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

by

AREGA DEMELASH ALENE

Submitted in partial fulfillment of the requirements for the degree of

PhD

in
Agricultural Economics

in the
Department of Agricultural Economics, Extension, and Rural Development
Faculty of Natural and Agricultural Sciences
University of Pretoria
Pretoria

August 2003
Dedication

This work is dedicated to my mother Aynadis Ayichew.
Acknowledgements

Several individuals and institutions have contributed to the successful completion of this study. I would like to thank them all for assisting me in the course of undertaking the study and in writing this thesis. I am highly indebted to my promoter, Professor Rashid Hassan, who took an active interest in this study and has been a continuous source of encouragement. I am very grateful to him for the confidence he gave me and for his valuable ideas, suggestions, and constructive comments that have helped to considerably improve the thesis. He has been very enthusiastic and open-minded and his moral as well as intellectual support at all stages of the research work is sincerely appreciated. I also would like to express my sincere gratitude to Professor Johann Kirsten for his valuable ideas and encouragement during his supervision of my fieldwork. I have also enjoyed his intellectual and moral support during my stay at the University of Pretoria.

In the course of collecting the data, I enjoyed the support of a number of enumerators and assistants. I am very grateful to all of them. I am particularly indebted to the farmers who took their valuable time to share their knowledge and experiences with us throughout the year without whose cooperation this study would have been impossible. Special thanks are due to Dr. Belay Kassa and Dr. Jeff Mutimba for their immense moral and intellectual support in the course of undertaking the study. My sincere gratitude also goes to Prof. Dr. Manfred Zeller, Dr. Atakely Hailu, Dr. Mulat Demeke, Dr. Bezabih Emana, Dr. Assefa Admassie, and Getu Hailu whose ideas and suggestions highly contributed to the successful accomplishment of the study. I must also thank my colleagues Dr. Tesfaye Baye, Shimelis Hussein, Getachew Animut, Tesfaye Lemma, Edilegnaw Wale, Tekalign Tsegaw, Yoseph Beyene, Getu Beyene, Yoseph Assefa, and Jemal Yousuf for their support and encouragement in the course of undertaking the study.

Last, but not least, I am highly indebted to Alemaya University for financing my studies.

AREGA DEMELASH ALENE

August 2003
Improved production technology and efficiency of smallholder farmers in Ethiopia: Extended parametric and non-parametric approaches to production efficiency analysis

by

AREGA DEMELASH ALENE

Degree: PhD
Department: Agricultural Economics, Extension and Rural Development
Promoter: Professor Rashid M Hassan

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.
TABLE OF CONTENTS

Acknowledgements........................................................................................................... i
Abstract................................................................................................................................... ii

CHAPTER 1
INTRODUCTION

1.1 Background to the Study ................................................................................................. 1
1.2 Motivation and Nature of the Research Problem ......................................................... 2
1.3 Objectives of the Study .................................................................................................. 5
1.4 Significance of the Study for Policy, Research, and Extension Services ................. 7
1.5 Organization of the Thesis............................................................................................... 8

CHAPTER 2
DEVELOPMENT STRATEGIES AND THE PRODUCTIVITY OF SMALLHOLDER
AGRICULTURE IN ETHIOPIA

2.1 Introduction...................................................................................................................... 9
2.2 Development Strategies During the Socialist Period (1975-1990) ............................ 11
  2.2.1 Socialist Organization of Agricultural Production................................................. 11
  2.2.2 Agricultural Development Programs and Productivity of Smallholders .......... 13
    2.2.2.1 The Package Agricultural Development Program ........................................ 13
    2.2.2.2 The Peasant Agricultural Development Program ......................................... 14
    2.2.2.3 Arsi Comprehensive Rural Development Program ......................................... 15
  2.2.3 Impediments to Smallholder Agricultural Productivity ....................................... 15
    2.2.3.1 Pricing and Marketing of Agricultural Produce............................................ 16
    2.2.3.2 Credit, Extension Services, and Input Distribution ...................................... 17
  2.2.4 Agricultural Sector Performance ......................................................................... 19
2.3 Current Development Strategies ................................................................................. 20
  2.3.1 Agricultural Development-led Industrialization Strategy .................................. 21
    2.3.1.1 The Sasakawa-Global 2000 Project .............................................................. 21
CHAPTER 3
PRODUCTION EFFICIENCY: CONCEPTS, APPROACHES TO MEASUREMENT, AND EMPIRICAL APPLICATIONS

3.1 Introduction .................................................................................................................. 34
3.2 Components of Production Efficiency ............................................................................. 34
3.3 Production Technology and Sources of Output Growth .................................................. 35
3.4 The Efficiency Hypothesis ............................................................................................... 36
3.5 Efficiency under New Technology .................................................................................. 39
3.6 Causes of Economic Inefficiency ................................................................................... 40
3.7 Approaches to Efficiency Measurement ........................................................................... 41
3.7.1 Deterministic Frontiers ............................................................................................... 43
3.7.1.1 Non-parametric Programming ................................................................................. 43
3.7.1.2 Parametric Programming ......................................................................................... 47
3.7.1.3 Statistical Frontier .................................................................................................. 48
3.7.2 The Stochastic Frontier Production Function ............................................................. 51
3.7.3 Stochastic Frontier Efficiency Decomposition ............................................................ 55
3.8 Empirical Applications of Production Frontiers ............................................................... 57

CHAPTER 4
CASE STUDY AREA, SURVEY DESIGN, AND SELECTED SOCIO-ECONOMIC CHARACTERISTICS OF THE SAMPLE HOUSEHOLDS

4.1 Introduction ................................................................................................................... 61
4.2 The Hararghe Highlands ................................................................................................. 61
4.3 Description of the Case Study Areas .............................................................................. 64
CHAPTER 5

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

5.1 Introduction ........................................................................................................... 83
5.2 The Analytical Framework ...................................................................................... 84
  5.2.1 The Stochastic Efficiency Decomposition Methodology ................................... 85
  5.2.2 A Consistent Approach to Efficiency Decomposition ....................................... 86
5.3 Empirical Analysis of Maize Production Efficiency of Smallholders Under Traditional and Improved Technology .......................................................... 91
  5.3.1 Data and Empirical Procedures ......................................................................... 92
  5.3.2 The Empirical Results ....................................................................................... 95
    5.3.2.1 Maize Production Efficiency Estimates ......................................................... 97
    5.3.2.2 Factors Influencing Maize Production Efficiency ........................................ 101
  5.3.3 Conclusions ...................................................................................................... 104
5.4 Empirical Analysis of Overall Farm Level Production Efficiency of Smallholders ............................................................................................................. 105
  5.4.1 Data and Empirical Procedures ......................................................................... 106
  5.4.2 The Empirical Results ....................................................................................... 110
    5.4.2.1 Farm Level Efficiency Estimates .................................................................. 113
    5.4.2.2 Factors Influencing Farm Level Efficiency ............................................... 116
  5.4.3 Conclusions ...................................................................................................... 119
CHAPTER 6
EMPIRICAL ANALYSIS OF RESOURCE USE EFFICIENCY
AND PRODUCTIVITY OF ALTERNATIVE CROPPING SYSTEMS IN EASTERN ETHIOPIA

6.1 Introduction ................................................................................................................. 121
6.2 Cropping Systems and Land Use in the Study Area ................................................... 122
6.3 The Analytical Framework ......................................................................................... 124
6.4 Data and Empirical Procedures ................................................................................ 129
6.5 The Empirical Results ............................................................................................... 130
6.6 Conclusions ............................................................................................................... 133

CHAPTER 7
CONCLUSIONS AND IMPLICATIONS FOR RESEARCH AND POLICY

7.1 Conclusions ............................................................................................................... 137
7.2 Implications for Research and Policy ...................................................................... 140
References .................................................................................................................. 143
Appendices .................................................................................................................. 155
LIST OF TABLES

Table 2.1: Average growth rates and sectoral shares in GDP ............................................ 25
Table 4.1: Indicators of the farming systems in East Hararghe Zone .................................... 63
Table 4.2: Sample farm households by district and PA ........................................................ 69
Table 4.3: Family structure and labor force of the sample farmers (mean) .......................... 72
Table 4.5: Distribution of the sample farmers by farm size (percent) ................................ 74
Table 4.6: Livestock holding of the sample households ....................................................... 76
Table 4.7: Distribution of oxen among the sample households ............................................ 77
Table 4.8: Distribution of labor use by source (man-days) .................................................. 80
Table 4.9: Per hectare labor input for the major cropping systems (man-days/ha) ............... 82
Table 5.1: OLS and ML estimates of the alternative maize production functions ................. 96
Table 5.2: Scale-adjusted and conventional maize production efficiencies .......................... 102
Table 5.3: Factors influencing efficiency of maize production in Meta ................................ 103
Table 5.4: Summary statistics of the variables used in the efficiency analyses ..................... 107
Table 5.5: OLS and ML estimates of the alternative crop production functions .................. 111
Table 5.6: Crop production efficiency distributions in Meta ............................................. 113
Table 5.7: Crop production efficiency distributions in Babile ........................................... 114
Table 5.8: Determinants of production efficiency of farmers in Meta ................................ 116
Table 5.9: Determinants of production efficiency of farmers in Babile ............................... 118
Table 6.1: Percentage of farmers practicing major cropping systems in Babile ................. 123
Table 6.2: Percentage of farmers practicing major cropping systems in Meta ..................... 124
Table 6.3: Total factor productivity estimates for cropping systems in Babile .................... 132
Table 6.4: Total factor productivity estimates for cropping systems in Meta ....................... 135
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Sectoral growth rates.</td>
<td>26</td>
</tr>
<tr>
<td>2.2</td>
<td>Trends in smallholder fertilizer use and prices.</td>
<td>27</td>
</tr>
<tr>
<td>2.3</td>
<td>Trends in improved seed utilization by major crop and sector.</td>
<td>28</td>
</tr>
<tr>
<td>2.4</td>
<td>Trend in productivity of food grains.</td>
<td>29</td>
</tr>
<tr>
<td>2.5</td>
<td>Trend in per capita food production.</td>
<td>31</td>
</tr>
<tr>
<td>2.6</td>
<td>Share of food aid and domestic production in food supply.</td>
<td>32</td>
</tr>
<tr>
<td>4.2</td>
<td>Amount of annual rainfall in Babile.</td>
<td>65</td>
</tr>
<tr>
<td>4.1</td>
<td>Maps of Oromia region and East Hararghe Zone.</td>
<td>66</td>
</tr>
<tr>
<td>5.2</td>
<td>Distribution of scale-adjusted and conventional technical efficiency.</td>
<td>99</td>
</tr>
<tr>
<td>5.3</td>
<td>Distribution of scale-adjusted and conventional economic efficiency.</td>
<td>100</td>
</tr>
</tbody>
</table>
# Acronyms and Abbreviations

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