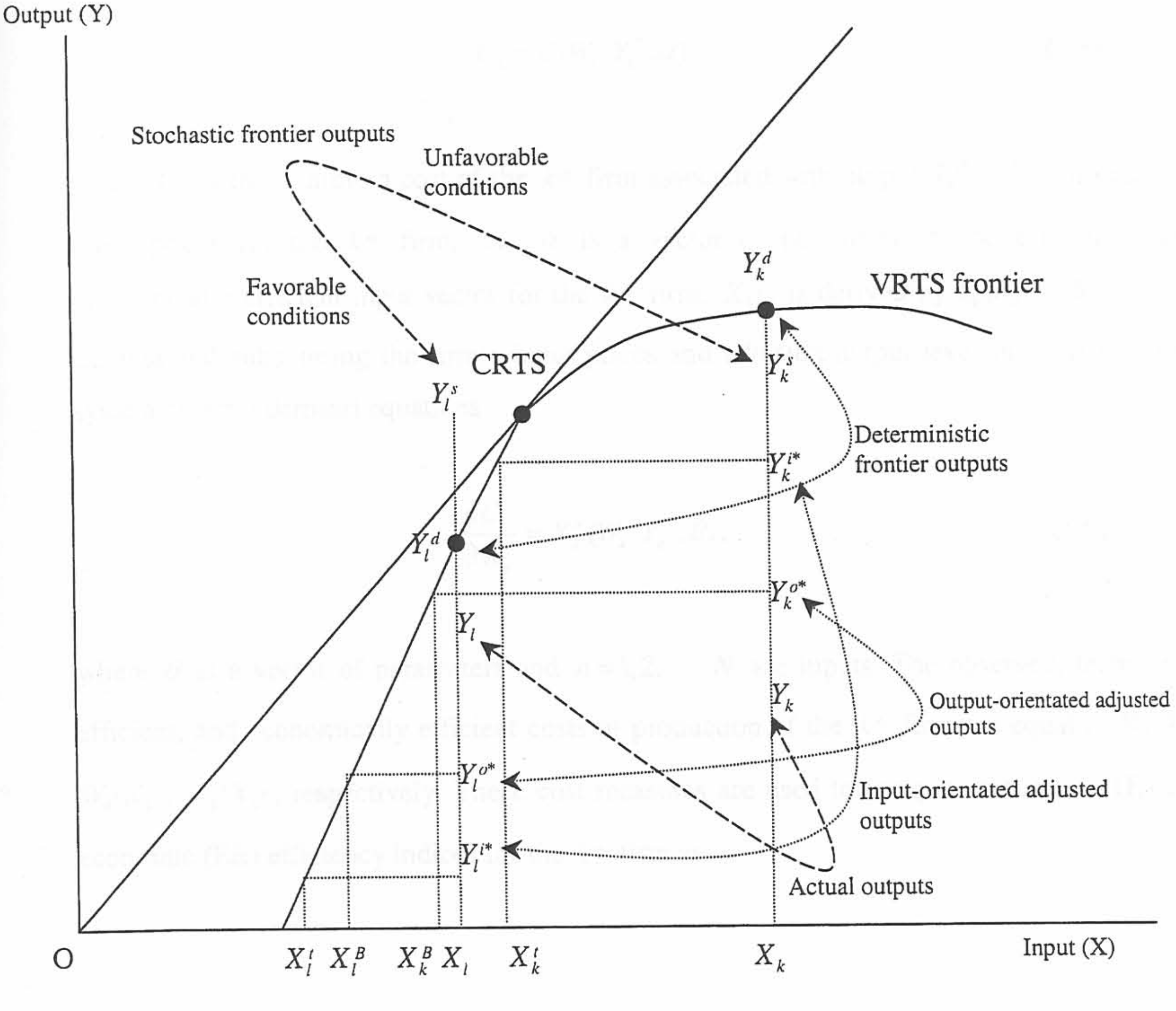

Figure 5.1: The stochastic frontier production function with output and input orientation.

Similarly firm l, operating under IRTS, uses inputs X_l to produce Y_l. Stochastic frontier output for this firm is Y_l^s. The total deviation from the deterministic frontier function, $Y_l^d Y_l$, may be partitioned into the random component $v = Y_l^s Y_l^d$ and the inefficiency component $u = Y_l^s Y_l$. The output-orientated adjusted output of firm l will similarly be $Y_l^{o*} = Y_l^d - Y_l^s Y_l$. The input-orientated adjusted output for this firm, Y_l^{i*}, that rationalizes the consistent technically efficient input vector X_l^t, is obtained by making a downward scale adjustment equivalent to the distance $Y_l^{i*} Y_l^{o*}$ to the output-orientated adjusted output, Y_l^{o*}, that rationalizes BUR technically efficient input vector X_l^B. In figure 5.1, $X_k{}^t$ and X_l^t refer to the consistent technically efficient input vectors for the k^{th} and l^{th} firms, respectively.

Assuming that the production function in equation (5.1) is self-dual (e.g., Cobb-Douglas), the dual cost frontier can be derived algebraically and written in a general form as

$$C_k = C(W_k, Y_k^{i*}; \alpha), \qquad (5.8)$$

where C_k is the minimum cost of the k^{th} firm associated with output Y_k^{i*}. W_k is a vector of input prices for the k^{th} firm, and α is a vector of parameters to be estimated. The economically efficient input vector for the k^{th} firm, $X_k{}^e$, is derived by applying Shephard's Lemma and substituting the firm's input prices and adjusted output level into the resulting system of input demand equations

$$\frac{\partial C_k}{\partial W_n} = X_k^e(W_k, Y_k^{i*}; \theta), \qquad (5.9)$$

where θ is a vector of parameters and $n = 1, 2, \ldots\ldots, N$ are inputs. The observed, technically efficient, and economically efficient costs of production of the k^{th} firm are equal to $W_k{}'X_k$, $W_k{}'X_k{}^t$, $W_k{}'X_k{}^e$, respectively. These cost measures are used to compute technical (TE) and economic (EE) efficiency indices for the k^{th} firm as

$$\mathrm{TE}_k = \frac{W_k{}' X_k{}^t}{W_k{}' X_k}, \tag{5.10}$$

and

$$\mathrm{EE}_k = \frac{W_k{}' X_k{}^e}{W_k{}' X_k}. \tag{5.11}$$

Following Farrell (1957) the allocative efficiency (AE) index can be derived from equations (5.10) and (5.11) as

$$\mathrm{AE}_k = \frac{W_k{}' X_k{}^e}{W_k{}' X_k{}^t}. \tag{5.12}$$

Following the quantification of the technical, allocative, and economic efficiency measures, a second stage analysis involves a regression of these measures on several hypothesized socio-economic and institutional factors affecting efficiency of farmers. This will help to identify the determinants of technical, allocative, and economic efficiency. Although few authors (e.g., Battese and Coelli, 1995; Kumbhakar, 1994) challenge this approach by arguing that the farm-specific factors should instead be incorporated directly in the first stage estimation of the stochastic frontier, many justify the two-stage method in that the variables can only have a round-about effect on efficiency (Bravo-Ureta and Rieger, 1991; Bravo-Ureta and Evenson, 1994; Sharma et al., 1999). The linear regression model[4] has thus been a common approach to the analysis of the effects of farm-specific factors on productive efficiency. However, because efficiency scores are bounded between zero and one and also cannot be assumed to be normally distributed as they are mostly skewed, transformation of these scores using Box-Cox procedures and taking their logs is important for regression analysis (Judge et al., 1985). A linear regression model of the following form could thus be used for the analysis of the determinants of efficiency (Squires and Tabor, 1991; Assefa, 1995).

$$\ln\left(\mathrm{E}_i / 1 - \mathrm{E}_i\right) = X_i'\beta + \varepsilon_i, \tag{5.13}$$

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[4] Censored regression models such as the tobit model could be used but these are less appealing because efficiency scores obtained from stochastic production frontiers are not censored at zero, one, or both and hence there is generally little or no basis for using censored regression as opposed to OLS.

where E_i is the i^{th} firm's level of efficiency, X_i is a vector of explanatory variables, β is a vector of parameters to be estimated, and ε_i are identically and independently distributed random errors $N(0, \sigma^2)$.

5.3 Empirical Analysis of Maize Production Efficiency of Smallholders Under Traditional and Improved Technology

Maize is the most important cereal grain in Ethiopia in terms of production, area coverage and better availability and utilization of new production technologies (CSA, 1997; Mulat, 1999). The maize sector has benefited from relatively better technological change in terms of high-yielding varieties of seeds, fertilizer, chemicals, and post-harvest techniques. The first maize hybrid in the Ethiopian breeding program was BH-140, which was released in 1988 from the Bako Research Center (Kebede, 1993). With subsequent efforts, BH-660 was also released in 1994 by the Bako Research Center and became one of the most successful hybrid varieties. It has a wider adaptability, growing at altitudes ranging from 1650 meters to 2200 meters with annual precipitation of 1000-1500 mm. It needs up to 170 days to maturity and performs better under high rainfall, good soil conditions and high dose of fertilizer. Maize research has yet to develop high-yielding and drought-tolerant varieties for the drought-prone farming zones. The yield potential of BH 660 is well over 100 quintals per hectare (ESE, 1997). The recommended packages for hybrid maize technology are 100 kg per hectare DAP, 100 kg per hectare UREA, 25 kg per hectare seed, and other appropriate cultural practices such as row planting. However, weak capacity in producing and distributing the hybrid seeds and the high risk associated with weather problems have been a major constraint to wider adoption of BH 660.

However, new maize technologies are known to require a new set of skills and knowledge, farmers' integration into the input and product markets, and access to infrastructure, credit and educational services to fully exploit their productivity-enhancing potentials. Mulat (1999) argued, for instance, that the potential to increase yield through improved management practices is not given due attention in Ethiopia. The effort directed towards enhancing the technical skill and management capacity of the farmers leaves much to be desired. The research system has yet to develop location-specific optimal fertilizer rates and management practices. The extension system operates based on recommendations that show little variation across different environments. Therefore, inefficiencies and the associated output losses under modern technology use in Ethiopia are expected to be potentially high. Any maize production gain through efficiency improvement requires that the farmers' technical and allocative efficiencies in maize production be quantified and the underlying factors identified and studied.

5.3.1 Data and Empirical Procedures

The data used in this study come from a survey of 47 traditional maize producers and 51 hybrid maize producers in Meta district in eastern Ethiopia during the 2001/2002 cropping season. Meta district is a high potential maize production zone given its better rainfall amount and distribution, ranging between 900 and 1200 mm, and NEP is widely implemented to enhance food grains production especially maize. The surveyed farmers were randomly selected after an initial stratification of farm households in three PAs into participants and non-participants in the extension program. Due to shortage of supply, farmers had to be registered as participants in NEP to get hybrid maize seeds. Although some participant farmers produced both hybrid and traditional maize, the latter was limited to small garden plots mainly for green harvest in view of critical land shortages and the perceived high yield advantages of hybrid maize.

As described earlier, data were collected through frequent visits to the sample households' crop fields to carry out interviews and to take plot-level measurements and observations throughout the 2001/2002 agricultural year. Input data were collected on a fortnight basis by asking the farmer to recall his/her activities on that particular plot during the past two weeks. Data included the quantities of seed and fertilizer used, labor time disaggregated by source, gender, age, and field operation and other miscellaneous inputs. The prices of all purchased inputs were also collected during this time. Output data on all the quantities of cereals, pulses, and oil crops harvested from each plot were recorded. A separate survey was conducted to collect output price information from nearby markets during planting and harvesting times of the major crops. Moreover, area measurements were taken in square meters from each plot with assistance from the farmers themselves and these were later converted to hectares.

The production technology of the sample farmers is represented by a Cobb-Douglas production function. The specification is admittedly restrictive in terms of the maintained properties of the underlying production technology. However, as interest rests on efficiency measurement, and not on the analysis of the general structure of the production technology, the Cobb-Douglas production function provides an adequate representation of the production technology (Taylor et al., 1986; Kopp and Smith, 1980; Battese, 1992). Further, the self-dual nature of the Cobb-Douglas production function and its cost function provides a computational advantage in obtaining estimates of technical and allocative efficiency.

Although the efficiency decomposition technique requires that the functional form be self-dual, a series of preliminary likelihood ratio tests were conducted to see whether the choice of the Cobb-Douglas functional form would actually be inappropriate. The tests revealed that the Cobb-Douglas stochastic frontier model was, in fact, an adequate representation of the data for participant and non-participant farmers in Meta and Babile, given the specifications of the more flexible translog frontier model. It was only the preferred (aggregate) model for the two groups of farmers in Babile for which the translog production frontier model would be more appropriate. Nevertheless, very similar technical efficiency estimates were obtained from the aggregate Cobb-Douglas and translog models.

For the investigation of the technical, allocative and economic efficiencies of traditional and hybrid maize production, separate stochastic frontier production functions, of the following form, are estimated

$$\begin{aligned}\ln Y_k &= \beta_0 + \beta_1 \ln land + \beta_2 \ln labor + \beta_3 \ln fertilizer \\ &\quad + \beta_4 \ln materials + \left(v_k - u_k\right)\end{aligned} \tag{5.14}$$

where ln denotes the natural logarithm; Y denotes the total quantity of traditional or hybrid maize output in kg; *land* denotes the total land planted to traditional or hybrid maize in hectares; *labor* denotes the amount of family labor, exchange labor, and hired labor used in traditional or hybrid maize production in man-days[5]; *fertilizer* denotes the amount of chemical fertilizer used in traditional or hybrid maize production in kg; and *materials* denotes the

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[5] A man-day is equivalent to 7 working hours in the study area.

implicit quantity index of seeds and chemicals used in traditional or hybrid maize production estimated as the value of all seeds and chemicals deflated by a weighted price index of the inputs, the weights being the share of each input in total cost. It has become a standard practice in efficiency analysis to include only the conventional inputs (i.e., land, labor, fertilizer, and other variable inputs) in the frontier production function. It is argued that the non-conventional inputs such as education, credit, and land quality influence output indirectly by raising the efficiency with which the conventional inputs especially land and labor are used. Therefore, the non-conventional inputs are used in the second stage analysis of factors influencing production efficiency.

The solution to the cost minimization problem in equation (5.15) is the basis for deriving the dual cost frontier, given the input prices (w_n), parameter estimates of the stochastic frontier production function ($\hat{\beta}$) in equation (5.14), and the input-orientated adjusted output level Y_k^{i*} in equation (5.7)

$$\underset{x}{\text{Min}}\, C = \sum_n w_n X_n \qquad (5.15)$$

$$\text{Subject to } Y_k^{i*} = \hat{A}\prod_n X_n^{\hat{\beta}_n},$$

where $\hat{A} = \exp(\hat{\beta}_0)$.

Substitution of the cost minimizing input quantities into (5.15) yields the following dual cost function

$$C(Y_k^{i*}, w) = \mathrm{H}Y_k^{i*\mu}\prod_n w_n^{\alpha_n}, \qquad (5.16)$$

where $\alpha_n = \mu\hat{\beta}_n$, $\mu = \left(\sum_n \hat{\beta}_n\right)^{-1}$, $\mathrm{H} = \frac{1}{\mu}\left(\hat{A}\prod_n \hat{\beta}_n^{\hat{\beta}_n}\right)^{-\mu}$. The input prices, w_n, are averages of observed prices per unit of the inputs used.

For the investigation of socio-economic and institutional factors influencing technical and allocative efficiency in traditional and hybrid maize production, a linear regression model is used. The variables that are hypothesized to influence efficiency in the Ethiopian context

(Assefa, 1995; Getachew, 1995) are: AGE (the age of the household head); RWEDUC (dummy for literacy of the household head in terms of reading and writing); PREDUC (dummy for attendance of primary education); CASHCR (amount of cash credit obtained); PLOTOWN (dummy for plot ownership that equals 1 if the plot is government-allocated and 0 if it has been sharecropped, rented in, or borrowed); EXTNSN (the number of visits to a farmer by an extension agent during the cropping season); PARTCPN (the number of years the farmer participated in extension programs); PLOTQ (plot quality dummy); LSTKUNT (livestock ownership in Livestock Units); OFINCM (amount of off-farm income obtained by the household); and KHATAR (area under khat , the main cash crop).

5.3.2 The Empirical Results

The maximum-likelihood (ML) estimates of the parameters of the stochastic frontier production function specified in equation (5.14) were obtained using the computer program LIMDEP 7.0 (Greene, 1995). These results are presented in Table 5.1. The standard ordinary least squares (OLS) estimates of the average production function are also presented for comparison.

For traditional maize, the signs of the slope coefficients of the stochastic production frontier are positive as expected. Land and labor inputs are highly significant while fertilizer and materials are not significant in traditional maize production in view of farmers' less reliance on purchased inputs. Based on restricted least squares regression, the hypothesis of CRTS was strongly rejected, indicating that traditional maize producers actually operated under DRTS. On the other hand, all the variables have turned out to be significant in determining hybrid maize output. The high elasticities of hybrid maize output with respect to land, labor, fertilizer and materials suggest that hybrid maize output is highly responsive to all these inputs. The hypothesis of CRTS was strongly rejected, indicating that hybrid maize producers operated under IRTS. This may be due to the fact that relatively small plots of land are planted to hybrid maize because of land shortages and seed supply constraints in the area as is the case with other parts of the country.

The estimate of the variance parameter, λ, is significant in both traditional and hybrid maize production implying that the inefficiency effects, as opposed to the random factors, are significant in determining the level and variability of traditional and hybrid maize output of farmers in the study area. This is also shown in Table 5.1 by the higher variance of the inefficiency term (0.293 for traditional maize and 0.101 for hybrid maize) than that of the random error term (0.074 for traditional maize and 0.048 for hybrid maize). Therefore, variation in maize output level across farmers is mainly due to factors within the control of farmers and not due to random factors beyond their control like weather and disease. Alternatively, the traditional production function with no technical inefficiency effects is not an adequate representation of the data.

Table 5.1: OLS and ML estimates of the alternative maize production functions

	Traditional Maize (N=47)			Hybrid Maize (N=51)		
Variable	Mean (S.D.)	OLS estimates	ML estimates	Mean (S.D.)	OLS estimates	ML estimates
Intercept	-	5.389***	5.507***	-	5.133***	5.264 ***
		(0.724)	(0.704)		(0.505)	(0.650)
ln (Land)	0.26	0.352*	0.297**	0.32	0.343***	0.357 ***
	(0.13)	(0.213)	(0.121)	(0.16)	(0.105)	(0.101)
ln (Labor)	25.32	0.388***	0.437***	48.94	0.360***	0.345***
	(14.21)	(0.152)	(0.119)	(44.55)	(0.053)	(0.061)
ln (Fertilizer)	15.32	0.042	0.027	30.46	0.283***	0.242**
	(11.30)	(0.054)	(0.054)	(16.77)	(0.092)	(0.119)
ln (Materials)	11.13	0.019	0.064	4.96	0.188*	0.165*
	(6.32)	(0.114)	(0.132)	(4.46)	(0.105)	(0.098)
Function coefficient	-	0.801	0.825		1.174	1.109
F or X^2-statistic (CRTS)	-	41.43*** (F)	42.89*** (X^2)		109*** (F)	95.2*** (X^2)
R^2		0.86			0.87	
λ			1.989*			1.461*
			(1.142)			(0.893)
σ^2_v			0.074			0.048
σ^2_u			0.293			0.101
Log-likelihood			-25.52			-8.87

Notes: *** = significant at 0.01 level; ** = significant at 0.05 level; * = significant at 0.1 level.

S.D. = standard deviation. Figures in parentheses represent asymptotic standard errors.

Source: Own computation.

The dual frontier cost function for hybrid maize, derived analytically from the stochastic production frontier shown in Table 5.1, is given as

$$\begin{aligned} \ln C_h = & -3.728 + 0.322 \ln w_A + 0.311 \ln w_L + 0.218 \ln w_F \\ & + 0.149 \ln w_M + 0.902 \ln Y_k^{i*} . \end{aligned} \tag{5.17}$$

The corresponding dual cost frontier for traditional maize production is similarly derived and is given as

$$\begin{aligned}\ln C_t = & -5.653 + 0.360 \ln w_A + 0.530 \ln w_L + 0.033 \ln w_F \\ & + 0.077 \ln w_M + 1.211 \ln Y_k^{i*} .\end{aligned} \qquad (5.18)$$

where C_h and C_t are, respectively, per-farm costs of producing hybrid and traditional maize, respectively; Y_k^{i*} is total maize output in kg of the k^{th} farm adjusted for any statistical noise and scale effects as specified in equation (5.7); w_A is the seasonal rent of a hectare of land estimated at 1000 Birr; w_L is the wage rate estimated at 7 Birr/day; w_F is the price of fertilizer estimated at 2.75 Birr/kg; and w_M is the price index of materials (i.e., seeds and chemicals) estimated at 6 Birr/kg for hybrid maize and 1.5 Birr/kg for traditional maize production. Inadequate farm level price data coupled with little or no input price variation across farms in Ethiopia precludes any econometric estimation of a cost or profit frontier function. Therefore, the use of self-dual production frontier functions allows the cost frontier to be derived and used to estimate economic efficiency in situations where producers face the same input prices.

5.3.2.1 Maize Production Efficiency Estimates

The frequency distributions and summary statistics of both the scale-adjusted and conventional efficiency measures for traditional and hybrid maize production are presented in Table 5.2. For traditional maize, the estimated scale-adjusted mean TE, AE, and EE indices are 68 percent, 83 percent, and 56 percent, respectively, and the corresponding results for hybrid maize production are 78 percent, 77 percent, and 61 percent, respectively. The results indicate that hybrid maize production is more technically and economically efficient than traditional maize production. The higher average technical efficiency of hybrid maize production compared with traditional maize production is consistent with the higher average yields of hybrid maize (5100 kg/ha) than local maize (2030 kg/ha) as shown in Table 5.4.

The conventional mean TE, AE, and EE indices for traditional maize production are 62 percent, 83 percent, and 51 percent, respectively, confirming that the conventional technical and economic efficiency measures are consistently and proportionally lower than the scale-adjusted measures under the DRTS technology in traditional maize production. The corresponding conventional measures for hybrid maize production are 80 percent, 77 percent, and 62 percent, confirming that the conventional approach consistently overestimates the technical and economic efficiency measures under IRTS technology.

The conventional TE and EE measures are consistently lower than the scale-adjusted measures under the DRTS technology (e.g., traditional maize production) and higher under the IRTS technology (e.g., hybrid maize production). Using the paired-difference *t*-test of the conventional and scale-adjusted mean efficiency measures, the conventional mean TE and EE measures were significantly lower than the corresponding scale-adjusted efficiency measures in traditional maize and higher in hybrid maize production (Table 5.2). The scale-adjusted and conventional AE measures were found to be identical, confirming that the scale-adjusted TE and EE measures are actually a neutrally scaled version of the corresponding conventional measures. Depending on the returns to scale, a neutrally scaled-up or scaled-down conventional TE and EE estimates ensure identical conventional and scale-adjusted AE measures. Taylor et al. (1986), following the conventional technique, obtained considerably lower average TE (17 percent) and EE (13 percent) when the AE measure, that is not sensitive to scale effects, was 74 percent for traditional farming in Brazil. This certainly confirms that the TE and EE measures they obtained from the conventional approach actually underestimated the true measures and the conclusions drawn could be very misleading.

Figure 5.2 depicts the distribution of the scale-adjusted and conventional technical efficiency measures whereas Figure 5.3 presents the corresponding economic efficiency distributions. Figure 5.2 shows that, for traditional maize production, the conventional approach classifies a greater proportion of farmers in the technical efficiency ranges less than 50 percent and a smaller proportion in the ranges greater than 50 percent than does the scale-adjusted approach. Further, while some farmers achieved scale-adjusted technical efficiency greater than 90 percent, no farmer is classified in this range based on the conventional approach. This confirms that the conventional approach consistently underestimates the true individual technical efficiency measures such that the conventional technical efficiency distribution is also a neutral downward shift of the true distribution under decreasing returns to scale.

Figure 5.2 also shows that, for hybrid maize production, the conventional approach classifies a greater proportion of farmers in the technical efficiency ranges between 80 and 100 percent and a smaller proportion in the ranges between 60 percent and 80 percent than does the scale-adjusted approach. This confirms that the conventional approach consistently overestimates the true individual technical efficiency measures such that the conventional technical efficiency distribution is also a neutral upward shift of the true distribution under increasing returns to scale. Figure 5.3, on the other hand, shows that, for traditional maize production, the conventional approach classifies a greater proportion of farmers in the economic efficiency ranges less than 50 percent and a smaller proportion in the ranges greater than 50 percent than does the scale-adjusted approach. This again confirms that the conventional approach consistently underestimates the true individual economic efficiency measures such that the conventional economic efficiency distribution is also a neutral downward shift of the true distribution under decreasing returns to scale.

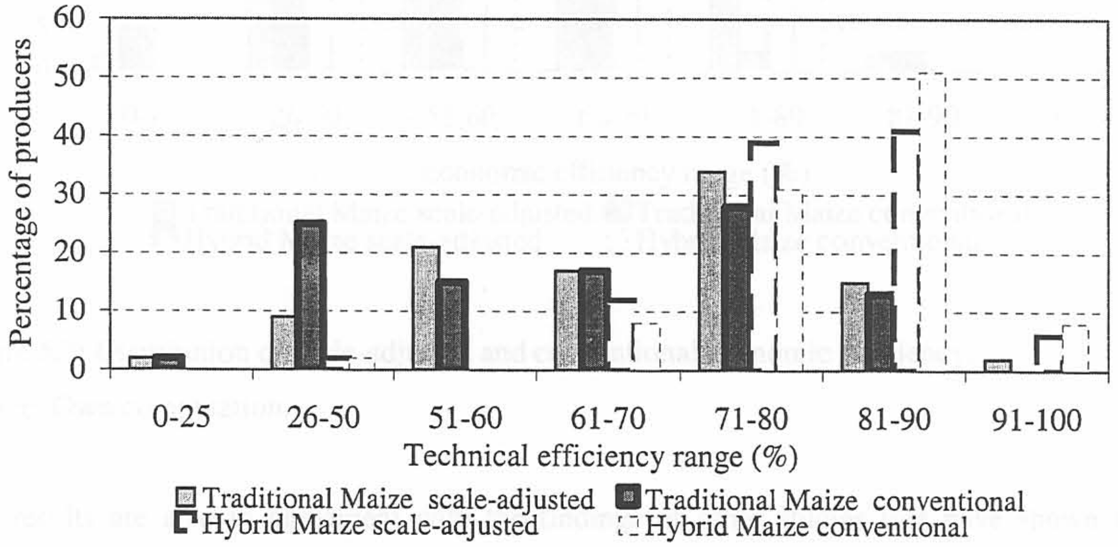

Figure 5.2: Distribution of scale-adjusted and conventional technical efficiency.
Source: Own computation.

Figure 5.3 also shows that, for hybrid maize production, the conventional approach classifies a greater proportion of farmers in the economic efficiency ranges between 60 and 80 percent and a smaller proportion in the ranges between 25 and 60 percent than does the scale-adjusted approach. This confirms that the conventional approach consistently overestimates the true individual economic efficiency measures so that the conventional economic efficiency distribution is also a neutral upward shift of the true distribution under increasing returns to scale. Based on the scale-adjusted measures, a 56 percent EE indicates that traditional maize producers can increase maize production by an average 44 percent by operating at full technical and allocative efficiency levels. The results suggest that a considerable part of economic inefficiency under traditional technology is due to technical inefficiency. This is consistent with the Schultzian argument that traditional farmers are allocatively efficient in view of their accumulated experience in allocating own resources and their less use of purchased inputs.

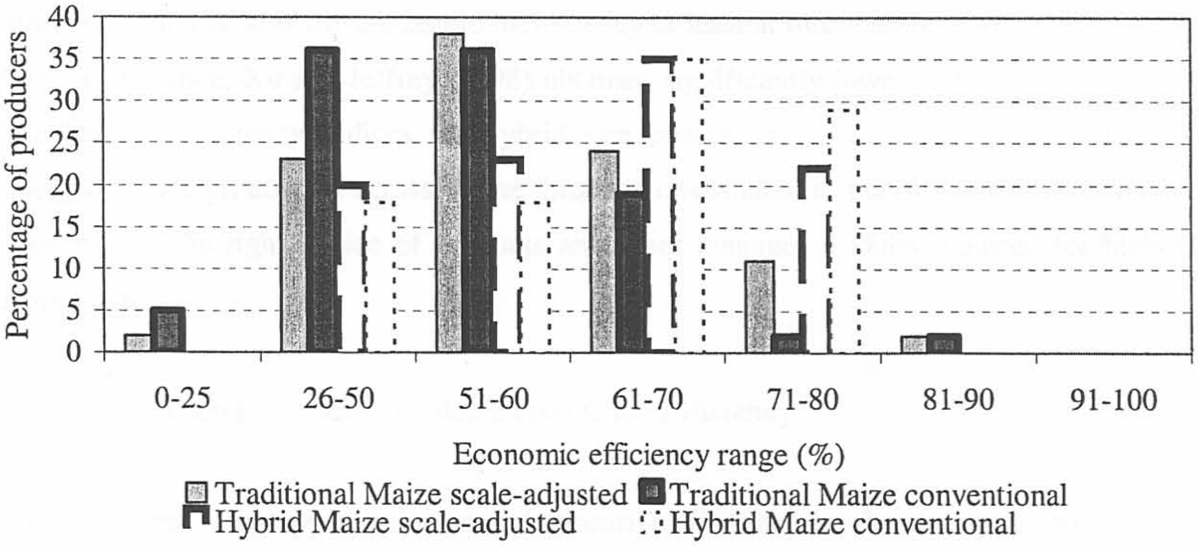

Figure 5.3: Distribution of scale-adjusted and conventional economic efficiency.
Source: Own computation.

The results are also in agreement with the findings of other studies that have shown the existence of substantial technical inefficiencies in developing agricultural economies and the consequent implications for agricultural growth possibilities with existing resources and technology. For example, high technical inefficiency has been found to exist among cereal producers in Ethiopia (Getu et al., 1998; Getachew, 1995; Corppenstedt and Abbi, 1996), suggesting that technical efficiency improvement is one of the possible avenues for increasing cereals production with available resources and (traditional) technology. For hybrid maize production, a 61 percent EE indicates that farmers can increase hybrid maize output by an average 39 percent by operating at full technical and allocative efficiency levels. Technical and allocative inefficiencies in hybrid maize production make equivalent contribution to the observed high economic inefficiency.

The results suggest that the potential of hybrid maize technology is underutilized and its use causes substantial allocative errors on the part of the producers. Efficient use of new technologies is possible only if farmers have adequate technical and financial support through the extension and credit systems, and adequate and timely provision of inputs and information. For instance, Seyoum et al. (1998) obtained an average TE score of 94 percent for maize producers within the SG project in eastern Ethiopia. The purpose of the SG project was mainly to demonstrate packages of technologies on farmers' own plots with substantial technical support and credit services and hence production was technically superior. Unlike project-level use of new technology, wider dissemination of the program to the farming community is likely to involve sizeable inefficiency at least at initial stages (Ali and Byerlee, 1991). For instance, Xu and Jeffrey (1998) obtained significantly lower technical, allocative, and economic efficiency indices for hybrid rice production in China as compared with conventional rice production across all the three regions studied as they needed time to reach full operation, the right choice of products and other managerial skills required for higher performance.

5.3.2.2 Factors Influencing Maize Production Efficiency

Maize producers' variation in technical and allocative efficiency levels are hypothesized to be due to several farm and farmer attributes, mainly reflecting the managerial ability of farmers and their access to information. An OLS estimation procedure was employed to identify the important socio-economic and institutional factors influencing technical and allocative efficiency. The parameter estimates of the OLS regression are presented in Table 5.3. As can be judged based on the R^2 values of the four regressions and the corresponding F-statistics, the model fits the data reasonably well. Technical efficiency in traditional maize production is positively and significantly influenced by age, education, and plot quality. This suggests that farmers acquire better management skills for traditional maize production through experience and education. Moreover, plot quality differences cause technical efficiency variation among traditional maize farmers due to the fact that some farmers in the wet highland zone allocated degraded land to maize while most farmers planted the most fertile plots in their homestead to maize. The rest of the variables, including extension, credit, off-farm income, livestock unit, and the area under khat have the expected positive signs but are insignificant.

Table 5.2: Scale-adjusted and conventional maize production efficiencies

Level (percent)	TE Number of farmers (percent farmers)				AE Number of farmers (percent farmers)				EE Number of farmers (percent farmers)			
	Traditional Maize		Hybrid Maize		Traditional Maize		Hybrid Maize		Traditional Maize		Hybrid Maize	
	scale-adjusted	conventional	Scale-adjusted	conventional	scale-adjusted	conventional	scale-adjusted	conventional	scale-adjusted	conventional	scale-adjusted	conventional
<25	1(2)	1(2)	-	-	-	-	-	-	1(2)	2 (5)	-	-
26-50	4(9)	12(25)	1(2)	1(2)	1(2)	1(2)	-	-	11(23)	17(36)	10(20)	9(18)
51-60	10(21)	7(15)	-	-	-	-	2(4)	2(4)	18(38)	17(36)	12(23)	9(18)
61-70	8(17)	8(17)	6(12)	4(8)	3(7)	3(7)	11(22)	11(22)	11(24)	9(19)	18(35)	18(35)
71-80	16(34)	13(28)	20(39)	16(31)	9(19)	9(19)	16(31)	16(31)	5(11)	1(2)	11(22)	15(29)
81-90	7(15)	6 (13)	21(41)	26(51)	24(51)	24(51)	17(33)	17(33)	1(2)	1(2)	-	-
91-100	1(2)	-	3 (6)	4(8)	10(21)	10(21)	5(10)	5(10)	-	-	-	-
Mean	68	62	78	80	83	83	77	77	56	51	61	62
Minimum	20	14	41	44	49	49	57	57	18	12	30	33
Maximum	91	88	93	93	96	96	91	91	86	84	76	86
t -ratio (paired-difference)	-24***		20.51***		0.00		0.00		-21***		19.85***	

Note: *** = Paired-difference of means significant at 0.01 level. The *t* -ratios are based on the paired-difference *t* -test.

Source: Own computation.

Technical efficiency in hybrid maize production is positively and significantly influenced by basic education, credit, and plot quality, suggesting that better utilization of new maize technology is facilitated by education through its effect on acquiring and using information, by credit through its effect on farmers' ability to settle the required down payments for input credit, and by plot quality through its effect on supplementing the high fertilizer requirements of hybrid maize against the background of low fertilizer application rates coupled with highly degraded land in the wet highland zone.

Age has turned out to negatively and significantly influence technical efficiency, suggesting that farmers who have accumulated experience in traditional farming are less likely to easily change their traditional practices to more modern ones as required by new varieties. Seyoum et al. (1998) also obtained a negative and significant influence of age on the technical efficiency of maize producers within the SG project in eastern Ethiopia. The extension variable, though positive, is not significant. Seyoum et al. (1998) also obtained a positive but insignificant influence of extension advice on the technical efficiency of maize producers within the SG project.

Table 5.3: Factors influencing efficiency of maize production in Meta

Variable	Traditional Maize		Hybrid Maize	
	TE	AE	TE	AE
Constant	-0.093 (-0.231)	2.056*** (14.235)	3.267*** (9.365)	2.367*** (9.310)
AGE	0.135* (2.023)	0.082 (1.229)	-0.206* (-1.931)	-0.035 (-0.232)
EXTNSN	0.142 (1.231)	0.102 (1.0325)	0.054 (1.326)	0.134 (1.035)
RWEDUC	0.265*** (3.299)	0.125 (1.230)	0.369*** (4.236)	0.102 (1.369)
PREDUC	0.095 (1.332)	0.256** (1.985)	0.021 (1.234)	0.323*** (2.367)
PLOTOWN	0.021 (1.200)	0.130 (1.357)	0.022 (1.233)	0.223* (1.811)
CASHCR	0.027 (0.106)	0.402** (1.95)	0.195** (2.325)	0.186* (1.752)
PARTCPN	0.023 (1.114)	0.024 (1.355)	0.133 (1.200)	0.206 (1.378)
LSTKUNT	0.103 (1.06)	0.127 (1.201)	-0.015 (-1.026)	0.098 (1.058)
OFINCM	0.012 (1.025)	0.188 (1.102)	0.140 (1.023)	0.208 (1.455)
PLOTQ	0.432*** (4.235)	0.023 (1.388)	0.233*** (2.369)	0.023 (1.027)
KHATAR	0.106 (1.265)	0.108 (1.354)	-0.025 (-1.235)	0.087 (1.0248)
R^2	0.65	0.47	0.55	0.53
F	12.548***	12.42***	4.236***	2.065***

Notes: *** = significant at 0.01 level; ** = significant at 0.05 level; * = significant at 0.10 level.
Figures in parentheses are t-ratios.

Source: Own computation.

Allocative efficiency in traditional as well as hybrid maize production is positively and significantly influenced by primary education and credit. The significant influence of primary as opposed to basic education on allocative efficiency suggests that allocative efficiency requires greater skills and knowledge that does technical efficiency. Farmers with better education and access to credit have more information and capacity for optimal allocation of traditional and new inputs. This is also consistent with the findings of Assefa and Heidhues (1996) for cereals producers in the central highlands of Ethiopia and Sharma et al. (1999) for swine producers in Hawaii. Allocative efficiency in hybrid maize production is also positively and significantly influenced by plot ownership, suggesting that owner cultivators are more allocatively efficient than non-owner cultivators. This may be due to sub-optimal applications of fertilizer and seeds on sharecropped, rented in and borrowed lands. These plots received, on average, 66 kg fertilizer and 11 kg seeds per hectare, whereas owned plots received, on average, 114 kg fertilizer and 19 kg seed per hectare when the recommended rates are 200 kg fertilizer and 25 kg seed per hectare. Hayami and Otsuka (1993) argued that informal contractual tenure arrangements such as sharecropping and other forms of indigenous land tenure rights result in an inefficient allocation of resources as well as reduced incentives to improve agricultural lands.

5.3.3 Conclusions

Using an extended efficiency decomposition technique to maize production in eastern Ethiopia, we obtained mean technical, allocative, and economic efficiency indices, respectively, of 68 percent, 83 percent, and 56 percent for traditional maize and 78 percent, 77 percent, and 61 percent for hybrid maize production. The results confirmed that the conventional efficiency decomposition approach actually overestimates efficiency measures under increasing returns to scale and underestimates under decreasing returns to scale. Because of proportional upward or downward biases of the conventional technical and economic efficiency estimates relative to the scale-adjusted estimates, both the conventional and scale-adjusted allocative efficiency measures have turned out to be identical. Economic inefficiency in traditional maize production is dominated by technical inefficiency, suggesting that improvement of technical efficiency needs a priority attention as it provides a significant source of growth in maize output. Economic inefficiency in hybrid maize production, on the other hand, is equally dominated by technical and allocative inefficiency, suggesting that both technical and allocative inefficiencies are equally relevant targets that need to be overcome to enhance the production of hybrid maize. An examination of the relationship between efficiency and various socio-economic and institutional variables revealed that education, access to credit, and greater security of tenure are the key determinants of the efficiency of maize producers.

5.4 Empirical Analysis of Overall Farm Level Production Efficiency of Smallholders

Low agricultural productivity and adverse climatic conditions have been largely responsible for the growing gap between food demand and supply in Ethiopia. One of the major policy shifts since the change of government in 1992 has been the substantial emphasis placed on improving the productivity of peasant agriculture through increased use of a package of improved agricultural technologies. The Ethiopian government introduced NEP based on the experiences of SG project, which embarked upon the popularization of large-scale (usually half-hectare) on-farm demonstration plots for already available improved agricultural production technologies. NEP was designed with the aim of improving the productivity of smallholder farmers through better access to and use of improved production technologies such as fertilizer, improved seeds, pesticides and better cultural practices mainly for cereal crops such as maize, wheat, and tef.

Despite considerable yield increments obtained from the demonstration plots of the SG project in the high potential agricultural areas, cereal yields have rather stagnated following large-scale applications of improved production technologies in recent years. This has become a source of growing concern regarding the effectiveness of NEP on the efficiency with which smallholders use their limited resources through the use of improved technologies. The success of NEP depends critically on how well the three functions of extension, credit and input delivery meet the particular needs of smallholders, a situation very different from that of SG project which was limited to specific high potential zones with relatively better functioning credit and input delivery services (Befekadu and Berhanu, 1999; Mulat, 1999).

There is, however, lack of adequate empirical evidence of whether NEP has actually enhanced production efficiency in different agro-climatic zones, given a package of improved technologies. One of the objectives of this study was, therefore, to assess the impact of NEP on the technical and allocative efficiency of farmers and to identify the underlying factors influencing farmer efficiency in eastern Ethiopia.

5.4.1 Data and Empirical Procedures

The data for this study come from two samples of farmers, one sample composed of farm households participating in the extension program and another composed of non-participant farm households, in two selected districts, Meta and Babile, each representing distinct agro-climatic zones in eastern Ethiopia. Meta district was selected to represent a typical wet highland zone where there is very high population pressure on land (see Table 5.4) and receives relatively better rainfall amount and distribution ranging between 900 and 1200 mm per annum. Meta is a high potential cereal production zone where NEP is widely implemented to enhance the production of food grains. The most widely grown cereals in Meta are maize, barley and wheat. On the other hand, Babile district was selected to represent a dry land zone receiving an annual rainfall between 500 and 700 mm and has got an average altitude of 1650 masl. Babile is an important target of NEP and NGO's activities in view of widespread food insecurity. Dry land technologies generated by Alemaya University and other research centers are mainly tested and promoted in Babile. Technologies include short-cycle, drought-tolerant, and better yielding varieties of maize and sorghum along with the appropriate fertilizer recommendations and agronomic practices. Sorghum, maize and groundnuts are widely grown in Babile.

The surveyed farmers were randomly selected after an initial stratification of farm households in three PAs into participants and non-participants in the extension program. The participant and non-participant sample farm households surveyed in Meta were, respectively, 53 and 47, whereas 50 farm households from each group were surveyed in Babile. Data were collected through frequent visits to the sample farm households' crop fields to carry out interviews and to take plot-level measurements and observations throughout the 2001/2002 agricultural year. Input data were collected on a fortnight basis by asking the farmer to recall his/her activities during the past two weeks. Data included the quantities of seed and fertilizer used, labor time disaggregated by source, gender, age, and field operation and other miscellaneous inputs. The prices of all purchased inputs were also collected during this time. Output data on all the quantities of cereals, pulses, and oil crops harvested were collected. A separate survey was conducted to collect output price information from Muti, Chelenko and Babile markets during planting and harvesting times of the major crops.

A summary of the values of the variables used in the crop level and farm level efficiency analyses is presented in Table 5.4. Participants in NEP in both districts obtained higher average crop output value per hectare of cultivated land in view of higher average yields of the major crops, including maize, sorghum, groundnuts, wheat and barley.

Table 5.4: Summary statistics of the variables used in the efficiency analyses

	Meta		Babile	
	Participants	Non-participants	Participants	Non-participants
Variable	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)
Value of crop output (Birr/ha)	3350 (1306)	1490 (769)	3660 (1508)	1471 (714)
Hybrid maize yield (kg/ha)	5100 (2460)	---	---	---
Local maize yield (kg/ha)	2040 (670)	2030 (1300)	1070 (740)	930 (550)
Sorghum yield (kg/ha)	---	1460 (1000)	1100 (510)	980 (470)
Groundnuts yield (kg/ha)	---	---	740 (390)	670 (300)
Wheat yield (kg/ha)	2000 (920)	1700 (1070)	---	---
Barley yield (kg/ha)	1380 (970)	1420 (2150)	---	---
Cultivated land (ha)	0.73 (0.60)	0.65 (0.16)	1.70 (0.66)	1.45 (0.60)
Labor (Man-days/ha)	65 (32)	68 (16)	57 (29)	53 (80)
Fertilizer (kilogram/ha)	69 (36)	22 (24)	42 (12)	17 (10)
Age	39 (12)	41 (12)	37 (10)	38 (10)
Education (literacy) dummy	0.77 (0.35)	0.66 (0.31)	0.66 (0.42)	0.40 (0.26)
Off-farm income (Birr)	209 (62)	91 (143)	327 (91)	287 (28)
Extension visit	6 (3)	0.8 (1)	8 (7)	4 (3)
Man equivalent	1.58 (0.8)	1.39 (0.53)	1.57 (0.57)	1.45 (0.57)
Cash credit (Birr)	71 (96)	32 (78)	337 (421)	50 (21)
Livestock Unit	2.47 (1.69)	2.04 (1.24)	5.67 (0.59)	3.90 (0.45)
Maize-potato share (percent)	54 (12)	63 (33)	---	---
Cereal-Pulse share (percent)	8 (2)	11 (5)	45 (10)	39 (13)

Note: S.D. = Standard deviation.

Source: Own computation.

The differences between the two groups of farmers in terms of yields of major crops is substantial in the case of maize. While they obtained comparable local maize yields, the participants obtained higher hybrid maize yields in view of the maize technology package promoted by NEP. Moreover, the participants have higher cultivated land, livestock units, off-farm income, cash credit, household labor, and extension visits than the non-participants. Both groups of farmers in Meta have comparably high average percentage of cultivated area allocated to the maize-potato cropping system, which provides greater opportunities for efficient use of land in the face of increasing land shortages in the wet highland zone. Both participants and non-participants in Meta and Babile applied far less amount of fertilizer per hectare of cultivated land than recommended. This is due to shortage of supply of improved seeds, shortage of cash credit to buy fertilizer or to settle the required down payments for fertilizer credit, and production and price risks. For example, highly depressed maize prices following increased maize production have greatly undermined the profitability of improved technologies especially fertilizer and the consumption of fertilizer has shown a declining trend over the last 3 years.

In view of the increasing pressure on land in the wet highland zone, both participant and non-participant farmers in Meta have less average cultivated land and livestock than farmers in the dry land zone, Babile. Both groups of farmers in Babile have comparably high average percentage of cultivated area allocated to the cereal-pulse cropping system, which offers opportunities for crop diversification to cope with the risk of crop failure due to drought as well as for improving yield through soil fertility improvement and better control of pests and diseases (Bezabih, 2000).

The objective of the farm level production efficiency analysis is to assess the impact of NEP on the technical, allocative, and economic efficiency of smallholder farmers. However, because it is impossible to observe a farmer with and without program participation simultaneously, and lacking a panel data set that allows observation of households before and after program participation, impact analysis in this study is based on comparing production efficiency estimates differentiated by participation in NEP. It could be argued that if certain socio-economic factors such as education, access to land, and family size affect a household's participation in NEP or acceptance into NEP, selection bias results and attribution becomes difficult. This type of selection bias may lead to either overestimation or underestimation of impact depending on the farmers' initial socio-economic conditions. However, farmers in the study areas choose to participate in NEP and there is no specific target group of farmers served by the program. Although there seem to be clear differences between the two groups in some of the socio-economic characteristics as shown in Table 5.3, these differences are not significant. Moreover, differences in education, credit access, livestock ownership, and income could actually be brought about by NEP itself and hence do not imply selection bias and differing initial conditions of the two groups of farmers. Therefore, production efficiency analysis differentiated by participation in NEP is a reasonable approach to measuring the impact of the program on the efficiency of farmers.

Like the crop level analysis, the production technology of the sample farmers for the farm level efficiency analysis is represented by a Cobb-Douglas production function. For the investigation of the technical, allocative, and economic efficiencies of participant and non-participant farmers, separate stochastic frontier production functions, of the following form, are estimated for each group of farmers

$$\begin{aligned}\ln Y_i = \beta_0 + \beta_1 \ln \mathit{land} + \beta_2 \ln \mathit{labor} \\ + \beta_3 \ln \mathit{fertilizer} + \beta_4 \ln \mathit{materials} + (v_i - u_i),\end{aligned} \tag{5.19}$$

where ln denotes the natural logarithm; Y_i denotes the gross value of crop output of the i^{th} farmer; *land* denotes the total cultivated land in hectares; *labor* denotes the total amount of labor used in crop production in man-days; and *materials* denotes the implicit quantity index of seeds and chemicals used in crop production.

The solution to the farm level cost minimization problem like in equation (5.15) is the basis for deriving the dual farm level cost frontier, given the input prices (w_n), parameter estimates of the stochastic frontier production function ($\hat{\beta}$), and the input-orientated adjusted output level, Y_i^*. The investigation of factors influencing the technical and allocative efficiencies of participant and non-participant farmers is carried out by estimating the same regression model used for the crop level analysis. Most of the variables that are hypothesized to influence crop level technical and allocative efficiency also affect farm level technical and allocative efficiency. The variables that are hypothesized to influence farm level production efficiency in the Ethiopian context (Assefa, 1995; Getachew, 1995) are: AGE (the age of the household head); RWEDUC (dummy for literacy of the household head in terms of reading and writing); PREDUC (dummy for attendance of primary education); CASHCR (amount of cash credit obtained); FARMSZ (the size of cultivated land in hectares); EXTNSN (the number of visits to a farmer by an extension agent during the cropping season); PARTCPN (the number of years the farmer participated in previous extension programs); HHLABR (household labor availability in man equivalents); LSTKUNT (livestock ownership in Livestock Units); OFINCM (amount of off-farm income obtained by the household); CERPULS (percentage of cultivated area allocated to the cereal-pulse cropping system) for Babile; MZPOT (percentage of cultivated area allocated to the maize-potato cropping system) for Meta; and MKTDIST (distance to the district market in walking minutes).

5.4.2 The Empirical Results

The maximum-likelihood (ML) estimates of the parameters of the stochastic frontier production function are presented in Table 5.5. The ordinary least squares (OLS) estimates of the average production functions are also presented for comparison. The OLS estimates are only slightly different from the ML estimates in the case of the participant farmers in the wet highland zone of Meta while the differences between the two estimates become substantial in the case of non-participant farmers in Meta and the aggregate sample in Babile. This is a preliminary indication of the relatively lower level of technical efficiency among the non-participants in Meta and the aggregate sample farmers in Babile, because a higher similarity in the two estimates is actually associated with higher technical efficiency. The use of the SFPF is justified by the presence of the one-sided inefficiency term in the production function that is not accounted for in the traditional average production functions. From this it follows that as long as output variations among farmers due to inefficiency are believed to be negligible, there is little or no reason to expect the OLS estimates of the average production function and the ML estimates of the SFPF to be different.

A common stochastic frontier model for all farmers in each of the districts, irrespective of whether they participated in NEP, was estimated to see if the two samples of farmers actually used different technologies. Using the generalized likelihood ratio (LR) test (Coelli and Battese, 1996), the aggregate model for Babile could not be rejected while the corresponding model for Meta was strongly rejected[6]. This indicates that while the participant and non-participant farmers actually used different production technologies in the wet highland zone, those in the dry land zone used homogenous technologies. This confirms the serious shortage of improved technologies for Babile, as is the case with other moisture-stressed agro-climatic zones (Bezabih, 2000). Therefore, the aggregate model for Babile was chosen as the preferred model to predict the efficiency indices for both groups of farmers.

Table 5.5: OLS and ML estimates of the alternative crop production functions

	Meta				Babile	
	Participants		Non-Participants		Aggregate	
Variable	OLS estimates	ML estimates	OLS estimates	ML estimates	OLS estimates	ML estimates
Intercept	6.174*** (19.414)	6.632*** (19.785)	5.624*** (10.968)	6.013*** (12.146)	6.069*** (19.053)	6.615*** (24.374)
ln (Land)	0.262*** (3.372)	0.330*** (3.774)	0.884*** (2.500)	0.747** (2.095)	0.415*** (3.477)	0.433*** (3.631)
ln (Labor)	0.179*** (2.669)	0.171** (2.011)	0.309** (2.183)	0.256* (1.787)	0.145*** (2.990)	0.183*** (3.812)
ln (Fertilizer)	0.140** (2.152)	0.118** (2.105)	0.069 (1.168)	0.063 (0.971)	0.141*** (3.991)	0.098** (1.936)
ln (Materials)	0.111*** (3.028)	0.092** (2.454)	0.044 (0.738)	0.075 (1.208)	0.089 (1.031)	0.058 (0.796)
R^2	0.82		0.60		0.70	
Function Coefficient		0.703		1.141		0.772
λ		4.146* (1.715)		2.332* (1.624)		2.729*** (2.513)
σ_u^2		0.978		0.195		0.283
σ_v^2		0.006		0.036		0.038
Log-likelihood		12.64		-12.919		-39.57

Notes: *** = significant at 0.01 level; ** = significant at 0.05 level; * = significant at 0.1 level.
Figures in parentheses represent asymptotic t-ratios.

Source: Own computation.

As expected, the output elasticities of all variables are positive in all SFPF specifications. Land has the highest output elasticity in the study areas especially in Meta among the non-participant farmers who are cultivating extremely small plots of land (Table 5.4) with the result that they seem to operate in an irrational production zone. For participants in Meta, all input variables are positive and highly significant in determining crop production. For non-

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[6] The LR test-statistic for the null hypothesis of aggregate function is equal to 8 for Babile and 12 for Meta compared to 9.5, the 95 percent χ^2 critical value with 4 degrees of freedom.

participants in Meta, who have no access to input credit and can neither afford to buy adequate amounts fertilizer and chemicals, these variables are not statistically significant.

The estimate of the variance parameter, λ, is significant in the SFPF of both participant and non-participant farmers in both districts implying that the inefficiency effects are significant in determining the level and variability of crop production in the study areas. Therefore, variation in food crop output level across farmers is mainly due to factors under their control and not to the random factors beyond their control like weather and disease.

The dual frontier cost function for participant farmers in Meta, derived analytically from the stochastic production frontier shown in Table 5.5, is derived as

$$\begin{aligned}\ln C_i = -7.107 + 0.464 \ln w_A + 0.240 \ln w_L + 0.166 \ln w_F \\ + 0.129 \ln w_M + 1.406 \ln Y_i^* .\end{aligned} \tag{5.20}$$

The dual cost frontier for non-participants in Meta is given as

$$\begin{aligned}\ln C_i = -4.132 + 0.655 \ln w_A + 0.225 \ln w_L + 0.055 \ln w_F \\ + 0.065 \ln w_M + 0.876 \ln Y_i^* .\end{aligned} \tag{5.21}$$

The dual cost frontier for all sample farmers in Babile is given as

$$\begin{aligned}\ln C_i = -7.445 + 0.561 \ln w_A + 0.236 \ln w_L + 0.127 \ln w_F \\ + 0.075 \ln w_M + 1.295 \ln Y_i^* .\end{aligned} \tag{5.22}$$

where C_i is the minimum cost of production of the i^{th} farmer; Y_i^* is the index of output adjusted for any statistical noise and scale effects; w_A is the seasonal rent of a hectare of land estimated at 1000 Birr/ha for Meta and 600 Birr/ha for Babile; w_L is the wage rate estimated at 7 Birr/day; w_F is the price of fertilizer estimated at 2.75 Birr/kg; and w_M is the price index of seeds and chemicals estimated at 1.5 Birr/kg.

5.4.2.1 Farm Level Efficiency Estimates

Using the cost frontiers and average input prices, the scale-adjusted[7] technical, allocative, and economic efficiency indices are computed for each producer. The frequency distributions and summary statistics of these indices for participant and non-participant farmers in NEP are presented in Tables 5.6 and 5.7.

Table 5.6: Crop production efficiency distributions in Meta

	TE		AE		EE	
Level (percent)	Number of farmers (percent farmers)		Number of farmers (percent farmers)		Number of farmers (percent farmers)	
	Participants	Non-participants	Participants	Non-participants	Participants	Non-participants
<50	-	5(11)	-	4(9)	9(17)	13(28)
51-60	6(11)	5(11)	3(6)	2(4)	13(24)	8(17)
61-70	5(10)	7(15)	8(15)	1(2)	21(40)	11(23)
71-80	11(21)	12(25)	22(41)	4(9)	10(19)	10(21)
81-90	25(47)	16(34)	15(28)	12(25)	-	5(11)
91-100	6(11)	2(4)	5(9)	24(51)	-	-
Mean	79 ^{a}	72 ^{a}	80 ^{b}	85 ^{b}	65	63
Minimum	50	37	52	26	36	24
Maximum	97	93	95	99	80	85

$^{a,\,b}$ Means significantly different at 0.05 level.

Source: Own computation.

For participant farmers in Meta, the estimated mean technical, allocative, and economic efficiency indices are 79 percent, 80 percent, and 65 percent, respectively, whereas the corresponding results for non-participants are 72 percent, 85 percent, and 63 percent. The results indicate that both participant and non-participant farmers exhibit comparably high economic inefficiencies due to their low technical and allocative efficiencies in food crop production. Relative to their respective technologies, the participants have, on average, higher technical but lower allocative efficiencies than the non-participant farmers, with the result that both groups have similar economic inefficiencies. The participants and non-participants can gain, respectively, an average crop output growth of 35 percent and 37 percent through

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[7] As the extended efficiency decomposition technique is already demonstrated in the preceding section, the farm level efficiency estimates reported are the scale-adjusted measures.

improvements in both technical and allocative efficiency with their respective technologies. Moreover, the hypotheses of equal technical and allocative efficiencies between the two groups of farmers were rejected, implying that although NEP improved technical efficiency it rather caused considerable allocative inefficiencies among participant farmers in Meta.

Therefore, due to the counteracting impacts of NEP, the hypothesis of equal economic efficiencies could not be rejected, implying that both actually encountered similar levels of economic efficiencies. The results thus suggest that although NEP improved the technical efficiency of participant farmers in Meta, given their improved technology, it rather induced greater allocative inefficiencies and hence didn't impact on overall productive efficiencies.

For participant farmers in Babile, the results in Table 5.7 show that the mean technical, allocative, and economic efficiency indices are 68 percent, 81 percent, and 54 percent, respectively, whereas the corresponding results for non-participants are 66 percent, 84 percent, and 57 percent, indicating substantial economic inefficiencies among both groups of farmers. The hypothesis of equal technical and allocative efficiencies between the two groups of farmers could not be rejected implying that NEP did not impact on technical and allocative efficiency in the dry land zone. Apart from using homogenous technologies, the two groups do not have significantly different technical and allocative efficiencies. Therefore, apart from using homogenous technologies, the two groups do not have significantly different overall productive efficiencies, suggesting that NEP did not have a positive impact on productive efficiency in the dry land zone.

The results in both agro-climatic zones confirm that NEP has had no impact on the productive efficiencies of farmers. The empirical evidence regarding the influence of new technological interventions on technical efficiency is mixed. The positive impact of NEP on technical efficiency in the wet highland zone is in agreement with Seyoum et al. (1998) who found considerably higher technical efficiency of maize production among participants in the SG project compared with the non-participants in eastern Ethiopia. Taylor et al. (1986) also obtained a positive influence, though insignificant, of an agricultural credit program on technical efficiency of farmers in Brazil. On the contrary, Xu and Jeffrey (1998) obtained significantly lower technical efficiency for hybrid rice production in China as compared with conventional rice production while Singh et al. (2000) obtained lower technical efficiency for newly established Indian dairy processing plants after liberalization of the dairy industry compared to the old plants.

Table 5.7: Crop production efficiency distributions in Babile

	TE		AE		EE	
	Number of farmers (percent farmers)		Number of farmers (percent farmers)		Number of farmers (percent farmers)	
Level (percent)	Participants	Non-participants	Participants	Non-participants	Participants	Non-participants
<50	5(10)	8(16)	7(14)	-	14(28)	16(32)
51-60	4(8)	7(14)	1(2)	-	24(48)	15(31)
61-70	16(32)	12(25)	3(6)	3(6)	12(24)	3(6)
71-80	16(32)	9(18)	9(18)	6(12)	-	14(29)
81-90	9(18)	12(25)	23(46)	30(61)	-	1(2)
91-100	-	1(2)	7(14)	9(19)	-	-
Mean	68	66	81	84	54	57
Minimum	23	25	16	32	13	16
Maximum	88	92	99	98	68	88

Source: Own computation.

The negative impact of NEP on allocative efficiency in the wet highland zone is actually consistent with all the above studies. For example, Taylor et al. (1986) obtained a significant negative impact of an agricultural credit program in Brazil on allocative efficiency of participant farmers; Xu and Jeffrey (1998) also obtained significantly lower allocative efficiency for hybrid rice production in China as compared with conventional rice production across all the three regions studied; and Singh et al. (2000) obtained lower allocative efficiency for newly established Indian dairy processing plants after liberalization of the dairy industry compared to the old plants as they needed time to reach full operation, the right choice of products and other managerial skills required for higher performance. Therefore, the negative (or lack of) impacts of new establishments and interventions on overall productive efficiency obtained in this and other studies are generally attributed to the considerably high allocative inefficiencies associated with new introductions. An extension service that is provided by small numbers of poorly trained staff with inadequate technical knowledge of either new technology or local innovative practices, in the face of growing numbers of farmers being encompassed in NEP over the years, coupled with poor credit, inefficient input supply systems, and lack of appropriate and adequate technology for most cereal crops

(Mulat, 1999), especially for the dry land zone, may hinder the effectiveness of NEP in promoting efficient food crop production.

5.4.2.2 Factors Influencing Farm Level Efficiency

The parameter estimates of the OLS regressions employed to identify the factors influencing farmers' levels of technical and allocative efficiencies in the respective districts are presented in Tables 5.8 and 5.9. For participant farmers in Meta, the results show that technical efficiency of participants is positively and significantly influenced by education, credit, previous participation in extension programs, and the share of the maize-potato system while their allocative efficiency is positively influenced by education, credit, and previous participation in extension programs.

Table 5.8: Determinants of production efficiency of farmers in Meta

Variable	Participants		Non-participants	
	TE	AE	TE	AE
Constant	1.211** (1.982)	0.231* (1.611)	0.523 (1.125)	0.125 (0.658)
AGE	-0.025 (-0.369)	-0.129 (-1.478)	0.036 (1.150)	0.063* (1.854)
EXTNSN	0.032 (1.021)	0.012 (0.055)	0.001 (0.667)	0.003 (0.656)
RWEDUC	0.183** (1.986)	0.088* (1.705)	0.058* (1.670)	0.063* (1.667)
PREDUC	0.021 (1.063)	0.101 (1.535)	0.011 (1.023)	0.028 (1.002)
FARMSZ	-0.321 (-1.012)	0.001 (0.002)	-0.014 (-0.101)	0.014 (1.023)
CREDIT	0.117** (2.116)	0.205** (2.189)	0.082* (1.635)	0.102* (1.852)
PARTCPN	0.201** (2.354)	0.091* (1.820)	0.087 (1.221)	0.033 (1.153)
LSTKUNT	0.01(0.985)	0.066 (1.033)	0.005 (0.036)	0.009 (0.786)
OFINCM	0.012 (1.01)	0.188 (0.963)	0.160 (1.185)	0.005 (1.001)
HHLABR	0.001 (0.687)	0.023 (0.990)	0.001 (0.855)	0.022 (0.881)
MZPOT	0.228 ** (2.132)	0.022 (1.021)	0.174 * (1.812)	0.029 (1.020)
MKTDIST	0.021 (1.212)	-0.034 (-1.425)	0.014 (1.127)	-0.071(-1.188)
R^2	0.72	0.54	0.53	0.51
F	5***	4***	6***	3***

Notes: *** = significant at 0.01 level; ** = significant at 0.05 level; * = significant at 0.10 level.
Figures in parentheses are t -ratios.

Source: Own computation.

The role of credit and education cannot be overemphasized in the effective functioning of NEP. The serious shortage of cash facing the farmers partly due to deteriorating product prices and the demands of new inputs for adequate knowledge of proper utilization have undesirable impact on timely farming operations and optimal input applications, thereby influencing farmers' levels of technical and allocative efficiencies (Ali and Byerlee, 1991; Assefa, 1995). Further, the positive and significant impact of previous participation in extension programs on technical and allocative efficiency confirms the important role of greater experience with new techniques of production in promoting farmers' technical and allocative efficiency under improved technology. This also implies that NEP is likely to enhance the technical and allocative efficiency of farmers in the long run as farmers fully respond to the new demands of the technologies and the program also begins to have better credit and input supply systems.

For non-participant farmers in Meta, the results show that technical efficiency is positively and significantly influenced by education, credit, and the share of the maize-potato system while their allocative efficiency is positively and significantly influenced by age, education, and credit, indicating that traditional farmers make better technical and allocative decisions if they acquire basic education, have greater experience with traditional technology, and have better access to credit. However, unlike in the case of the participants, previous participation in extension programs does not significantly influence the technical efficiency of non-participant farmers. This is mainly because these farmers have rarely benefited from extension programs in view of their poor access to sufficient amount of land to allocate for the application of new technology, poor awareness of the benefits of new technology, serious cash constraints to settle down payments for input credit, and their highly risk averse behavior (Assefa, 1995).

Furthermore, even when farmers happen to participate in previous programs, they do not seem to apply new methods and cultural practices they acquired through programs and projects to their own traditional crops in the subsequent years after 'graduation'. For instance, farmers destroyed soil conservation structures following the phasing out of projects and also continued planting traditional maize by broadcasting instead of planting in rows which they practiced while growing improved maize. They are generally little prepared to take advantage of new techniques learnt to improve their efficiency in traditional crops production, and neither could they continue using improved technology to improve their efficiency in food production due to the serious supply constraints especially of improved seeds which are only rationed through NEP (Mulat, 1999).

Farmers practicing the maize-potatoes cropping systems are also technically superior in view of more efficient use of land through appropriate intercropping. Although not significant, extension visits, household labor, primary education, off- farm income, and livestock ownership have a positive influence on technical and allocative efficiency of farmers in Meta. The mixed impact of market distance is not clear, however. While it has a negative impact on allocative efficiency as expected, its positive influence on technical efficiency in Meta is unexpected, however. Nevertheless, it has no significant impact either on technical or allocative efficiency partly because of little variation among the sample farmers in terms of distance from the district town in view of the homogeneity of the villages based on which they were selected.

Table 5.9: Determinants of production efficiency of farmers in Babile

Variable	Participants		Non-participants	
	TE	AE	TE	AE
Constant	2.195***(3.698)	2.103*** (5.223)	3.101*** (3.589)	1.523** (2.325)
AGE	0.029 (1.135)	0.071* (1.655)	0.044 (1.201)	0.102* (1.944)
EXTNSN	0.071 (1.178)	0.023 (1.02)	0.087 (1.457)	0.149 (1.052)
RWEDUC	0.095* (1.825)	0.108** (2.078)	0.067* (1.626)	0.121** (2.005)
PREDUC	0.132 (1.452)	0.021 (1.077)	0.021 (1.142)	0.022 (1.014)
FARMSZ	-0.028 (-1.014)	0.033 (1.025)	-0.014 (-0.101)	0.027 (1.110)
CREDIT	0.017 (0.116)	0.022 (1.350)	0.002 (0.833)	0.103 (1.425)
PARTCPN	0.037 (1.256)	0.049 (1.057)	0.087 (1.921)	0.009 (0.981)
LSTKUNT	-0.021 (-1.211)	0.038 (1.422)	-0.005 (-0.036)	0.004 (0.861)
OFINCM	0.128* (1.950)	0.092* (1.735)	0.260** (2.268)	0.092* (1.967)
HHLABR	0.092 (1.015)	0.025 (1.273)	0.113 (1.481)	0.002 (0.699)
CERPULS	0.119**(2.070)	0.002 (0.989)	0.233*** (3.568)	0.011 (1.089)
MKTDIST	-0.011 (-1.058)	-0.102 (-1.512)	-0.027 (-1.201)	-0.020 (-1.114)
R^2	0.61	0.57	0.56	0.49
F	10***	4.5**	7***	3.6**

Notes: *** = significant at 0.01 level; ** = significant at 0.05 level; * = significant at 0.10 level.
Figures in parentheses are *t* -ratios.

Source: Own computation.

For both participant and non-participant farmers in Babile, the results in Table 5.9 show that their technical efficiency is positively and significantly influenced by education, the share of the cereal-pulse system, and off-farm income, whereas their allocative efficiency is positively and significantly influenced by age, education and off-farm income. Although not significant, while previous participation in extension programs, credit, extension visits, and household labor have a positive influence, market distance has a negative influence on the technical and allocative efficiency of farmers in Babile. Although insignificant, livestock ownership negatively influences technical efficiency but has a positive impact on allocative efficiency. The negative influence on technical efficiency may be due to the competitive nature of crop and livestock production under conditions of serious feed shortages where farmers have to feed livestock through heavy thinning and defoliation (Storck et al., 1997) or have to travel long distances in search of feed, thereby delaying critical cropping operations. The positive influence on allocative efficiency may be due to the fact that the income generated from more livestock keeping activity helps relieve the liquidity constraints farmers face to acquire adequate amounts of inputs such as fertilizer at the right time.

The results also confirm that the cereal-pulse system in Babile offers opportunities for higher technical efficiency in crop production. This cropping system is mainly practiced to manage the risk of crop failure due to drought and to increase production per unit area through soil fertility improvement, better control of pests and diseases and more efficient use of land. Further, the results confirm the positive impact of off-farm income on technical and allocative efficiency in crop production probably through its influence on timely and adequate use of new inputs like fertilizer.

The available off-farm employment opportunities in Babile such as petty trade, charcoal selling, and food-for-work programs greatly relieve farmers' liquidity constraints enabling them to buy inputs such as fertilizer, to settle down payments for fertilizer acquired from NEP, and to acquire food during critical times of food shortage, thereby maintaining the productive capacity of the household (Bezabih, 2000). The significance of off-farm income as opposed to credit also confirms the critical shortage of both formal and informal credit in the area probably due to the low repayment capacity of farmers and the consequent loan defaults as a result of frequent crop failures.

5.4.3 Conclusions

The participant and non-participant farmers in the two agro-climatic zones have considerable overall productive inefficiencies, suggesting the existence of immense potentials for enhancing production through improvements in efficiency with available technology and resources. In the wet highland zone, the participants in the program used a superior technology and have higher technical but lower allocative efficiencies than the non-participant farmers, relative to their respective technologies, with the result that both groups exhibited greater and comparable overall productive inefficiencies. Therefore, the results show no evidence of impact of NEP on production efficiency in the wet highland zone. In the dry land zone, apart from using homogeneous technology, the two groups of farmers do not have significantly different technical and allocative efficiencies and hence they exhibit similar overall productive efficiencies. Therefore, NEP has had no positive impact on overall productive efficiency of farmers in the dry land zone. An investigation of the influence of several socio-economic and institutional factors on efficiency revealed that education, credit, previous participation in extension programs, off-farm income, and the share of the leading cropping system in each zone have a positive impact on efficiency.

CHAPTER 6

EMPIRICAL ANALYSIS OF RESOURCE USE EFFICIENCY AND PRODUCTIVITY OF ALTERNATIVE CROPPING SYSTEMS IN EASTERN ETHIOPIA

6.1 Introduction

In eastern Ethiopia, smallholder farmers respond to the increasing pressure on land and the risks associated with drought and pest infestation by adopting a variety of cropping systems and management practices. These systems evolved over time depending on changing circumstances including population pressure, agro-climatic changes, and new agricultural technologies (Storck et al., 1991). For instance, it has been observed that improved maize and sorghum are intercropped with both annual and perennial cash crops (Bezabih, 2000). Cropping patterns such as sole and intercropping of annual crops and intercropping of annual and perennial crops are practiced by farmers to varying degrees of complexity as part of the their strategy to cope with dwindling land resources, pest and disease problems, and risks of crop failure.

Variations in these cropping systems and practices are observed at the farm as well as at plot levels. Whilst several socio-economic and institutional factors that affect farm level performance can be observed and analyzed at the farm level, that is not the case with plot-level management practices and cropping systems, which are so complex even within one farm with several fragmented plots (Storck et al., 1997). Many agronomic practices are measurable only at plot-level and the identification of the management practices, which are believed to explain much of the resource use efficiency gap is possible only through productivity analysis of cropping systems.

Current research efforts both in Ethiopia and elsewhere fail to consider variations in cropping systems and management practices at plot level in conducting efficiency analysis, thereby investigating only the very general (at best at farm level) social and economic factors impeding efficient production in agriculture. Consequently, the influence of farm management practices that are observable only at plot level on resource use efficiency largely remains unexplained. This study compares the resource use efficiency of alternative cropping systems and technologies in both the dry land and the wet highland zones using interspatial total factor productivity analysis.

6.2 Cropping Systems and Land Use in the Study Area

Adoption of alternative cropping systems by farmers in the study area is mainly dictated by land availability and the objectives of the farm household (Storck et al., 1991; Bezabih, 2000). Farmers' choice of the types of crops and cropping systems involve complex decisions. The decision of what combination of cash and food crops to produce depends on land availability, primacy of food self-sufficiency, and the managerial skills of the farmers (Storck et al., 1997; Bezabih, 2000). Farmers' choice of a cropping system involves the following decisions: 1) What food to produce for own consumption? 2) What land area is needed to produce enough food for the family? 3) How to partition available land to produce other crops for some cash income either in sole or intercropped systems? 4) Which cash crops to produce? 5) How to allocate available land, labor and other farm resources between seasons for satisfaction of the household subsistence needs and generation of a surplus to trade for cash? This complex decision process also involves managing a risk factor given the unreliable weather conditions under which farmers operate. Farmers with different land endowments face different constraints on their choice of a suitable cropping system. To capture the influence of differing land constraints and other factors on farmers' choices of types of crops and cropping systems the sampled households were classified into small, medium, and large farms. Land constraints are more critical in Meta, the wet highland zone, than in Babile, the dry land zone although available land is generally continually declining and scarce resource in both areas.

Accordingly, a wide range of crops and cropping systems are adopted in the two districts reflecting farmers' strategy to minimize crop failure, intensify production in face of the increasing pressure on land, and overcome the increasing losses due to crop pests and diseases, among others. The most widely grown cereal in Babile is sorghum whereas maize is the leading cereal in Meta. The fact that maize and sorghum are the main food staples in the respective districts reflects the influence of the crop suitability factor as sorghum is more adapted to the marginal conditions of Babile while maize suits better the high potential lands of Meta. The two crops are grown both as sole crops and intercrops in a variety of combinations with other crops (see Tables 6.1 and 6.2).

Farmers with smaller land areas in Babile tend to resort to more intercropping (43.8 percent and 37.5 percent in combinations of beans, sorghum and maize) than medium and large farms

(Table 6.1). On the other hand, sole cropping tends to increase with farm size for all types of sorghum and maize (local and improved). This reflects the need to intercrop on smaller farms as less land is available for sole cropping. Farm size also influences the choice of production technology as more medium and large farms use improved sorghum and maize seeds while all small size farms use local land races. Availability of land also determines how much area to use for cash crops, which significantly increases with farm size (see, for instance, groundnuts and khat, the main cash crops in the area, in Table 6.1).

Table 6.1: Percentage of farmers practicing major cropping systems in Babile

Cropping system	Small farms (< 1 ha)	Medium farms (>=1ha <=2 ha)	Large farms (>2 ha)	All farms
Groundnut/Local sorghum	6.3	3.3	-	3
Khat	31.3	62.3	82.6	62
Local Maize/Local sorghum	37.5	18	17.4	21
Haricot beans/Improved maize	-	4.9	21.7	8
Groundnut	37.5	95.1	95.7	86
Local sorghum	31.3	62.3	78.2	61
Khat/Groundnut	6.3	1.6	8.7	4
Local/Local sorghum	-	6.6	34.8	12
Local maize	12.5	19.7	26.1	20
Improved maize	-	14.8	56.5	22
Khat/local maize	6.3	4.9	4.3	5
Improved sorghum	-	3.3	17.4	6
Local/Local maize/Local sorghum	43.8	10.2	17.4	16
Local/local maize	6.3	3.3	-	3
Improved maize/local sorghum	-	1.6	4.3	2
Improved/Improved maize/Local sorghum	-	1.6	4.3	2

Source: Own survey.

As mentioned earlier, being the food staple, maize is grown by all farmers in Meta either as sole or intercropped (Table 6.2). Like in the case of Babile, more medium and large farms use improved seed than small farms, which may simply be explained by the financial inability of small farmers to purchase seed and hence tend to use their own. Nevertheless, significant proportions of the medium and large farms continue to use local maize varieties, possibly for their non-yield traits (taste, color, etc). The most intercropped system is maize-potatoes with larger percentage of small farmers (35.3 percent) intercropping compared to medium (23.5 percent) and large farms (6.7 percent), again confirming the influence of land availability on the choice between sole crops and intercrops.

Due to the bimodal nature of the rainfall in Meta, farmers grow barley and potatoes during the short rainy season and other crops during the long rainy season. Potatoes are also intercropped with other cereals during the long rainy season. Almost all sample farmers in Meta produced Irish potatoes either sole cropped during the short rains or intercropped with other annuals during the long rains. Irish potatoes are produced either for sale or for own consumption during critical times of food shortages in the wet highland zone. As large farmers can afford to allocate land to barley and potatoes during the short rains beginning February/March, once maize has been planted during that period, most of them grow barley (60 percent) and potatoes (53.3 percent) as sole crops that release land for wheat and beans to be planted during the long rains beginning June/July, once more confirming the importance of land availability in determining the choice of cropping systems.

Table 6.2: Percentage of farmers practicing major cropping systems in Meta

Cropping system	Small farms (< 0.5 ha)	Medium farms (>=0.5ha <1 ha)	Large farms (>=1 ha)	All farms
Khat	2.9	7.8	6.7	6
Local Maize/ Local Sorghum	11.8	13.7	13.3	13
Local sorghum	-	5.9	20	6
Local maize	32.4	41.2	66.7	42
Improved maize	26.5	33.3	53.3	34
Khat/local maize	-	11.8	13.3	8
Local/Local maize/Local sorghum	-	3.9	6.7	3
Barley	29.4	31.4	60	35
Tef	-	9.8	26.7	9
Potatoes	5.9	13.7	53.3	17
Beans	17.6	11.8	20	15
Wheat	8.8	23.5	33.3	20
Improved maize/Potatoes	5.9	13.7	6.7	10
Khat/Local maize/Potatoes	8.8	11.8	13.3	11
Local Maize/Potatoes	35.3	23.5	6.7	25

Source: Own survey.

6.3 The Analytical Framework

Partial productivity measures such as yield per hectare (land productivity) or output per person (labor productivity) are applied in most productivity analyses. However, such productivity measures can be misleading if considerable input substitution occurs as a result of widely differing input prices due to market imperfections. Although partial productivity measures provide insights into the efficiency of a single input in the production process, they mask many of the factors accounting for observed productivity differentials. A conceptually superior way of estimating productivity, and thus resource use efficiency, is to measure total factor productivity (TFP) defined as the ratio of aggregate outputs to aggregate inputs used in the agricultural production process.

There are two basic approaches to the measurement of productivity: the growth accounting approach, which is based on index numbers, and the parametric approach, which is based on an econometric estimation of the production, cost, or profit functions. In this paper we use the index number approach for three reasons. First, with the index number approach, detailed data on many input and output categories can be used regardless of the number of observations over time, which implies less problems with degrees of freedom or statistical reliability in working with small samples. Second, there is no need to aggregate outputs into a single index, thus avoiding input-output separability assumptions. Finally, under certain technical and market conditions, the econometric and index number approaches are equivalent. Advances in growth accounting theory have shown that non-parametric methods do indeed impose an implicit structure on the aggregate production technology (Diewert, 1976; Denny and Fuss, 1983).

The major difficulty with the index number approach is to derive the aggregate output and input measures that represent the numerous inputs and outputs involved in most production processes. Earlier approaches to TFP measurement used a Laspeyres or a Paasch weighting system where base period prices were used as aggregation weights. However, the Laspeyres and Paasch indexing procedures are inexact except when the production function is linear and all inputs are perfect substitutes in the relevant range (Christensen, 1975; Diewert, 1976). The most popular indexing procedure is the Divisia index, which is exact for the homogenous translog aggregator functions (Capalbo and Antle, 1988). The translog function does not require that inputs be perfect substitutes, but rather permits all marginal productivities to adjust proportionally to changing prices. Hence the prices from both production systems being compared enter the Divisia index to represent the differing marginal productivities. There have been relatively few applications of this in the context of cropping systems. Ehui and Spencer (1993) used an interspatial and intertemporal TFP to measure the sustainability and economic viability of alternative farming systems in Nigeria. Gavian and Ehui (1999) used an interspatial TFP to measure the production efficiency of alternative land tenure contracts in the Arsi area of Ethiopia.

This study analyzes the interspatial TFP, land productivity, and factor intensities of alternative cropping systems and technologies in eastern Ethiopia. The study adapts the methodology of Denny and Fuss (1983) proposed for measuring the intertemporal and interspatial TFP and that of Caves, Christensen, and Diewert (1982) proposed for a productivity comparison of several production units. Assume that the agricultural production process in land held under cropping system j can be represented by the production function

$$Y_j = Y(X_{nj,}D_j)\,, \qquad (6.1)$$

where Y_j is the output level of cropping system j, j=1,2,..., J. X_{nj} is a vector of factor inputs n for cropping system j, and D_j is a vector of dummy variables for every cropping system other than the reference base cropping system which, in a multilateral setting, is not fixed and rather changes whilst deriving the TFP measure for a given system with respect to every other system. D_j denotes also the interspatial efficiency difference indicators. Equation (6.1) assumes that the production function in each cropping system has common elements as well as differences resulting from the cropping pattern maintained by the additional argument D_j. Suppose that we wanted to know the difference between the level of output on land held under cropping system j and on land held under cropping system k. Diewert's (Diewert, 1976) Quadratic Lemma is useful for the transformation of the production function for comparisons of several production units at a given time. Diewert's Quadratic Lemma basically states that if a function is quadratic, the difference between the function's values evaluated at two points is equal to the average of the gradient of the function evaluated at both points multiplied by the difference between the points $F(Z^1) - F(Z^0) = \frac{1}{2}\left[F(Z^1) + F(Z^0)\right]^r (Z^1 - Z^0)$, where $F(Z^r)$ is the gradient vector of F evaluated at Z^r, $r = 0{,}1$. Application of Diewert's Quadratic Lemma to a logarithmic approximation of equation (6.1), in a multilateral setting, gives

$$\begin{aligned}
\Delta \ln Y &= \left[\left(\ln Y_j - \overline{\ln Y}\right) - \left(\ln Y_k - \overline{\ln Y}\right)\right] \\
&= \frac{1}{2}\sum_n \left[\left(\left.\frac{\partial \ln Y}{\partial \ln X_n}\right|_{X_n = X_{nj}} + \overline{\left(\frac{\partial \ln Y}{\partial \ln X_n}\right)}\right)\right]\left(\ln X_n\big|_{X_n = X_{nj}} - \overline{(\ln X_n)}\right) \\
&\quad - \frac{1}{2}\sum_n \left[\left(\left.\frac{\partial \ln Y}{\partial \ln X_n}\right|_{X_n = X_{nk}} + \overline{\left(\frac{\partial \ln Y}{\partial \ln X_n}\right)}\right)\right]\left(\ln X_n\big|_{X_n = X_{nk}} - \overline{(\ln X_n)}\right) \qquad (6.2) \\
&\quad + \frac{1}{2}\left[\left.\frac{\partial \ln Y}{\partial D_j}\right|_j + \left.\frac{\partial \ln Y}{\partial D_j}\right|_k\right]\left(D_j - D_k\right),
\end{aligned}$$

where the interspatial or cropping system effect is defined as

$$\eta_{jk} = \frac{1}{2}\left[\left.\frac{\partial \ln Y}{\partial D_j}\right|_j + \left.\frac{\partial \ln Y}{\partial D_j}\right|_k \right]\left(D_j - D_k\right). \tag{6.3}$$

Constant returns to scale and perfect competition in the input and product markets imply that $\left(\frac{\partial \ln Y}{\partial \ln X_n}\right) = s_n$, where the term s_n represents the cost share for the n^{th} input.

Using these assumptions, we can rewrite equation (6.2) as

$$\begin{aligned} \Delta \ln Y = & \frac{1}{2}\sum_n \left[\left(s_{nj} + \overline{s_n}\right)\right]\left(\ln X_n|_{X_n = X_{nj}} - \overline{\left(\ln X_n\right)}\right) \\ & - \frac{1}{2}\sum_n \left[\left(s_{nk} + \overline{s_n}\right)\right]\left(\ln X_n|_{X_n = X_{nk}} - \overline{\left(\ln X_n\right)}\right) \\ & + \eta_{jk} \end{aligned} \tag{6.4}$$

From equation (6.4) the output differential across cropping systems may be broken down into an input effect and a cropping system effect. Let A denote the land input so that equation (6.4) can be rewritten as

$$\begin{aligned} \Delta \ln\left(\frac{Y}{A}\right) = & \frac{1}{2}\sum_n \left[\left(s_{nj} + \overline{s_n}\right)\right]\left(\ln\left.\left(\frac{X_n}{A}\right)\right|_{X_n = X_{nj}} - \overline{\left(\ln\left(\frac{X_n}{A}\right)\right)}\right) \\ & - \frac{1}{2}\sum_n \left[\left(s_{nk} + \overline{s_n}\right)\right]\left(\ln\left.\left(\frac{X_n}{A}\right)\right|_{X_n = X_{nk}} - \overline{\left(\ln\left(\frac{X_n}{A}\right)\right)}\right) \\ & + \eta_{jk}, \end{aligned} \tag{6.5}$$

where $\Delta \ln\left(\frac{Y}{A}\right)$ denotes the change in land productivity levels. The first expression on the right hand side of equation (6.5) denotes the weighted sum of differences in factor intensities. Let's define this expression as

$$\psi_{jk} = \frac{1}{2}\sum_{n}\left[\left(s_{nj}+\overline{s_n}\right)\right]\left(\ln\left(\frac{X_n}{A}\right)\Bigg|_{X_n=X_{nj}} - \overline{\left(\ln\left(\frac{X_n}{A}\right)\right)}\right)$$

$$-\frac{1}{2}\sum_{n}\left[\left(s_{nk}+\overline{s_n}\right)\right]\left(\ln\left(\frac{X_n}{A}\right)\Bigg|_{X_n=X_{nk}} - \overline{\left(\ln\left(\frac{X_n}{A}\right)\right)}\right) \qquad (6.6)$$

The difference in land productivity can therefore be decomposed into two effects: (i) a factor intensity effect ψ_{jk} and (ii) a cropping system effect η_{jk}. If we want to measure the resource use efficiency levels across cropping systems, we rearrange the terms to isolate the cropping system effect as

$$\eta_{jk} = \left[\left(\ln\left(\frac{Y_j}{A}\right) - \overline{\ln\left(\frac{Y}{A}\right)}\right) - \left(\ln\left(\frac{Y_k}{A}\right) - \overline{\ln\left(\frac{Y}{A}\right)}\right)\right]$$

$$-\frac{1}{2}\sum_{n}\left[\left(s_{nj}+\overline{s_n}\right)\right]\left(\ln\left(\frac{X_n}{A}\right)\Bigg|_{X_n=X_{nj}} - \overline{\left(\ln\left(\frac{X_n}{A}\right)\right)}\right) \qquad (6.1)$$

$$-\frac{1}{2}\sum_{n}\left[\left(s_{nk}+\overline{s_n}\right)\right]\left(\ln\left(\frac{X_n}{A}\right)\Bigg|_{X_n=X_{nk}} - \overline{\left(\ln\left(\frac{X_n}{A}\right)\right)}\right).$$

The expression η_{jk} is the Tornqvist-Theil approximation (Capalbo and Antle, 1988) to the change in productivity levels due to the type of cropping system. The difference in the TFP of two systems is a function of the differences in land productivities and factor intensities. Factor intensities are the weighted sum of differences in the levels of the variable inputs applied per unit of land. Equation (6.1) indicates that there are two components that contribute to any observed differences in TFP. First are the changes in the level of land productivity. This is the major component underlying TFP differences. Second are changes in factor intensities. TFP is therefore the residual, or the portion of the change in output levels that is not explicitly explained by changes in input levels. However, increases in factor intensities may occur without any increase in TFP. Changes in TFP levels and factor intensities are not independent but they are of different significance. Increases in TFP will occur if land productivity increases proportionally more than the increases in factor intensity levels. But increases in land productivity that are due to increases in factor intensities are qualitatively (although not quantitatively) less significant than changes in TFP. Indeed land productivity will increase if a farmer applies more purchased inputs. Unless there are improvements in the use of these inputs, this will be a change in factor intensity and not TFP. It is clear that with TFP changes, in contrast with factor intensity differentials, the farmers' capability to produce more with the same resources has improved.

6.4 Data and Empirical Procedures

As clearly described in Chapter 4, data were collected from the 200 sample households through frequent visits to their crop fields to take plot-level measurements and observations throughout the 2001/2002 cropping season. The sampled households operated a total of 960 plots: 477 plots in Babile and 483 plots in Meta, where a plot was defined as a distinct management unit due to the farmer's choice to plant a unique crop or an intercrop on it. Input data were collected on a fortnight basis by asking the farmer to recall his/her activities on that particular plot during the past two weeks. Data included the quantities of seed and fertilizer used, labor time disaggregated by source, gender, age, and field operation and other miscellaneous inputs. The prices of all purchased inputs were also collected during this time. Output data on all the quantities of cereals, pulses, and oil crops harvested from each plot were recorded. A separate survey was conducted to collect output price information from Muti, Chelenko and Babile markets during planting and harvesting times of the major crops. Moreover, area measurements were taken in square meters from each plot with assistance from the farmers themselves and these were later converted to hectares.

For the purposes of this analysis, the different types of cropping systems were hypothesized to have different effects on the structure of production in the two agro-climatic zones in eastern Ethiopia. Given that the various cropping systems had multiple and dissimilar crop outputs and inputs, it was necessary to aggregate the varying inputs and outputs into meaningful categories. All crop outputs in each cropping system were aggregated into a single output index except in the case of sole cropped systems where the quantity of output in kg was considered. An implicit output quantity index was derived by deflating the value of all crops from a given cropping system by the weighted price index of crop outputs, the weights being the share of each crop output in total revenue. Inputs were aggregated into four categories: Labor, Oxen, Fertilizer (manure, DAP, UREA), and Seed. The indices of fertilizer and seed (for intercropped systems) were derived by deflating the value of all inputs in a given category by the weighted price index of inputs using the cost shares of each input involved as weights.

The markets for labor and oxen are, however, thin in the study area and may pose a problem of aggregation if one has to rely on observed wages for human labor and observed rents for oxen. Nevertheless, most of the sample farmers in the study area actually faced shortage of oxen and human labor but got assistance through the well-established tradition of labor- and oxen-exchange arrangements in their villages except that they had to actually provide adequate meals and khat with *hodja* (i.e., boiled coffee with or without milk) for the exchange labor (or *guza*) and feed for the exchange oxen. These were the actual costs facing sample farmers and their estimates obtained from the farmers were used as prices in this study. The prices used for the rest of the fertilizer and seed inputs were those obtained during the survey at planting time while output prices used were averages of the prices at harvesting and planting times. For manure, the price estimate of 0.15 Birr/kg for the Hararghe highlands by Storck et al. (1991) was used for this study.

6.5 The Empirical Results

The total factor productivity estimates along with the land productivity and factor intensity levels of the alternative cropping systems in Babile and Meta districts are presented in Tables 6.3 and 6.4, respectively. The productivity estimates, unlike their bilateral counterparts, allow us to compare a given cropping system with all other cropping systems. The results reveal considerable variation in total factor productivity, and thus resource use efficiency, among cropping systems in both agro-climatic zones. This means that much of the variation in resource use efficiency at farm level could be explained more by this variation in cropping systems.

In Babile, the cereal-pulse system performed better than the system with intercropped annuals, sole cropped annuals, and annual-perennial intercrops. The *haricot beans-improved maize* cropping system has turned out to be the most efficient system followed by the *haricot beans-local maize-local sorghum* cropping system. The later conforms with the practices of small farmers as the *haricot beans-local maize-local sorghum* is their dominant (43.8 percent) cropping system (Table 6.1) followed by the local maize-local sorghum (37.5 percent), which also gave high performance in terms of TFP (Table 6.3).

However, these results did not correspond to the actual practices of medium and large farmers, who chose sole cropping of cash crops (groundnuts and khat- Table 6.1) as well as sole food crops (local sorghum and improved maize) as their dominant cropping systems. As observed earlier, land availability for sole cropping is a key determinant of cropping system choices and possible reason behind such deviation. One should note, however, that sole cultivation of improved maize (ranking third in TFP) is a very dominant system (56.5 percent) among large farmers in Babile (Table 6.1). Regardless of its high productivity, the cereal-pulse system involving improved maize was not the dominant choice among farmers in Babile.

Sole cropping is generally a less efficient cropping strategy even in the case of improved crop varieties in Babile. For instance, the *haricot beans-improved maize* system is 40 percent more efficient than the sole *improved maize* system, indicating considerable efficiency gain from new technology through intercropping with pulses. However, improved sorghum is among the least efficient systems, even less than the local sorghum system, implying that new varieties of sorghum promoted in Babile are not that superior. While the results clearly show the dominance of maize (especially improved maize) over sorghum if productivity considerations are important, more farmers are growing sorghum (especially local) than maize. This may be due to the fact that local sorghum cultivars are more tolerant to drought that characterize this zone than improved maize (guaranteeing more stable harvest). Moreover, farmers tend to apply more purchased inputs such as fertilizer (see Table 6.3) to sole and intercropped sorghum plots than to maize plots in view of the relatively higher risk of maize crop failure (Bezabih, 2000). This confirms the importance of hedging against risk elements in farmers' choices of cropping systems when high production risks are involved such as in the dry land zone of Babile.

In Meta district, the results show that maize and potatoes (intercropped or sole) are the most efficient cropping practices (Table 6.4). These are also the dominant practices in this zone with improved maize more common among large farms versus local maize among smaller farms (Table 6.2). Table 6.2 shows that the maize-potatoes system, which is most efficient in Meta is more prevalent in small farms than in the medium and large farms implying that small farms use their highly scarce resources more efficiently than those facing less land constraints.

Table 6.3: Total factor productivity estimates for cropping systems in Babile

Cropping system	TFP	Land Productivity	Factor intensity	Labor	Oxen	Fertilizer	Seed
Groundnut	1.3710	1.1059	0.8066	0.7302	0.1846	0.0780	0.0072
Groundnut-Local sorghum	1.6848	1.3283	0.7884	1.1414	0.2886	0.1219	0.0113
Haricot beans-Improved maize	2.8560	2.1713	0.7603	0.5162	0.2098	0.0025	0.0781
Haricot beans-Improved maize-Local sorghum	1.5070	1.9359	1.2846	0.4414	0.2236	0.0578	0.0656
Haricot beans-local maize	0.9242	1.2655	1.3693	0.4455	0.2194	0.0866	0.0088
Haricot beans-Local maize-Local sorghum	2.7324	2.7770	1.0163	0.8767	0.3466	0.0475	0.0137
Haricot beans-Local sorghum	1.4060	1.9289	1.3719	0.7857	0.4677	0.1084	0.0075
Improved maize	1.9453	1.3917	0.7154	0.6382	0.2900	0.0764	0.0117
Improved maize-local sorghum	1.3698	1.5758	1.1504	0.8500	0.3794	0.1294	0.0130
Improved sorghum	1.0741	1.2904	1.2013	0.4247	0.2143	0.0690	0.0073
Khat-Groundnut	1.0000	1.0000	1.0000	0.7754	0.3537	0.0076	0.0137
Khat-local maize	0.7513	1.1743	1.5631	0.8003	0.3257	0.0683	0.0070
Local maize	1.1916	1.0782	0.9048	0.5617	0.2441	0.0897	0.0093
Local maize-Local sorghum	1.7656	1.8255	1.0339	0.6840	0.2805	0.0546	0.0149
Local sorghum	1.1557	1.3966	1.2085	0.7467	0.3388	0.1110	0.0120

Source: Own computation.

Moreover, apart from existing land constraints, input supply shortages and unavailability of credit make adoption of improved varieties more difficult for small farms and consequently they fail to take advantage of the higher efficiency and productivity of such technology. Therefore, inefficiencies among small farms may be considered exogenous, in general (i.e., part of the inefficiencies of the extension and credit systems that fail to adequately cater for their needs).

Although sole *improved maize* has turned out to be the second efficient, sole cropping is generally limited in Meta due to the critical land shortages in the wet highland zone compared to the dry land zone (Babile). The *improved maize-potatoes* system is 26 percent more efficient than the sole *improved maize* system, indicating considerable efficiency gain from new technology through intercropping with potatoes. On the other hand, intercropping of cereals with perennial cash crops such as khat is an inefficient practice. Furthermore, sorghum and the small cereals like wheat, barley, and tef have turned out to be among the least efficient cropping practices in Meta. This is probably due to the fact that less fertile degraded land is allocated to these crops in the wet highland zone that are highly eroded. It was observed during the survey that relatively more fertile plots were planted to maize while sloppy and degraded plots were planted with small cereals. Moreover, there are generally no improved technologies promoted in the wet highland zone to improve the productivity of these crops.

6.6 Conclusions

This chapter investigated the resource use efficiency of alternative cropping systems and technologies in two distinct agro-climatic zones in eastern Ethiopia. The total factor productivity, land productivity, and factor intensity levels of 15 cropping systems in the dry land zone and 14 cropping systems in the wet highland zone were derived. The results indicated considerable variation in resource use efficiency among the cropping systems in both areas, confirming that part of the variation in resource use efficiency at farm level could be explained by the variation in cropping systems.

The results for both study areas implied that as land and other resources become increasingly limiting and agricultural production highly conditioned by weather, farmers have greater incentives for pursuing more efficient cropping practices. When land available to a household is too small to produce subsistence requirements from sole cropping and risk considerations become increasingly important, farmers tend to intercrop in order to produce sufficient food for the household and hedge against production risks. But if sufficient land is available to support subsistence requirements, the farmer resorts more to sole cropping of both food staples and cash crops even though those may not be the most efficient. A good example is the production of groundnuts as a cash crop in Babile, which is especially common among large farmers in spite of its low efficiency, implying that efficiency considerations may be undermined by objectives of cash generation.

Table 6.4: Total factor productivity estimates for cropping systems in Meta

Cropping system	TFP	Land Productivity	Factor intensity	Labor	Oxen	Fertilizer	Seed
Barley	1.0000	1.000	1.000	0.1969	0.7032	0.0717	0.0281
Beans	0.7100	0.690	0.970	0.2211	0.6810	0.0443	0.0236
Haricot beans-Local maize-Local sorghum	1.3100	1.440	1.100	0.5620	0.4749	0.0182	0.0449
Improved maize	1.6800	3.750	2.230	0.5114	1.4032	0.2815	0.0339
Improved maize-Potatoes	2.1200	5.130	2.420	0.7076	1.2752	0.3287	0.1084
Khat-local maize	1.0800	2.100	1.940	1.3402	0.5609	0.0065	0.0323
Khat-Local maize-Potatoes	1.2000	3.010	2.510	0.8327	1.6159	0.0299	0.0315
Local maize	1.1300	1.930	1.720	0.5198	1.1303	0.0558	0.0140
Local maize-Local sorghum	1.3500	2.280	1.690	0.8698	0.7159	0.0818	0.0225
Local Maize-Potatoes	1.6100	2.420	1.500	0.4780	0.9229	0.0827	0.0165
Local sorghum	0.7400	1.100	1.480	0.7949	0.5855	0.0860	0.0136
Potatoes	1.9200	2.800	1.460	0.2631	1.0454	0.0731	0.0784
Tef (Eragrostis Tef)	0.4200	0.600	1.420	0.4568	0.8620	0.0851	0.0160
Wheat	1.1100	1.460	1.320	0.3343	0.7411	0.2152	0.0294

Source: Own computation.

CHAPTER 7

CONCLUSIONS AND IMPLICATIONS FOR RESEARCH AND POLICY

The objective of this study was to assess the role of new production technologies and Ethiopia's New Extension Program in promoting efficiency of production in eastern Ethiopia. As part of the agricultural development-led industrialization development strategy, the Ethiopian government introduced the New Extension Program based on the experiences of the Sasakawa-Global 2000 project. The rapid expansion of the program has taken place at a time of major changes in markets, policies, and institutions affecting the agricultural sector. It is now argued that agricultural production has shown considerable improvement over the 1970s and 1980s during which policies were against smallholder farming. Despite the growing number of farmers encompassed in the New Extension Program over the years and the increased use of improved technologies, however, cereal yields remained low. There has been a growing concern about the effectiveness of the extension program in enhancing new technology utilization and raising production efficiency.

There are a considerable number of studies that have dealt with the technical efficiency of farmers in developing countries. However, only very few studies have analyzed the technical as well as allocative and economic efficiencies. These studies employed the stochastic efficiency decomposition technique. However, this technique involves scale biases arising from imposing an input-orientated framework on the output-orientated stochastic production frontier results. The resulting efficiency estimates will either overestimate or underestimate the true measures depending on the returns to scale associated with the production technology and are thus inconsistent.

This study employed an extended efficiency decomposition technique that accounts for scale effects to analyze smallholders' technical, allocative and economic efficiencies under traditional and improved production technologies in eastern Ethiopia. Specifically, the extended efficiency decomposition approach was employed to assess the impact of improved maize technologies on the efficiency of maize production and the impact of the New Extension Program on farmers' overall technical, allocative, and economic efficiency. Socio-economic and institutional factors influencing farmer efficiency were also analyzed both at crop and farm levels. Further, to assess cropping system performance and its role in smallholders' production efficiency, resource use efficiencies of alternative cropping systems and technologies were derived and innovative practices identified using total factor productivity analysis.

The study used data obtained from a survey of two sample households, participants and non-participants in the New Extension Program, in two districts of East Hararghe Zone in eastern Ethiopia. Meta and Babile districts were selected to represent distinct agro-climatic zones in eastern Ethiopia. Two hundred farm households, one hundred households from each district consisting of a comparable group of participants and non-participants, were intensively surveyed for the entire 2001/2002 agricultural year. Data collection was accomplished in three major phases identified based on the major cropping operations in the respective districts, including land preparation and planting, weeding and cultivation, and harvesting and threshing of the major food crops.

7.1 Conclusions

Despite a positive impact of improved maize technology on maize production efficiency, the results indicated considerable inefficiencies of production under both traditional and improved technology. For traditional maize production, the study obtained mean technical, allocative, and economic efficiency estimates of 68 percent, 83 percent, and 56 percent, respectively. The corresponding results for hybrid maize production were 78 percent, 77 percent, and 61 percent. This indicated the possibilities of raising traditional maize production by an average 44 percent and that of hybrid maize by 39 percent through full efficiency improvement. While much of the production inefficiency in traditional maize production is attributed to technical inefficiency, the production inefficiency in hybrid maize production is equally attributed to technical and allocative inefficiencies. In other words, improvement in technical efficiency of traditional maize production needs a priority attention as it provides a significant source of growth in maize output.

The results support the argument that adopters of improved technologies encounter substantial technical and allocative inefficiencies due to their lack of familiarity with new technologies and failure to adjust quickly to new production and market conditions. Although there are technical and allocative inefficiencies associated with both traditional and improved maize technology, allocative inefficiencies under traditional technology are not significant relative to those associated with improved technology, which are considerably higher. Further, although improved technology has a slightly positive impact on technical efficiency, relative to traditional technology, a considerable potential for increased maize production remains to be exploited through raising technical efficiency. The study further revealed that education, access to credit, and greater security of tenure are the key determinants of the efficiency of maize production.

The analysis of overall farm level production efficiency revealed that both participant and non-participant farmers in the two agro-climatic zones have considerable overall productive inefficiencies. In the wet highland zone, the participants in the program used a superior technology and have higher technical but lower allocative efficiencies than the non-participant farmers, relative to their respective technologies. This indicated that both groups of farmers exhibited greater and comparable overall productive inefficiencies. In the wet highland zone, the participant farmers' mean technical, allocative, and economic efficiency levels were estimated at 79, 80, and 65 percent, respectively, and the corresponding results for non-participants were 72 percent, 85 percent, and 63 percent. This implied that participants and non-participants can achieve, respectively, an average 35 percent and 37 percent growth in food production through full technical and allocative efficiency improvements. This indicated that the New Extension Program has had no impact on production efficiency in the wet highland zone.

In the dry land zone, the participant and non-participant farmers used homogeneous production technologies, confirming the serious shortage of appropriate technologies for the low moisture areas. In the dry land zone, the participant farmers' mean technical, allocative, and economic efficiency levels were estimated at 68 percent, 81 percent, and 54 percent, respectively. The corresponding results for non-participants were 66 percent, 84 percent, and 57 percent. The results suggest that the participants and non-participants can achieve, respectively, an average 46 percent and 43 percent growth in food production through full technical and allocative efficiency improvements. Further, apart from using homogenous technologies, the two groups do not have significantly different technical and allocative efficiencies. The results thus indicated that the New Extension Program has had no positive impact on production efficiency of farmers in the dry land zone.

On average, the participant and non-participant farmers in the wet highlands zone have higher production efficiencies than their counterparts in the dry land zone. This indicated the low productivity in the dry land zones mainly due to poor support services such as extension, credit, input supply, and adverse climatic conditions. A regression analysis of the determinants of efficiency revealed that education, credit, previous participation in extension programs, and the share of the maize-potatoes cropping system positively influence production efficiency in the wet highland zone. In the dry land zone, on the other hand, education, off-farm income, and the share of the cereal-pulse cropping system have a positive impact on efficiency.

The results from the productivity analysis indicated considerable variation in resource use efficiency among the cropping systems in both areas. This confirmed that part of the variation in resource use efficiency at farm level could be explained by the variation in cropping systems practiced. The results showed, in general, that as land and other resources become increasingly limiting and agricultural production highly conditioned by weather, farmers have greater incentives for pursuing more efficient cropping practices. When land available to a household is too small to produce subsistence requirements from sole cropping and risk considerations become increasingly important, farmers tend to intercrop in order to produce sufficient food for the household and hedge against production risks. But if sufficient land is available to support subsistence requirements, the farmer resorts more to sole cropping of both food staples and cash crops even though those may not be the most efficient.

The results suggest that farmers pursue objectives other than higher yield levels, such as satisfaction of subsistence needs and risk management (i.e., stability of yield) in making their cropping system choices. For instance, while cropping systems involving maize were superior to sorghum in terms of productivity, sorghum systems are widely practiced in the dry land zone due to higher tolerance to drought under the prevailing unreliable weather conditions. On the other hand, intercropping of maize with potatoes showed the highest efficiency advantages over other cereals (wheat and tef) and potatoes combinations in the wet highland zone. In both areas, improved crop varieties such as improved maize appeared superior when planted as sole crops or intercropped with other crops. Intercropping of these varieties with potatoes in the wet highland zone and with pulses like haricot beans in the dry land zone offers the largest benefits. This confirmed the critical role of integrating improved production technologies into the traditional farming systems.

7.2 Implications for Research and Policy

The results of this study provided empirical evidence of the positive impact of new maize technologies on maize production efficiency. However, the study found no evidence of impact of Ethiopia's New Extension Program on the overall food production efficiency of smallholder farmers. It may yet be difficult to draw definite policy recommendations based on these results. This is because of the fact that the study was based on limited macro level data and cross-sectional data covering only one production year. Nevertheless, the results could still be very informative for re-designing agricultural development strategies aimed at raising the productivity of smallholder agriculture through technological change. The results could help design appropriate strategies to enhance the effectiveness and relevance of improved technology to the priority needs of the various agro-climatic zones in the country. Based on the results obtained, therefore, some important policy implications and recommendations can be drawn.

Greater availability and accessibility of appropriate agricultural production technologies for all ago-climatic zones is very crucial. This could help enhance the efficiency of smallholder agriculture and the effectiveness of the New Extension Program. Despite the emphasis on raising agricultural productivity and food security through improved technologies in all zones, there is actually a serious shortage of improved and appropriate crop technologies especially for the dry lands. This lack of appropriate technology has in turn undermined the role and effectiveness of the New Extension Program. This is because it is narrowly organized and properly functions only when there are appropriate and adequate packages of technologies to be promoted. Therefore, generation and adaptation of appropriate cereal technologies such as high-yielding and drought-resistant crop varieties for the dry lands would yield greater benefits in terms of increased food crop production and productivity.

The substantial inefficiency of production under both traditional and improved technology indicated the availability of ample opportunities to raise food crop production with existing technology. Therefore, given the country's existing capacity constraints to modernize agriculture, a feasible short term strategy to raise food production would be to raise the efficiencies of production under both traditional and improved technology. To properly tap the potentials implied by higher inefficiencies, agricultural development policies and strategies need to be redesigned to provide adequate support services to smallholder agriculture to help improve the efficiency of the agricultural and food systems in general. Agricultural research, extension, education, credit, and input supply systems need to respond to the technological, financial, infrastructural, and market demands of smallholder food production.

Policies and strategies that improve access to rural education, credit and inputs, and off-farm employment opportunities could help raise the efficiency of food production. Appropriate policies need to be designed to provide adequate and effective basic educational opportunities to the rural farming households. Extension services are poor mainly due to the poor technical and communication skills of the extension agents coupled with limited availability of trained agents. There is thus an urgent need for upgrading the quality and adequacy of the extension services. This could be done mainly through better pre-service as well as in-service training schemes for a greater number of extension staff in line with the agricultural development strategy that places emphasis on raising smallholder agricultural productivity. Further, given the complementarity of education and extension services, expansion of basic and functional educational provisions in the rural areas must also be considered a key strategy for achieving increased smallholder agricultural productivity.

This study provided evidence of the critical role of credit and off-farm income in raising efficiency of production. These enable timely and adequate use of new inputs like fertilizer and improved seeds in the face of serious liquidity constraints facing smallholder farmers. The existing off-farm employment opportunities, especially in the dry land zone, greatly relieve farmers' liquidity constraints. Off-farm incomes enable them to buy critical inputs, to settle the down payments for input credit, and to acquire food during critical times of food shortage, thereby maintaining the productive capacity of the household. Farmers have little or no access to both formal and informal credit, especially in the dry land zones, where there are frequent crop failures and consequent loan defaults. Strategies that strengthen existing off-farm employment opportunities would thus help enhance the use of improved technologies. Raising farmers' access to formal production credit in the short run may not be as feasible under the current production technology that fails to hedge against crop failures due to climatic shocks. In the long term, increased access to formal credit could be combined with the generation and promotion of more appropriate crop technologies especially for the dry land zone.

The complex and innovative traditional farming systems in eastern Ethiopia have evolved over time in response to changing agro-climatic and demographic conditions. The productivity of these systems has yet been greatly undermined by adverse climates and frequent shocks. Agricultural research and extension must thus play a greater role in generating, adapting, and integrating new technologies into such systems in order to raise their productivity.

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Appendices

Appendix A4.1: Conversion factors for man equivalent (ME)

Age group (Years)	Male	Female
<10	0.0	0.0
10-13	0.2	0.2
14-16	0.5	0.4
17-50	1.0	0.8
>50	0.7	0.5

Source: Storck et al. (1991, p. 188).

Appendix A4.2: Conversion factors for adult equivalents (AE)

Age group (Years)	Male	Female
<10	0.6	0.6
10-13	0.9	0.8
14-16	1.0	0.75
17-50	1.0	0.75
>50	1.0	0.75

Source: Storck et al. (1991, p. 188).

Appendix A4.3: Conversion factors for Livestock Units

Animals	Livestock Unit	Animals	Livestock Units
Calf	0.25	Donkey (Young)	0.35
Weaned Calf	0.75	Camel	1.25
Cows and Oxen	1.00	Sheep and Goat (Adult)	0.13
Horse	1.10	Sheep and Goat (Young)	0.06
Donkey (Adult)	0.70	Chicken	0.013

Source: Storck et al. (1991, p. 188).