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ECONOMIC EFFICIENCY AND RETURNS TO SCALE OF COMMUNAL AREA AGRICULTURE IN ZIMBABWE AND IMPLICATIONS FOR AGRARIAN REFORM

By

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ABSTRACT

ECONOMIC EFFICIENCY AND RETURNS TO SCALE OF COMMUNAL AREA AGRICULTURE IN ZIMBABWE AND IMPLICATIONS FOR AGRARIAN REFORM

By

Bernard Kupfuma

The first half of the twentieth century saw the creation of a dualistic agrarian structure in Zimbabwe with European settlers occupying the choicest land while the indigenous population was displaced into marginal areas. There is a large body of literature that supports the inverse relationship between farm size and efficiency, implying that the small, low-input communal area farms could be more efficient than the large commercial farms. But unavailability of data, among other reasons, makes it impossible to compare the efficiency levels of communal area and commercial farms.

To determine the options for alleviating poverty in the communal areas, this study seeks to establish the nature of returns to scale and level of economic efficiency of communal area farms. Then household characteristics, resource endowments and other farm-level factors are used to explain the variation in farm-level measures of economic inefficiency. Generalized, multi-product translog cost functions were found to be more appropriate than production functions in handling the data collected by the Ministry of Agriculture during the 1988/89, 1989/90 and 1992/93 seasons.

The estimated cost functions exhibited decreasing returns to scale. A one percent increase in all inputs would increase output by about 0.34, 0.25 and 0.72 percent during the seasons 1988/89, 1989/90 and 1992/93, respectively. This suggests that there are

increasingly limited productivity gains if the supply of all farm inputs is raised at current technology levels.

Measures of economic inefficiency were obtained from cost frontiers estimated assuming the distribution of the one-sided error term to be half-normal or exponential. The average measures of economic inefficiency for the three seasons were between 11 and 27 percent. The minimum and maximum values were 10 to 13 percent, 12 to 46 percent and 10 to 21 percent for 1988/89, 1989/90 and 1992/92, respectively. Thus, on average, a program to eliminate inefficiency on communal farms would reduce costs by 16 percent which is unlikely to significantly change living standards in communal areas. Household characteristics, resource endowments and farm-level factors were not significant in explaining the variation in farm-level inefficiency. These results supported the recommendation that a carefully planned and targeted technology development and transfer program is needed to raise productivity and incomes in Zimbabwe's communal areas.

DEDICATION

Happias, My Dearest Brother

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I: BACKGROUND AND INTRODUCTION

1.1 Introduction

Zimbabwe's economy is highly dependent on the agricultural sector. The agricultural sector contributed 12.78 percent to the gross domestic product (GDP) during the six-year period 1988 to 1993 (MOA, 1995). But although the contribution to GDP may be less significant, the overall economic performance is highly related to the performance of the agricultural sector. In addition the bulk of the country's population (about 70 percent) resides in the rural areas where they are dependent on agriculture for their livelihood. In terms of direct employment, agriculture (including forestry and fishery) accounts for about 24 percent of people in formal employment. Agriculture also contributed an average of 47.7 percent of the total exports during the period 1981 to 1990 (MOA, 1995).

The agricultural sector is therefore viewed as a strategic sector in national economic planning. The government's objectives for the agricultural sector are to ensure food security, increase export earnings and to improve the economic and social position of small scale farmers and their families. Raising living standards in rural areas is indeed a top priority of the Ministry of Agriculture (MLAWD, 1993). The government's strategy to meet these objectives, among other things, includes the provision of credit and access to input and output markets to small-scale farmers, promotion of appropriate technology development and transfer, resettlement of small scale farmers from overcrowded areas and development of irrigation schemes and other essential physical infrastructure. These efforts are in line with the shift in emphasis from large-scale commercial farming to small-scale agriculture after independence in 1980.

Table 1.1: Percentage Contribution of Small and Large Scale Farmers to Total National Agricultural Output in Zimbabwe, 1983-1992

Year	Small Scale (%)	Large Scale (%)	National Agricultural Output (Million Current ZWD)
1983	16.20	83.80	1,037
1984	19.90	80.20	1,351
1985	30.80	69.20	1,985
1986	28.20	71.80	2,116
1987	19.80	80.20	2,062
1988	27.90	72.10	2,582
1989	24.60	75.40	2,838
1990	28.30	71.70	3,755
1991	19.80	80.20	5,215
1992	14.00	86.00	4,184
Average	23.00	77.00	2,713

Source: Central Statistical Office

The provision of services to the once neglected small scale farmers after 1980 resulted in a major shift in the composition of national agricultural output. The contribution from small scale farmers increased dramatically over the years. In terms of value of total output, the percentage contribution of communal farmers rose from an average of 10 percent during the 1970s to more than 20 percent in the 1980s (MOA, 1995). The percentage contribution of small and large scale farmers to total national output is shown in Table 1.1. During the ten-year period the contribution of small scale farmers remained well above 20 percent. However, during the two-year period, 1991 and 1992, the percentage contribution of small scale farmers to total national agricultural output has shown a declining trend. This could be due to the low rainfall experienced during these years. The continued high frequency of drought years is likely to reinforce this declining trend in the future. The performance of small scale agriculture is highly dependent on rainfall since the bulk of these farmers are found in semi-arid areas[1].

However, the most dramatic change in the composition of national agricultural output after the implementation of the new 1980 government strategy was the increase in the intake of maize and cotton from the small scale farmers as a percentage of total national intakes. The small scale farmers' contribution to national intakes of these two commodities increased from less than 20 percent during the late 1970s and early 1980s to more than 50 percent during the mid 1980s and onwards. However, these impressive achievements, the *independence dividend*, came at some cost as the expansion of the support services that enabled small scale farmers to attain these achievements involved huge financial outlays from the national treasury. The high costs of supporting small scale agriculture raised the question of fiscal sustainability of these programs and therefore led to a rethink on the best ways to spur small scale agricultural growth to increase the well-being of most small scale farmers, especially those in the semi-arid areas.

The Economic Structural Adjustment Program (ESAP) initiated by the government in 1991 to revitalize the economy strived to reduce the high costs of running a controlled economy. In agriculture one of the aims of this program was to reduce the cost of supporting small-scale agriculture using the institutions designed for large-scale commercial agriculture. The program had profound effects on the agricultural sector, particularly small scale

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[1] More than 70 percent of communal areas are in Natural Regions IV and V; agro-ecological regions that have the least average annual rainfall in the country.

agriculture. Under this program the state-controlled agricultural marketing authorities were turned into private companies. However, initially the government owned all the shares of the new companies with the intent of gradually selling them to individuals and private institutions. The government has already given up over 40 percent of the stocks in two commercialized parastatals, the Cotton Company of Zimbabwe and the Dairy Marketing Board.

The provision of services to small scale farmers was adversely affected by the privatization of state corporations. In fact most of the new support services provided to small scale farmers were scaled down if not completely stopped. For instance the number of grain intake points in small-scale farming areas was cut from 148 in 1985 to less than 50 in 1992. Similarly the number of loans by the Agricultural Finance Corporation (AFC) fell from 77,000 in 1986 to 23,000 in 1994. As a result only a few small-scale farmers have access to crop intake points and/or are receiving less AFC credit. Most of these few fortunate farmers are located in the high rainfall areas leaving the bulk of the small-scale farmers without access to these essential services.

Some positive impacts are expected out of the ESAP program. ESAP is expected to create a conducive environment for competition in the purchasing of agricultural inputs and products. This will result in all farmers receiving market prices that are expected to direct resource allocation in agricultural production as dictated by market forces. Questions still linger about how agriculture can benefit from the creation of a competitive environment given the biological nature of agricultural production and the nature of the agricultural products themselves. However, the main political question emerging from this is why should a program that is supposed to boost economic activities to the benefit of all so adversely affect the poorest section of society? Are the nation's interests better served by a system that denies more than 97 percent of impoverished small-scale farmers access to the much needed credit?

These are socio-political questions that ESAP has not yet adequately addressed. Furthermore, it has been observed that farmers in developed economies rely heavily on subsidies for survival while their counterparts in the developing countries are heavily taxed by the state (Bates, 1981). Thus as the Zimbabwean economy modernizes it is expected that the demand for agricultural support services will increase[2].

1.2 The Problem Statement

The impressive performance of the small scale farmers during the early eighties attracted widespread international attention. However, the trend in agricultural production since the mid-eighties has become a major problem for policy makers. During good rainfall seasons the country experiences overflows of grain which are expensive to store. In fact the government asked farmers to cut back on maize production in 1986 following a good growing season. But when the rain is inadequate grain deficits are commonplace necessitating expensive grain imports. Communal area farmers are the most affected group during periods of grain deficits because the majority of them are located in the driest parts of the country. Infrastructure in these low potential areas is not well developed to allow for timely movements of imported grains (Eicher and Kupfuma, 1997). The challenge to policymakers is to find ways and means to ensure food supplies at reasonable cost during both surplus and drought seasons.

Because the bulk of Zimbabwe's communal area population is directly and indirectly dependent on agricultural production for a livelihood, not only is it important to ensure adequate supplies of agricultural commodities but to increase production on a sustainable

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[2] Bates' assessment does not apply to most southern African countries that heavily subsidized agriculture mainly for political reasons. These subsidies could not be maintained and have become the subject of policy reform programs.

basis. The high annual average intercensal rate of population growth of 3.1 percent (1982-1992) dictates that measures should be taken to spur communal area agriculture growth to levels higher than that of the population. In fact over a third of the communal areas were considered overpopulated in 1980 with close to 40 percent having three to five times the estimated carrying capacity of human population (Whitlow, 1980). Thus the major challenge is not only to smoothen the levels of production, but also to increase agricultural productivity to a level that will ensure communal area farming families an acceptable standard of living.

The production problems in communal area agriculture are a product of two policies. First, the advent of European settlers in the 1890s and the introduction of Land Acts of 1931 and 1940 resulted in the forced movement of communal farmers into areas with limited agricultural potential. Then there was a belief that only large scale farms were the best vehicles to modernize the countryside. Small farms were supposed to be consolidated and their previous occupants absorbed in the modern industrial economy. Large scale mechanized farms developed from state subsidies prematurely excluded small farmers from participating in the modernization of agriculture. Communal area farms in Zimbabwe were created to be reservoirs of cheap labor and hence never intended to be productive. Thus the current problem of poverty in Zimbabwe's rural areas is a product of both history and flawed economic development policies. The tragedy is that nothing significant has been done to reverse these past mistakes. In addition there is a dearth of information on communal area agriculture productivity and resource use efficiency. Development programs are designed mainly of the basis of "expert judgement". For instance, the 1980 government emphasis on extension, in terms of financial support, seems to suggest that the perceived problem in communal area agriculture is inefficiency in the use of resources.

Before a far-reaching program to reform communal agriculture can be implemented it is important to empirically assess the efficiency of communal agriculture. The crucial question is whether farmers are using available resources in such a way that there is no other way that these same resources can produce more output. Stated another way, communal area farmers would be efficient if it is not possible to produce current levels of output using less resource than those farmers use. If communal farmers are operating on the efficiency frontier then the focus of development programs should be on expanding the frontier through technology development and transfer and/or land redistribution. If farmers are not using resources efficiently then the main development programs should include the timely provision of inputs, appropriate and targeted technology development and transfer, improvement in the physical infrastructure, and increased access to output markets to enable these farmers to operate as close to the efficiency frontier as possible.

Information on the efficiency of communal agriculture can also be an important input to the debate on the economics of land reform. The crux of this debate is whether it is economic to divide large estates into small farms. Studies elsewhere show that small farms are more efficient than large estates (Johnson and Ruttan, 1994; van Zyl, Binswanger and Thirtle, 1995), . If communal farmers are similarly more efficient than their counterparts on larger farms then a land transfer program would serve both efficiency and equity concerns and bring together "....the moral concern for the welfare of the small cultivator, the technological discovery of his productive efficiency, and the economic ideal of social efficiency in resource allocation..." (Putterman, 1983).

Zimbabwe's communal areas urgently need to be rehabilitated so that the poor rural households can be integrated into the national economy. Indeed the government realizes the need for more efficient use of land as part of plans to change existing patterns of land ownership (MLAWD, 1993). Some communal farming areas are considered overpopulated and productivity there would be significantly improved by a land transfer program (Palmer, 1990). But some researchers also believe that there is considerable scope for increasing productivity in some communal farming areas through improved agricultural management practices (Cliffe, 1989; Muir and Blackie, 1994). There are many ways of putting together a program to rehabilitate communal areas depending on the assumptions made on the efficiency with which farmers use available resources. This assumption has not been tested quantitatively in Zimbabwe making it difficult for anyone to make more informed decisions concerning the improvement of communal area production systems. Policy making and development program and strategies design has been seriously handicapped by the dearth of information on this very critical issue.

1.3 Objectives and Hypotheses of the Study

This study is motivated by the problem of chronic poverty in Zimbabwe's communal farming areas. It is important at the onset to point out that this study is not intended to provide a blueprint on how to eliminate poverty in the country side. A broad based inquiry will be required to accomplish a task of this magnitude. The major objective of this study is to quantitatively assess the economic efficiency of communal farmers in Natural Regions II, III, IV and V in Zimbabwe with the hope that the information generated will be a vital input into the design of economic development programs.

Information on economic efficiency is particularly valuable as an input in programs such as agrarian/land reform. But, as demonstrated later on in this study, economic considerations are not the only determinants of economic development. Some of the most important preconditions for economic development are technological, political, social, historical and sometimes even cultural (Eicher and Kupfuma, 1997). The scope of this study allows us to concentrate only on estimating economic efficiency. Thus the main objective will remain that of measuring the of economic efficiency of communal farms. Because this study would be incomplete without addressing the other important preconditions, the discussion on implications will be broadened to accommodate the other considerations of economic development. Specifically this study has the following objectives:

1. To review the agrarian history of Zimbabwe and the literature on the relationship between farm size and productivity.

2. To describe the general characteristics (demographic, resource endowment and agricultural production practices) of communal farms using the results of a 1990 sample survey.

3. To review the literature on the empirical formulation of the relationship between agricultural output and factors of production and the measurement of relative economic efficiency.

4. To describe the specific characteristics of data collected from communal areas during the 1988/89, 1989/90 and 1992/93 seasons before it is used to estimate translog cost functions and frontier functions.

5. To estimate a generalized multi-product translog variable cost function and use the function to determine the nature of economies of scale.

6. To measure the economic efficiency of communal farmers in Zimbabwe during three seasons; 1989/90, 1990/91 and 1992/93 using a generalized translog multi-product variable cost frontier function.

7. To explain the variations in the estimated farm-level relative economic efficiency using agro-ecological, household and socioeconomic variables.

8. To draw the implications on future technical, economic and institutional reforms aimed at "transforming" communal agricultural production.

To accomplish these objectives a three-year data set will be used covering the seasons 1988/89, 1989/90 and 1992/93. The choice of these seasons was based on the availability of data and considerations about the normality of the seasons. The data for 1991/92 season is not included because this season was quite atypical[3]. If data availability was not a problem, one could have used panel data covering at least five agricultural seasons. This would have hopefully captured the full length of climatic cycles in Zimbabwe.

The following hypothesized relationships will be tested as a way of fulfilling the above objectives of the study:

★ Communal area agricultural production systems in Zimbabwe exhibit constant returns to scale.

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[3] Zimbabwe experienced the severest drought ever recorded in its history during the 1991/92 season.

★ Communal area production systems are economically efficient with an average inefficiency of less than 10 percent.

★ Farm-level economic inefficiency is inversely related to the years of education for household head, years of farming experience, family size, value of farm animals, value of farm implements and amount of remittances from relatives working off-farm.

★ Farm-level economic inefficiency is positively related to farm size in line with the inverse relationship hypothesis.

★ Farmers who use credit, apply manure, winter-plough and buy modern inputs are economically more efficient.

★ Small scale farms in high rainfall areas (Natural Regions II and III) are more efficient than those in the low rainfall areas (Natural Regions IV and V).

★ Farmers cultivating fertile soils (clays and loams) are more efficient than farmers cultivating infertile sandy soils.

In testing the above hypotheses, the following assumptions are explicit.

◆ First, farmers are assumed to be able to choose input quantities and hence the total cost to pay for producing a given level of output. The farmers cannot choose output and input prices because they are exogenously given. As a result the cost function is the best way to model the production decisions as compared to profit and production functions.

◆ Because farmers produce several products and cannot change their factors of production instantaneously, a generalized multi-product translog variable cost function is employed.

1.4 Organization of the Study

This study is divided into eight chapters. The first chapter is a statement of the problem, the objectives of the study and the hypotheses to be tested. In the second chapter the agrarian history of Zimbabwe is outlined and the literature on the relationship between farm size and productivity is reviewed. The third chapter describes the characteristics of communal agricultural production system in detail using the 1990/91 sample survey results. A literature review of the methods of measuring economic efficiency covering issues related to functional form and the justification for using the generalized multi-product translog variable cost function are covered in the fourth chapter. Chapter five outlines the data used in the estimating the generalized multi-product translog variable cost function. The results of diagnostic tests of the data for econometric problems and regularity conditions tests are presented in the sixth chapter. In this chapter multi-product translog variable cost functions are estimated and tests for the presence of economies of scale are performed. The cost frontier functions from which indicators of relative economic efficiency are derived are estimated in chapter seven. This chapter also presents results from relating measures of relative economic efficiency to farm-specific variables. Then a discussion of the implications of the findings based on the observed relationship between relative economic efficiency measures and the explanatory variables is presented. The last chapter is a conclusion of the study and highlights implications of the findings from the study on policy formulation in Zimbabwe. This chapter also identifies future research areas and issues to be emphasized.

CHAPTER II: THE ORIGINS OF THE DUALISTIC AGRARIAN STRUCTURE IN ZIMBABWE

2.1 Agrarian Reform in National Development

Rural poverty alleviation programs receive top priority in national economic development planning. Since the majority of developing nations' population resides and works in rural areas, increasing agricultural productivity is a major component of rural poverty alleviation. While there is considerable controversy on how exactly the pattern of land ownership affects agricultural productivity, it is generally acknowledged that land rights are an important institutional instrument for rural development (Berry and Cline, 1979). What is needed is an agrarian structure that puts people to work (Eicher and Kupfuma, 1997). Over time and across the whole world a lot of energy has gone into the search for that agrarian structure that increase efficiency and farm incomes, eradicate poverty and direct the economies onto a path that is economically, politically and socially sustainable. The main reason why the United States agriculture is probably the most productive in the world is because its family farm-based agrarian structure is inherently efficient (Powelson, 1964).

As early as the early seventies it had become clear that policies that focus solely on capital investment and output maximization could not spur the economies of developing countries because they did not increase the participation of all members of society in productive and socially useful labor (Dorner, 1972). These policies were derived from neo-classical economics which does not take into account the importance of institutions and time in the process of development (North, 1993). This is not solely a result of too much reliance on neo-classical economics but is a result of Cold War politics which considered agrarian reform programs as Marxist-oriented. Now that the Cold War is over, the World Bank development assistance activities, although still very much based on this neoclassical tradition, institutional reforms, now include agrarian reform as an essential components as current "country dialogues" and Eastern European assistance activities indicate (Platteau, 1992).

There are no significant conflicts in defining agrarian reform. Agrarian reform extends beyond land tenure reform where land belonging to one group is taken away and transferred to another group. It includes changes in the "legal or customary system under which land is owned, the distribution of ownership of farm property between large estates and peasant farms or among peasant farms of various sizes, land tenancy, the system under which land is operated and its products divided between the operator and the owner, the organization of credit, production and marketing, the mechanism through which agriculture is financed, the burdens imposed on the rural population by governments in terms of taxation, and the services supplied by governments to rural populations such as technical advice and education facilities, health services, water supply and communications" (Powelson, 1964; p. 65).

Agrarian reform is a continuous process that takes place as part of social change and development. It is an integral part of the whole process of modernization involving the economy, the social structure and cultural development. In Latin America agrarian reform was triggered by some form of political revolution (Alexander, 1974). The extent of the reform process (land reform versus agrarian reform) depends on how the revolution succeeded in weakening the position of the old political power structures. The Zimbabwean case is illustrative in this regard.

This chapter puts the agrarian problem in Zimbabwe into context by reviewing the history of land alienation. This review raises the question of the relationship between farm size and productivity. To answer this question the next section briefly reviews available evidence on the existence of an inverse relationship between farm size and productivity. The last section seeks to answer the question whether it is justified for one to compare the productivity of different farm sizes in Zimbabwe, given the available evidence of the existence of an inverse relationship hypothesis. The experience of Latin American countries in implementing agrarian reform programs is illustrative and will be used to draw some lessons for Southern African countries that are considering agrarian reform options,

2.2 The Agrarian History of Zimbabwe

The history of Zimbabwe is about a struggle for access to land especially after European settlement at the turn of the 19th century. This section seeks to highlight the events that have a profound impact on the development of the agrarian structure. This section reviews the period starting with European settlement in the 1890s and chronicles the process through which a dual agrarian system was developed. We then analyze the efforts of the new majority government since independence in 1980 to reverse the past inequities in land distribution.

2.2.1 Land Alienation: 1890-1980

The agrarian history of Zimbabwe took a dramatic turn with the arrival of European "pioneers" from South Africa in 1890. Initially drawn to the country by reports of large mineral deposits, many new settlers turned to agriculture after failing to find mineral and gold fields as large as speculated in the early pioneers' reports. The initial impact of European settlement was to stimulate surplus production from small-scale indigenous farmers through the creation of markets, infrastructure and the introduction of the ox-plough[4] (Masters, 1994).

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[4] The number of ploughs in use by Africans increased from 940 in 1905; to 16 900 in 1921; to 53 500 in1931 and to 133 000 in 1945 (Arrighi, 1970).

In fact the first two decades of the twentieth century witnessed a phenomenal rise in surplus crop production from the small-scale indigenous farmers (Muir, 1984).

But the new settlers found it difficult to compete with the indigenous population for land and agricultural markets. They lobbied the government to systematically remove communal farmers from the choicest land and shunted them into reserves[5]. This method of creating large estates was similar to experiences in Kenya, South Africa and Latin America (Deininger and Binswanger, 1995; Alexander, 1977). The state helped settler farmers by providing an extensive communication and marketing infrastructure and massive statutory subsidies and "soft" loans (Arrighi, 1970). The system of state marketing boards was created during the 1930's to help the emerging large-scale commercial farmers whose initial focus was on the export market to wrestle the now more lucrative domestic markets from the small scale indigenous family farms. This was done mainly through price discrimination based on racial lines (Muir, 1984).

In addition, during the early years of European settlement, 1900 to 1930s, a system of demonstration farms and experiment stations was established (Arrighi, 1970). They evolved to become the basis of a strong and efficient technology development and transfer system for European settler agriculture. This technology development and transfer system was not designed to serve small scale agriculture and was part of the marginalization of small scale indigenous agriculture. The ultimate aim was to reduce competition from these farmers and force the indigenous population into becoming a labor reservoir for European settler farms, mines and the emerging industrial sector. Thus, most of what is now communal areas

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[5] To allay the British government fears of abuse of indigenous people, the settler state had among many explanations for land alienation that this was done in order to preserve the "native culture" or that indigenous people were accustomed to farming the "thin sandveld" (World Bank, 1986).

were never meant to be productive settlements. It is a product of contradictory policies by the colonial government. On one hand there was a need to reduce competition from Africans in industry as per the dictates of the "parallel development" doctrine while there was also a desire for industrialization through the promotion of the growth of an internal market that involve increased production by Africans (Arrighi, 1970).

Marginalization of small-scale indigenous farmers was accomplished through the passing of several Land Acts (Rukuni, 1994). The Land Apportionment Act of 1931 became the cornerstone of the land policy in the country. This Act sharply reduced the land available to small-scale African farmers. For the first time, land ownership was divided along racial lines. The resultant land distribution pattern is shown in the first column of Table 2.1.

Table 2.1: Zimbabwe; Land Allocations After the Land Acts of 1931, 1951 and 1970 (million hectares).

Category	1931 Act	1951 Act	1970 Act
European Areas	19.67	18.96	18.11
African Communal Areas	8.64	9.99	16.29
African Purchase Areas	2.98	2.26	1.91
Unassigned Land	7.15	5.70	0.00
State Lands	0.24	1.58	2.73
TOTAL	38.68	38.49	39.04

Source: Roth, 1990.

The next significant Land Act did not change the ownership structure significantly. The Land Husbandry Act of 1951 was enacted because of the growing awareness that the reserves were not adequate to support the growing small-scale African farming population.

The potential of the land set aside for small-scale African farmers had been overestimated and the indigenous African population growth underestimated. It also became apparent that the African population could not be absorbed by the expanding European-owned farms, mines and industries. The aim of the Land Husbandry Act was, therefore, to reform African husbandry and turn the African small scale farmers into capitalist entrepreneurs. The distribution of land after the Land Husbandry Act is shown in the second column of Table 2.1. The resultant pattern of land distribution is not significantly different from that which occurred after the 1931 Act. The percentage of land under European areas fell marginally from 51 percent in 1931 to 49 percent after the 1951 Land Husbandry Act.

The administration of the Land Husbandry Act during the fifties and sixties proved difficult as political agitation increased throughout the country[6]. In an attempt to resolve these difficulties, the responsibility of administering the Tribal Reserves (to become known as Communal Areas after independence in 1980) was partially transferred to local authorities with the passage of the Land Tenure Act of 1970. This left the distribution of land at levels shown in the third column of Table 2.1. Again this Act did not significantly alter the agrarian structure established in 1931. The European areas, as a percentage of the total available area, fell marginally to 46 percent. This Act was passed on the understanding that the state could not guarantee every "unborn native" the right to own land. This pattern of land distribution has since been preserved even after independence in 1980. In 1990, large scale farmers owned about a third of the national agricultural land.

These legislative moves were not popular with most of the indigenous population. As a result most of the small-scale farming population popularly and actively supported the

[6] The first shots of the war against colonialism were fired in 1966 near what is now Chinhoyi, 110 km to the north of Harare.

fifteen-year guerrilla war against settler colonialism (Chung, 1989). Land was at the center of this revolution (Moyo, 1995). In the late seventies, the war had escalated to levels that opened the possibility of a negotiated settlement. During the negotiations, two contradictory issues had to be addressed; redistributing land to the landless majority and preserving the "efficient" large-scale commercial farming sector. The short-term effects of a rapid transfer of land to land-hungry small-scale farmers would economically ruin the new nation as experience in Mozambique had shown. In addition there was pressure from Frontline State[7] leaders to accept peace at any cost. In what was considered a "crucial capitulation" the nationalist liberation movements[8] accepted a constitution that limited the scope of the inevitable post-independent agrarian reform (Suba, 1989). The liberation movement abandoned any expectations they had of pursuing a radical land reform program when they agreed to a market-bound process of land acquisition (Moyo, 1994).

2.2.2 The Land Resettlement Program

The resettlement program implemented in Zimbabwe beginning in September 1980 was constrained by the Lancaster House Agreement. The Agreement stipulated that land was to be acquired on a "willing-buyer-willing-seller" basis with the seller being paid "promptly" and in a currency of his or her choice. In the absence of land taxation speculative pricing resulted in very high land prices (Moyo, 1994). Though the Zimbabwean and British governments equally split the costs of land acquisition, the high land values and Zimbabwe's

[7] Frontline states are comprised of neighboring countries that actively supported the struggle against minority rule in Zimbabwe, Namibia, and South Africa. The most influential included Botswana, Mozambique, Tanzania and Zambia.

[8] The Zimbabwe African National Union (ZANU) and Zimbabwe African People Union (ZAPU) formed the Patriotic Front as an alliance to ensure continued external financial and material support.

limited fiscal capacity[9] limited the breadth of the ensuing resettlement program. The new settlers were not asked to pay for the land on which they were resettled. The 52,000 households resettled by 1989 fell short of the 162,000 target (Palmer, 1990). Thus, by 1989, 416,000 people had been resettled on 2.7 million hectares bought from commercial farms. The distribution of land by natural region and by farming sector is shown in Table 2.2. The land under large-scale farms fell to 32 percent of the total national land. However, this 32 percent remains the prime agricultural land in the country. Table 2.2 shows that the land acquired for resettlement purposes was mainly in the semiarid areas. Thus not only is the proportion of the land for resettlement insignificant, but is also of poor quality.

Table 2.2: Zimbabwe: Percentage Distribution of Land Area by Natural Region and Sub-Sector, 1990.

Land Use	Natural Region*						
	I	II	III	IV	V	X	Tot.
Communal Areas	0.2	3.1	7.0	18.1	12.8	1.5	42.7
Large-scale Areas	1.2	9.8	5.6	9.7	5.7	0.1	32.1
Small-scale Areas	-	0.6	0.7	1.5	0.5	0.2	3.5
Resettlement Areas	0.1	0.4	2.4	0.5	1.1	-	4.5
National Land	0.3	0.9	2.1	6.5	6.0	1.4	17.2
Total	1.8	14.8	17.8	36.3	26.1	3.2	100

* Natural Regions are based on average annual rainfall. Natural Region I has the highest average annual rainfall while Natural Region V has the lowest.

Source: Central Statistical Office

[9] Zimbabwe could not provide its share of the land acquisition budget partly because of the devaluation of the Zimbabwe dollar against major currencies starting from 1981.

The implementation of the land resettlement program did not proceed at a pace required by a government brought to power on a revolutionary ticket. As a result government was under pressure to acquire more farms. In 1985 a Land Acquisition Bill was passed requiring all willing sellers to first offer their farms to the government for purchase. If government lacked funds to purchase the farms offered, the sellers were allowed to sell to other buyers. Nevertheless, since the government did not have enough funds to purchase all the farms offered to it, very few farms were purchased for resettlement.

The second reason the resettlement program target was not met includes the influence of the Commercial Farmers' Union (CFU)[10]. The CFU and its allies were successful in lobbying the government to slow the Resettlement program by pointing out the importance and efficiency of large-scale farmers in generating foreign exchange earnings and employment[11]. Resettled farmers would not only fail to match the productivity of the former occupants, but would also cause considerable environmental damage because of their inappropriate farming methods. The CFU has used its dominance over the emerging independent and high profile international media and official policy-making fora and institutions to advance this point of view (Moyo, 1994). Accordingly, the business community, black and white, and the urban elite regard the government land policy as irrational and a mere political gimmick to garner votes for the ruling party come election

[10] The CFU is a powerful organization for large-scale, mainly white, farmers which actively promote the interests of its constituency.

[11] To some researchers the centrality of large-scale commercial agriculture to the agricultural success and economic survival of Zimbabwe is a myth (Weiner, et al, 1985; Riddell, 1978; Cliffe, 1988). The scepticism with the superiority of large-scale agriculture is borne out of numerous findings in Asia and Latin America of an inverse relationship between farm size and productivity.

time.[12] What the CFU and its allies have done is to take advantage of the dearth of information on government land policy to confuse public opinion (Moyo, 1994). The CFU and its followers have therefore successfully stalled the resettlement program even though they all agree that there is need for land redistribution as a statement from the CFU president confirms; ".....prior to and since Zimbabwe's Independence the CFU .... understood and accepted the need for land reform (Swanepoel, 1997).

The third reason for the slow pace of resettlement was the impressive performance by small-scale farmers in the early and mid eighties that took off pressure from the polity to effect land reform. For maize and cotton alone the contribution of small-scale farmers to the marketed produce increased from 10 percent before independence to over 60 percent in less than ten years after independence (Matanyaire, et al, 1992). It appeared that improvements in access to markets, credit, and other services could effectively bring small-scale farmers into the money economy. Thus resettlement, after all, appeared not to be important as a vehicle for the empowerment of the rural poor. During the late eighties and early nineties crop production growth rates in the communal areas have shown signs of stabilizing and sometimes even declining (Jayne, et al, 1994). The universal empowerment of communal farmers is far from being attained as over 80 percent of the benefits were captured by 20 percent of the communal area population who happens to be found in the high potential areas (Shumba, 1990). This has been used to show that rural socioeconomic problems cannot be resolved by simply improving access to markets and other essential services. The bulk of small-scale farmers in the marginal areas, most of whom are net-food buyers, have not benefitted from these programs (Jayne, Jones, Mukumbu and Jiriyengwa, 1997).

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[12] An editor of the only independent newspaper then, The Financial Gazette, dismissed claims of land hunger as a mere excuse by government leaders to grab land.

The resettlement program sparked off several studies to evaluate the costs and benefits of replacing large-scale farmers with small-scale farmers. The earlier studies by Kinsey (1982) and the Whitson Foundation (1983) found the costs of resettling the 162,000 families on large-scale commercial land potentially high. The pessimism in these studies is in line with the belief that large farms are more efficient than small farms (Weiner et al, 1985). But these studies used data that grossly underestimated the potential of the small-scale farmers. Kinsey (1982) admitted that his analysis was based on the land use planners' models which lacked dynamism and realism[13]. Dan Weiner et al (1985) have challenged the myth of the efficient large-scale farmer by showing that, in terms of yields and output-input ratios, resettlement and communal areas "can produce comparable yields to those of the large-scale commercial farms with significantly less inputs" in areas of comparable production potential. Matanyaire et al (1992) also concluded that "... resettlement can replace large-scale commercial farms .... without losses in total production" using crop yields of a cotton-maize rotation. Both analyses were based on crop yields comparisons that do not account for total farm productivity. To compare across farms of varying sizes, total farm productivity measures should be used.

[13] The planners' *ex ante* models were not realistic because they lacked details on the productivity levels of the resettled farmers. The figures and assumptions used were not adjusted to take into account the effects of time as the new settlers adjusted to the new environment.

2.3 Review of Agrarian Reform Literature

The controversy on whether it is economic to replace large scale with small scale farms in Zimbabwe is not unique. The question of what the relationship between farm size and productivity is like has dominated the literature on agrarian reform for a long time. In this section the literature on the farm size-productivity relationship is reviewed.

2.3.1 The History of Agrarian Reform

Binswanger, Deininger and Feder (1993) documented the evolution of land relations as societies evolve from land abundant to land scarcity settings, drawing heavily from Boserup's theory of the evolution of farming systems. If land is abundant, the critical factor is labor and there is no incentive to invest in land improvement. Degraded land is abandoned for a period long enough for natural soil productivity restoration. Over time countries have solved their demographic pressures by moving into new unoccupied lands (Powelson, 1964). As human and livestock population pressure increases on limited land resources, the fallow period becomes shorter. The land frontier is quickly exhausted and marginal land is opened for cultivation. This, coupled with adoption of improved production practices, results in continual cultivation.

With continual cultivation, especially on marginal land, land productivity-improving investments become necessary. Then property rights over land become important since they directly influence the uncertainty, perceived and real, of benefits from investments made to improve agricultural production. Property rights can take various forms depending on the intensity of population pressure on land. When population pressure is very intense, the likelihood of individuals demanding formal institutions that protect complete private property rights is high. Informal laws are relied upon if the population pressure, and therefore, the pressure for agrarian change is less intense.

History has shown that widespread change in property rights has mostly been associated with revolutionary change (Alexander, 1977). The genesis of formalized property thus might be from the bottom up in response to the inability of formal law to connect property rights and ownership arrangements as defined by informal law. The driving force behind formalization is the potential benefits generated by widespread, formal property rights through low cost exchange that encourages specialization and thus greater productivity from investments. This has been part of the modernization of agriculture in several cases around the world.

The process of modernizing agriculture occurs in stages involving social differentiation between lower and upper classes (Kanel, 1971). The initial stages exhibit low social differentiation with communal property relations dominating production. In the next stages a rural elite that favors the establishment of the state to promote their interests emerges. Feudalism and other similar systems correspond to these stages of evolution in land relations. But other interest groups, such as industrialists and the urban elite, in alliance with the oppressed cultivators, start to challenge the power of the rural upper class at the next stage. This is the stage in which the demand for land reform is strongly expressed. The final stage of the evolution process involves a decisive shift of land relations from being based on status to those governed by contract, stripping the tenure system of most of its political and social dimensions (Kanel, 1971). This is the stage when economies are driven by market forces with limited interventions by the state. One major difference between developed and developing countries is that the economies of the former are more reliant on markets with well-defined and formalized property rights than the former.

But Binswanger et al (1993) point out that instances of smooth transformation of land rights from communal to complete private rights are uncommon. Rarely are transitions to formalized property rights unpremeditated. During the transformation process a class of political and military elites can and do take advantage of their power to extract rents from the cultivators. In India the caste system is used to this day to deny the "untouchables" access to quality land (Mallick, 1992). In Latin America the establishment of the exploitative hacienda system by the Spanish settlers after the conquest of the local villagers aptly illustrates this phenomena (Williamson, 1997). The freedom of the small-scale cultivator is restricted as the rural elite close most of their exit options to coercion.

If coercion cannot be used to extract rents, especially during the later stages of the evolution of land relations, then the utility of the small-scale farmers must be reduced by limiting their access to high quality land and through distorted policies. In Zimbabwe, South Africa and Kenya large landowners influenced their respective governments to pass laws and regulations that marginalised small-scale farmers, who were then unorganized to resist (Orvis, 1997). The large scale farms have to survive on government support programs especially those that drive the reservation price of small-scale cultivators' labor down.

But exploitative production relations and large farmer-biased policies cannot be sustained indefinitely. As the economy develops the relation of ownership structure to the social structure create stresses and conflicts that force the system to adjust resulting in the emergence of new political coalitions (Kanel, 1971). In most of Latin America the large estates did not only prevent a large part of the population from participating in the political and economic markets but could not also supply the needs of a growing population and the developing industrial sector (Alexander, 1974). In fact the main driving force for agrarian reform in Latin America was the desire to break the political stranglehold of parasitic landowners (Powelson, 1964). Thus eventually it is the internal contradictions within the relationship between the cultivator class and the rural upper class over rights to expropriate rents that are the source of the demise of these exploitative systems.

From the resultant political upheavals emerge wide variations in land relations evident across the globe today. These include, among others, the Cuban type of revolution which ended with the state owning all means of production, Mexico and its *ejido* system, South Africa which have maintained the status quo, India and its caste system-based pattern of land ownership and China which has now moved from state ownership to family farms. It is also noteworthy that the Latin American land reforms had minimal impact since dualistic land ownership structures still persist.[14] The dominant agrarian structure is therefore dependent on who "wins" the struggle between the large landowners and the peasants. In Latin America and Southern Africa the anti-reform advocates (rural elite, agricultural capitalists and their allies in urban areas) successfully contained the extent of effective land redistribution (De Janvry, 1989; Moyo, 1994). In both cases the main argument of the anti-reform advocates has been that of the superior performance of large estates, the peasants' lack of managerial experience due to high levels of illiteracy and the high cost extending the appropriate social and physical infrastructure. The question that follows from this is whether large estates are inherently more efficient than small family farms that characterize peasant agriculture. The section below explores this issue through a review of some of work done throughout the world on the relationship between farm size and economic efficiency.

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[14] De Janvry, Marsh, Runsten, Sadoulet and Zabin (1989) reported that in 1980 large estates accounted for 22 percent of farm units and occupied 82 percent of total area in Latin America as a whole.

2.3.2 Farm Size-Productivity Relationship

The differences in economic efficiency found between small-scale family operated farms and large-scale farms are used to justify land reform. In the 1950s western development economists believed that the key requirement for agriculture was to free labor and other resources for industrial development and provide relatively cheap food for the expanding industrial labor force (Dorner and Kanel, 1971). It was further noted that large plantations had "well known economic advantages over the family size unit" (Lewis, 1954). Large-scale farms were thus favored on the belief that they were technically more efficient and productive than small-scale farms. But by the 1960s some economists, citing the United States as an example, believed that family owned and operated farms were better that large estates operated by non-family labor on the basis of efficiency (Powelson, 1964). Even Lewis had observed in the 1950s that the more successful organizational units for settlement schemes in underdeveloped countries were small family farms because of their advantage as social and economic units (Johnson and Ruttan, 1994). Thus even without the support of empirical studies the relationship between productivity and farm size has since then been specified as an inverse one.

Over time economists developed the Official Doctrine of Land Reform (ODLR), as a radical departure from the traditional myth of the superiority of large-scale farming over small scale agriculture (Platteau, 1991). The ODLR postulates an inverse relationship between farm size and land productivity[15] and is supported by the historical dominance of small-scale family farming all over the world (Deininger and Binswanger, 1992). There are two ways to explain the ODLR; the Labor Cost-based and the Transaction cost-based

[15] Size here refers to area of the farm and not farm scale which refers to total economies of size that involve all inputs. Land productivity is normally in terms of yield per unit area with yield expressed in physical terms or in monetary terms.

explanations. There are no serious contradictions between these two approaches to explaining ODLR. In fact the farm size to productivity relationship could be best viewed as a result of the two processes. They are presented here separately to ensure clarity only.

2.3.3 Labor Cost-Based Explanations of the Inverse Relationship

The search for the causes for the inverse relationship dates to the time of classical economics. J.S. Mill explained this relationship in terms of labor cost advantages of small farms that exploit "imperfections" in the rural labor markets. The inverse relationship between farm size and output per unit of land is due to the inverse relationship between farm size and labor use. The inverse relationship between farm size and labor use is due to differences in labor costs between the two farm types; Labor Market Dualism. The basic explanation of the dualism in the labor market is the difference in mode of employment between large farms, which rely mainly on hired labor, and small farms that are dependent on family labor. The market wages facing large farmers are higher than the cost of using family labor on small family farms. This results in small family farms using more labor per unit area than large farms. By using labor more intensively than large farms smaller farms put larger proportions of the land they own under cultivation than large scale farms. There are various ways to explain the differences in labor costs.

- The original Mill's explanation of the inverse relationship was based on the observation that individuals prefer to work on their own land. In neoclassical theory it was noted that "the disutility of given quantities of work efforts is smaller when these efforts are applied to one's own property than when they are made under the control and on the account of another person" (Platteau, 1992; p 54). As a result the effective cost of labor on small farms (its imputed price) is lower than on large ones. Furthermore, the large farm workers' wives and children do not offer their labor to the large farms. Thus as noted by Lipton (1974), small farmers end up producing more output from a given bundle of inputs of (land and capital) because they use the labor input more effectively.

- The labor cost differences also arise from the egalitarian mode of income distribution within small farm families (Platteau, 1992). The share of each member of the farm family is the average product and not the marginal product. The former is greater than the latter at the level small farms use labor[16]. Figure 2.1 illustrates this scenario.

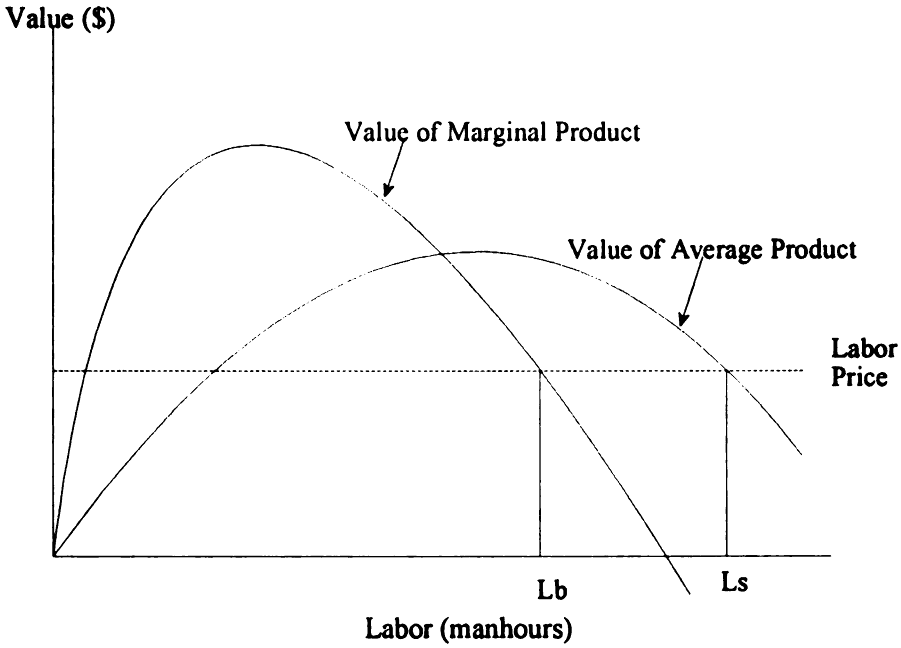

Figure 2.1: Differences in Intensity of Labor Use Between Large and Small Farms

[16] This assumes that small farms operate within phase II of the production function when the average product curve is above the marginal product curve.

A large farm would use labor up to point Lb on Figure 2.1 while a small family that employs average product pricing would use more labor at Ls. For a family member to leave the farm for alternative employment the market wage must at least be equal to the average product of labor. The lower bound of the market wage is therefore set at a level well above the marginal product of labor that is the real opportunity cost of family labor. Thus small family farms end up using more labor than large hired labor-based farms since the former can continue using labor beyond the point where the marginal product of labor equals the market wage rate. In Figure 2.1 the marginal product labor for a small family farm is below that of a large farm that utilizes hired labor.

- The market wage rate exceeds the marginal product of labor because of the uncertainty in the rural labor markets especially in labor-surplus economies where alternative employment opportunities are scarce. Thus even if small farm family members are willing to be hired at market wages equal to the marginal product of labor, the risk of finding off-farm employment results in the market wage being discounted for the risk involved. The discounted market wage rate would be greater than the marginal product of labor. When the probability of finding employment in rural labor markets is low, assuming that small farm family members have no preference for leisure, then rural labor markets will not clear. Thus small farms will have more labor available than large farms which can only attract more labor at higher market wage rates.

2.3.4 Transactions Cost-Based Explanations of the Inverse Relationship

The other way of explaining the differences in the cost of labor between family and hired labor is the transaction cost approach (Platteau, 1992). Effective per unit costs of labor, made up of direct wage costs and supervision costs, increase with increases in farm size. This occurs because the supervision costs increase with farm size and operational scale. The supervision costs are high because of the difficulty of monitoring the quality of the labor efforts produced due to the variability and unpredictability of agricultural operations and outcomes. This then becomes a classic principal-agent problem.

The variability and unpredictability of agricultural production activities lead to information asymmetries between the employer/owner and the worker making it difficult for the employer to determine the extent to which the agent is responsible for the good or bad outcomes. This is a typical incentive problem of both the moral hazard and/or adverse selection type. The presence of exogenous risk thus makes small family farms more efficient in that the workers are the sole residual claimants of farm profits. There are no incentive problems on small family farms because monitoring the workers' effort is less important. In addition family farmers have a more intrinsic knowledge of the biophysical attributes of their land (Ellis, 1993). Thus Mill's original argument that guaranteeing individuals `the fruits of their own labor and abstinence' eliminates the incentive problem remains intact and is the basis of the higher efficiency of small family farmers.. What we get out of the transactions costs approach is that large non-family labor farms have to deal with the incentive problem at positive transaction costs. They have to ensure, for example, that labor shirking and pilferage of inputs by workers are avoided. This extra effort of labor supervision to avoid managerial diseconomies increases the price of wage labor above that of family labor.

Managerial diseconomies of scale also mean that the per unit cost of labor increases with farm size even when we consider small farms operated by family workers only. Platteau (1992) thus noted that the inverse relationship can exist independently of production relations in what is termed the "incentive dilution effect". The larger the family is, the more diluted the shares of each member and thus the greater the incentive problem. Worker efficiency declines or the cost of labor rises with the scale of operation.

Among large farms that rely on wage labor, researchers have found out that those farms that have more family members staying on-farm were more efficient than those that did not, *ceteris paribus*. This led to what became known as *Sen's reformulation of the supervision cost argument*. This reformulation is based on the effectiveness of avoiding "supervising the supervisor" by entrusting the supervision of hired workers to family members. This makes family labor a complement of hired labor but only up to a certain point beyond which benefits from substituting hired workers for family labor become negligible. Sen used evidence from a study in Punjab (India) to prove that continuing to hire labor beyond a certain point without more family labor available is difficult. Large farms are often less efficient than small ones because shortages of family labor supply cannot be overcome indefinitely through hired labor.

Sen's reformulation illustrated that supervision problems can be reduced by reducing the social distance[17] between the employer/owner and the worker or when the hired workers work side by side with the employer. The social distance tends to increase with farm size. The inverse relationship between farm size and productivity is also a result of the inverse

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[17] Social distance is a measure of the closeness of farm labor. The social distance between family members is short by virtue of the family relationship. If a farm only hires a few workers (2 or 3) relatives are most likely to be hired or the non-relatives are treated as relatives, hence the social distance will be short.

relationship between social distance and wage labor's willingness to apply effort. If the social distance is "short" then the effective per unit costs of hired labor are lower. Sen's reformulation to explain differences in labor costs seems to yield the recommendation that large landowners should develop close personalized ties with their workers, if class relations permit, so that they can lower their effective labor costs.

The other transaction cost-based observation is that subjective conditions, such as preference for leisure and/or non-farm activities, by determining labor use also determine the large farm equilibrium labor price. It may not be labor market condition alone (which assumes that labor has no preference for leisure and non-farm work).

The transaction costs approach also enables us to explain why small family farms use more family and hired labor per unit of land than large hired labor-based farms; and why the marginal product of labor on the large farms is greater than the market wage rate and that it increases with farm size. There is also a suggestion that agriculture sometimes experiences diseconomies of scale (Johnson and Ruttan, 1994). The diseconomies of scale in agriculture occur when the labor market fails or does not exist in the agricultural sector. Without a well-functioning labor market, labor exchange activities become expensive such that the more hired labor one uses the higher the transaction costs.

What emerges from the ODLR debate is an illustration of the constraints associated with different farm structures. Large farms have to deal with the problems of controlling labor, that is, an imperfect labor market. Hired labor is difficult to motivate. Family labor is cheap and self-motivated. Large farms in many developing countries are usually owned by absentee landlords and have been severely underutilized (Rukuni, 1994). Small farms on the other hand have to deal with imperfect capital, and very often, political markets. The small farmer-led agricultural growth strategy is constrained by the high costs of ensuring small farmers access to capital markets and their transparency in political markets.

But the differences in farm sizes around the world is not only a product of imperfect input markets. There are other reasons for the observed differences. Differences in the relative availability of factors of production explain some of the differences in farm size across nations. For instance countries that have relatively more land per capita have larger farms. The United States farms are larger that those in Japan. Because of the relative shortage of land and abundance of labor, Japan's agrarian structure is based on small farms that use labor intensively while the United States farms are relatively larger and dependent on the use of mechanical inputs. In many developed countries small farms are being consolidated into larger farms because with development the percentage of labor working in the agricultural industry falls. The few who remain on farm are forced to use modern machinery to maintain viability in the face of declining terms of trade. Thus farm sizes in developed nations are becoming larger. It remains to be seen if this trend will be witnessed when developing countries' economies modernize.

Despite the differences in farm sizes observed around the world the argument that small farms are more efficient, economically and socially, than large farms remains strong. The question that is addressed in the next section is whether there is consistence between theoretical and empirical work on this subject. In other words what can we learn from the empirical studies on the inverse relationship hypothesis?

2.3.5 The Inverse Relationship: Some Evidence

The continued survival of large-scale farming challenges strong theoretical literature on the existence of the negative relationship between farm size and land productivity.

Theoretically, the inverse relationship hypothesis holds if both small and large farms use identical technology and market imperfections and other policy induced distortions are absent. Part of the upsurge in agricultural production in Kenya and Zimbabwe after independence is attributed to the restructuring of distorted institutions that accompanied the reform of the agrarian structure (Orvis, 1997).

The appraisal of the performance of Zimbabwe's Resettlement Schemes is characteristic of the whole debate on what is the most productive farm type in Zimbabwe. A vital question is whether land acquired for resettlement is being used as productively as it was under previous owners (Matanyaire, et al, 1992). Muir and Blackie (1994) found the productivity record of resettled farmers unimpressive and attributed the poor performance to poor land quality and insecure tenure. They point out that most of the land used for resettlement is marginal for crops in which resettlement farmers have shown a comparative advantage and thus could not compete with the crops previously grown such as tobacco. The Commission of Inquiry into Appropriate Agricultural Land Tenure Systems, while acknowledging the problem of insecurity of tenure, was "impressed by the high standard of farming" and concluded that the conventional wisdom that resettlement areas are unproductive was not objective (Rukuni, 1994). The debate on the most productive farm type in Zimbabwe, and indeed the whole question of agrarian reform, remains unresolved in the absence of empirical studies (Moyo, 1994).

The experience in Kenya has been more conclusive than the Zimbabwean case. Kenya witnessed a dramatic increase in output after the land titling schemes which were initiated toward the end of the colonial period and pursued by post-independent governments (Migot-Adholla, Place and Oluoch-Kosura, 1990). Hunt (1984) reported strong inverse correlation between farm size and income, labor use, and marketed output per hectare. Migot-Adholla, et al (1990) concluded from survey data that plot size was negatively related to yields for all cropping patterns. Muir and Blackie (1994) attribute the success in Kenya to the high quality of land on which smallholders were resettled. They were, unlike their Zimbabwean counterparts, able to farm their new land more intensively than the previous owners without causing serious land degradation.

There is empirical evidence from South Africa's commercial farming sector suggesting that there is an inverse relationship between efficiency and farm size (van Zyl, Binswanger and Thirtle, 1995). Using the data from the 1988 census of agriculture small farms (less than 500 hectares) had average gross margins per hectare over 17 and 42 times greater than the average gross margin per hectare from middle farms (500 - 1000 hectares) and large farms (over 1000 hectares), respectively. Small farms also employed about 23 and 22 times more workers per thousand hectares than middle and large farms. Van Zyl et al (1995) also showed that small-scale black farmers, when given adequate support, performed just as well as or even outperformed their large-scale white colleagues.

Several studies on the inverse relationship have been conducted in several of Asian countries with most of them being affirmative. Among them, Yotopoulos and Lau (1973) used a profit function-based model to measure relative economic efficiency between groups of farms based on Indian farm-level data. The study concluded that small farms were relatively more efficient economically. Their superiority was due to both allocative and technical efficiency. The study also found constant returns to scale in Indian agriculture. These findings yielded a strong case for agrarian reform to increase both efficiency and equity. But there are also a few studies, in India, that have conclusions to the contrary. Barnum and Squire (1979) found no differences in relative economic efficiency between small and large farms and thus found no basis for land reform other than for social and/or political objectives.

The main reason for the inverse relationship found in many studies is the dual labor market hypothesis[18] (Feder, 1985). The universality of the dual labor market hypothesis as an explanation of the inverse relationship has been weakened by lack of conclusive evidence. In a 1979 review, Berry and Cline found some studies that refuted the inverse relationship and showed positive or no relationship between farm size and productivity. Feder (1985) showed that including market distortions helps explain the ambiguity of the observed relationships between farm size and productivity. By proposing that supervision of hired labor by family members improve the productivity, Feder (1985) was able to show that the systematic relationship between farm size and productivity can be negative or positive. This occurs though there are constant returns to scale and all farmers face the same prices.

In Latin America, most countries experienced a reduction in agricultural output a few years after the reform, with the exception of Venezuela (Alexander, 1974). But this fall in production is expected as Powelson (1964) observes that "it is scarcely possible to carry out any change in land tenure without adverse effects on production" (p. 65). A study by Heath (1992) in Mexico evaluating the impact of land reform on agricultural productivity concluded that there were no major differences in productivity between privately operated land and *ejido* (communal land) that resulted from agrarian reform. In Honduras, Larson (1997) found out that efficiency was dependent not only on the nature of land markets but also on that of other markets particularly credit.

Thus the fall in output immediately after agrarian reform is not a product of small farms being inherently inefficient. The main reason why production did not fall in Venezuela

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[18] The labor market is made up of the "family" labor market and the wage-labor market. Because of high costs of searching for jobs with wages higher than the value of the average product, it often occurs that the family labor market end up operating at a lower wage than the wage-labor market. The difference in wages also gives rise to the duality.

was that the resettled farmers were lavishly supported by the government which drew from its vast oil revenues. Resettled small farmers have not performed as well in other countries because their governments could not afford to finance the establishment of the essential physical, economic and social infrastructure. De Janvry et al (1989) and Williamson (1997) reported the existence of acute landlessness in Latin America suggesting that the reforms were not effective. Overally, however, the new agrarian structures have been able to not only increase production to meet the needs of growing populations and developing industrial sectors, but has effectively broken down the landlords' hold over the lives of the peasants and allowed peasants to participate in national politics (Alexander, 1974).

One crucial issue in the presentation of evidence on the existence of the inverse relationship is the assumption of competitive capital and land markets. If these assumptions are violated, then the relationship between farm size and productivity can take forms other than the expected inverse relationship. What is the relationship between farm size and economic efficiency in the real world? Specifically are small farms economically efficient relative to the large mechanized farms in Southern Africa?[19] Also, have past policies and distortions affected the relationship between farm size and productivity in Southern Africa? An attempt to answer these question is made in the next section drawing from work down in South Africa and Zimbabwe.

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[19] Southern Africa includes all the countries that are members of the Southern African Development Community (SADC) but in this study the focus is on those countries that have dualistic agrarian structures such as Malawi, Namibia, South Africa and Zimbabwe.

2.4 Lessons for Southern Africa

The review of studies on the relationship between farm size and productivity has shown that, generally, small family-operated farms are more efficient than large farms especially when inputs markets are competitive (Berry and Cline, 1979). because of the way these small family farms organize labor relations. This is particularly evident in cases where factor markets exist and are not affected by distorting policies. If markets are imperfect because of policy distortions, the relationship between farm size and economic efficiency will not be an inverse one. Removing market imperfections would not only allow for efficiency-farm size relations to properly manifest themselves but would also eliminate the societal deadweight losses that they cause. Thus privileges and distortions that favor large farms should, wherever possible, be removed to allow efficient markets to operate.

In many Southern Africa countries, markets reflect the distribution of power, rights and privileges. This distribution favors large scale farming hence their dominance in the economy as a whole and agriculture in particular. However, recent studies in South Africa report the presence of an inverse farm size-efficiency relationship despite an agrarian history tailored specifically to entrench large scale farms (van Zyl, Binswanger and Thirtle, 1995). An important issue here is whether there are gains in efficiency to be made from subdividing the large scale farms in Southern Africa.

Thus the most pressing question in Southern Africa is whether small farms are more efficient than large farms even in the presence of distorted input and output markets. The other issue to be clarified is how to create agrarian structure through, among other things, leveling the playing field not only to ensure no particular section of the society enjoys a privileged position relative to others but also to enable society to maximize benefits. Land reform involving the subdivision of large scale farms is one of the main options given that

Southern Africa has exhausted its land frontier. Unlike Latin America, the sub-region does not have new unoccupied lands which makes the resettlement of marginalised small farmers politically easy (Powelson, 1964). The other option, addressed in this study, is to look at small-scale agriculture and examine whether it is possible to change production patterns in ways that will eliminate poverty.

Accordingly the search for solutions should begin by looking at the way small scale family farms have been operated. Are these farms economically efficient? If they are not, what are the factors that explain inefficiency? Then what measures could be taken to ensure that the current and future small family farms operate efficiently? In doing so, one should recognize that the odds were staked against the small farmer all along. Policy distortions and market imperfections were a result of efforts to marginalize small scale family farms and promote large scale farming. The extend to which the results of an analysis of small scale farm are dependent on these deliberate policy distortions and market imperfections should be explored.

2.5 Summary

Zimbabwe's agrarian history is a product of an era when large scale farms were considered the primary vehicle to transform the economy from being agriculturally-base to one based on industrial production. When the industrial sector failed to absorb all the labor released when large scale farms were established, there was no attempt to change the agrarian system so that it could provide opportunities for the majority of the population to work and fully participate in the national political and economic markets. Instead, before independence, in 1980, economic policies were enacted to entrench large scale farming and reduce the competitiveness of small scale family farms. After independence, the new government changed the focus of policy making to focus on communal farmers. The support infrastructure that had been geared to serve a small number of large scale white commercial farmers was expanded into the once neglected communal farming areas. In addition a market-driven land redistribution program was implemented. These programs did result in a marked change of the national agricultural system in terms of access to resources and production by farm type. But the changes were not thorough enough to level the playing field between communal area and large-scale commercial farmers. Conditions have risen in Zimbabwe, and in other Southern African states, that call for changing the distribution of power, rights and privileges in the use of land.

The central issue discussed in this chapter has been the economic justification of agrarian reform. The literature review revealed that there is an inverse relationship between farm size and economic efficiency when input markets are free of distortions. Labor market imperfections turned out to be the main cause of the inverse relationship between farm size and farm-level economic efficiency. The inverse relationship was explained using both the labor cost-based and transaction cost-based explanations. What emerges from this analysis is that, generally, small family farms are more efficient than large scale farms because of the way in which labor relations are organized. The only case when the farm size-efficiency relationship is ambiguous is when there are capital market imperfections due to policies enacted specifically to support large scale farms. Experience from Latin America indicate that small farms should have access to inputs and essential support services for them to take full advantage of their comparative advantage in labor utilization. This provides valuable lessons for Southern Africa countries that are trying to move from a dualistic agrarian structure to one that put people to work. But without new unoccupied land on which to resettle landless communal farmers, Southern African countries need to look at how far they can increase communal area production without engaging on the politically difficult land redistribution. Understanding the characteristics of current small scale agricultural production system is an important step along this direction.

CHAPTER III: DESCRIPTION OF ZIMBABWE'S COMMUNAL AREA PRODUCTION SYSTEMS

3.1 Introduction

The previous chapter describes in detail the creation of communal farming areas by European settlers at the turn of the twentieth century and how from then on land has been a festering political and economic problem in Zimbabwe. Also raised was the question about the economic costs of the current agrarian structure and how it can be socially and morally justified. What emerged as a challenge is devising ways and means to consistently ensure that the nation's natural resources are used for the benefit of as broad a spectrum of Zimbabwean society as is possible. Ensuring that the farming community uses the scarce production inputs (land, labor and capital) is an important component of current and future development programs.

Southern African agrarian systems have not been changed ever since the advent of European settlement. The current political and socioeconomic systems have effectively preserved the old colonial structures and have resisted change. Political coalitions against current agrarian structures have not grown to levels of strength and sophistication that can generate change. Thus, similar to what Cardoso and Helwege (1992) noted in Latin America, the economic poverty in communal areas reflects the political poverty were the communal farmers lack the means for voicing their interests. Given that over 90 percent of land in communal areas is not suitable for agriculture using available technology, the stresses and conflicts generated by the current agrarian systems will eventually lead to an overhaul of the system (Chasi and Shamudzarira, 1992).

The government realizes that improving the lives of the rural population should start at the individual farm-level (MLAWD, 1993). Rural infrastructural improvement is only a necessary condition in this process. The sufficient condition is efficient resource utilization at the farm household level. To understand what is involved in improving the efficiency in the use of farm resources by communal farmers, a detailed characterization is required. Detailed characterization of communal agricultural production systems is also essential for specification of measures of farm productivity.

The purpose of this chapter is to provide such a characterization of the current communal production systems. This characterization is based on a multi-visit survey of communal farms by the Ministry of Agriculture (MOA) during the 1990/91 season. A brief description of the survey instrument used to collect data reported in this chapter can be found in the appendix. It is followed by a discussion of how to improve the productivity of communal agriculture. The chapter ends with a summary of what lessons can be drawn from the status of communal agriculture and how this information can be used in designing policies, programs and strategies to alleviate poverty in communal areas.

3.2 Communal Area Production Systems

This section looks at three major features of communal farms; the demographic characteristics of the communal households, the resource endowment levels and conditions, and the agricultural production practices. This section primarily based on the 1990/1991 Annual Report of the Farm Management Data for Communal Area Farm Units published by the then Ministry of Lands, Agriculture and Water Development (MLAWD)'s Farm Management Research Section. This annual report is based on a sample survey of 453 communal farmers in Natural Regions II (6.7%), III (16.4%), IV (31%) and V (45.9%). This sample represents the distribution of communal farms by Natural Region with the exception that provincial representation was not equal[20]. In addition the proportions for Natural Regions IV and V should be reversed if they are to mirror the distribution of communal farms by Natural Region. However, the similarity between these two Natural Regions makes this reversal inconsequential. They are both considered unsuitable for crop production. An attempt is made to compare and contrast the characteristics of households (especially resource endowment and production practices) in the high potential (HP) Natural Regions (II and III) and the low potential (LP) Natural Regions (IV and V). The findings from other studies and surveys are also used in this characterization exercise.

3.3.1 Demographic Characteristics

Because most communal farm labor requirements are provided by family members, several insights can be gained from examining the demography of farm households. It helps in the determination of the availability of labor at the farm-level and helps in assessing the quality of family labor. The most important demographic variables are on the household head and the composition of the family.

Nearly 75 percent of the farms surveyed during the 1990/91 agricultural season were headed by males with an average age of around 48 years. These household heads have been farming for more than 17 years on average. Thus the households are headed by old and experienced farmers considering that the average life expectancy is 53 years in Zimbabwe (World Bank, 1995). Because of the near universal primary education of the Zimbabwean population it is not surprising that the average years in school for household heads are above eight years. This means that most of the farms are headed with people with more than just

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[20] Farmers from the two Matebeleland provinces were not included in this sample.

primary education.[21] However, of the 75 percent of farms headed by males, 49 percent are nonresident. Thus, the decisions on day to day activities are taken by women effectively making the majority of communal households female-headed. As a result, efforts to encourage efficiency in the use of scarce resources should involve women. The female household heads have the same level of education as their male counterparts.

Family size is usually used as an indicator for the household's labor force (Shumba, 1992). The average communal farm household consists of about nine members. Just more than 52 percent of household members are female. Most of the family members are children below the age of 15 (40 percent) who attend local schools. This coupled with the fact that nearly 70 percent of the communal farm households have on average two of their members residing away from the farm results in the total number of adult family members available for farm work falling to between three and four[22]. Because few farmers use hired labor to work on their farms, the three to four adult family members and the children attending local schools are the main supply of farm labor. Labor availability becomes a limiting factor during peak periods in the cropping calender such as seed-bed preparation, planting, weeding and harvesting (Shumba, 1992).

The high percentage of young people in the rural population as shown by the dependency ratio of nearly 50 percent is a great cause for concern. This phenomenon implies that there is going to be more pressure on the already fragile communal environment unless

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[21] Primary education in Zimbabwe takes seven years to complete. Previously this used to take eight years.

[22] However, the high percentage of households with nonresident family members implies that there are very strong linkages between farm and off farm activities. The strong farm to off-farm linkage is further illustrated by the fact that remittances from the nonresident family members make up more than 40 percent of the total annual household income.

the youngsters are absorbed elsewhere in the economy. The average percent of elderly people (above 60 years) of just 4 percent means that the population structure is pyramidal.

3.3.2 Resource Endowment

As in any production process the main factors of production are land, labor and capital assets. In the last section it was shown that communal farms rely exclusively on family members for their labor requirements. On average, between three and four adults are available to work on the farm. The next issue is to determine the average level of the other inputs that these family members use in agricultural production activities.

The land tenure system in communal areas is based on customary law which gives farmers usufruct rights over the arable land allocated to them by the traditional authorities. They do not own the land they cultivate. Farmers are, therefore, not able to use their land as collateral to borrow money for investments on-farm. However, some studies have concluded that the claim that communal land tenure is constraint to land productivity is less compelling (Heath, 1992; Rukuni, 1994). Farmers are not just interested in ownership but tenure security. Communal land tenure, while not providing individual ownership, acts as a social security system for the poor.

Communal farmers surveyed during the 1990/91 season had access to 4.83 hectares of arable land on average. This means that, on average, an adult residing on-farm has more than a hectare to work on. Communal farmers in the LP zones have more than two hectares more arable land than their counterparts in the HP zones (Table 3.1).

Table 3.1: Average Arable and Fallow Land Owned by Communal Households in Zimbabwe, 1990/91

Average Area	Low Potential	High Potential	All Areas
Arable (hectares per household)	5.41	3.12	4.83
Fallow (hectares per household)	0.27	0	0.2

Source: MLAWD, 1993

The LP area farmers left about 5 percent of their land fallow (about a third of a hectare on average per household) while farmers in the HP areas did not leave any land fallow. This seems to suggest that, in terms of absolute sizes, the farmers in HP areas have less arable land available to them while those in LP areas cannot put all the arable land they own under crop production. However what HP farmers are missing in terms of the size of the arable land is compensated for through the high quality of their land. It can also be reasonably hypothesized that LP farmers are unable to cultivate all the land available to them because of erratic rains that do not last for a period long enough to allow for the preparation of all arable land. Some farmers stagger plantings as a way to minimize the risk of crop failure in both the LP and HP zones (Shumba, 1985). Rainfall is an important variable in communal area agriculture.

Although 6 percent of land under irrigation in Zimbabwe is on smallholder farms[23] the area under irrigation in communal areas as a percentage of the area under cultivation nationwide is almost negligible (Rukuni and Makhado, 1994). Even in the small-scale commercial farming sector and the resettlement schemes the area irrigated is less than one

[23] Smallholder here includes communal farms, small-scale commercial farms and resettlement area farms.

percent of the total arable area while the large-scale commercial farmers irrigate 29.1 percent of their arable land (MOA, 1995). Thus while the bulk of the communal farmers is in the dry areas there are no significant irrigation projects and programs. It is mainly the availability of capital to put up irrigation schemes that is a critical limiting factor to be included as a variable in any analysis of agricultural production systems in Zimbabwe.

Communal farmers do not enjoy the same level of access to capital markets as commercial farmers do due to their inability to use land as collateral. Only 11.5 percent of the farmers surveyed in 1990/91 received credit from the Agricultural Finance Corporation (AFC)[24] during the year 1989/90 as shown in Table 3.2. Table 3.2 shows that while nearly 36 percent of farmers in the better endowed Natural Regions use AFC loans, only less than 4 percent of farmers from the dry zones get loans from the AFC. This disparity may help to explain why fewer LP area farmers, in percentage terms, buy inputs than HP area farmers do[25]. It thus appears that farmers in the HP zones have more access to working capital than LP area farmers. But it is the inability of all communal farmers to use their land as collateral that prevent them from borrowing money from financial institutions. With limited participation in the capital markets, communal area farmers are unable to make the necessary investments required for intensive and commercial oriented agricultural production.

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[24] The Agricultural Finance Corporation (AFC) is the only public-lending institution that provides farmers with agricultural credit in Zimbabwe.

[25] Fertilizer and seed are the main inputs that communal area farmers purchase. A few others also buy chemicals for pest, weed and disease control.

Table 3.2: Percentage of Households Using Purchased Inputs and AFC Credit in Zimbabwe Communal Areas, 1989/90

Item	Low Potential	High Potential	All Areas
Households buying Inputs	84.9	98.2	88.1
Households Receiving AFC Loans	3.7	35.6	11.5

Source: MLAWD, 1993

Another line of inquiry is to find out how family income was used within the household during the 1989/90 season with particular emphasis on the percentage of family income that is used in capital investments. Most of the household income is spent on non-agricultural expenditures such as food, clothing, school fees and other consumables. Capital expenditure on agriculture as a percentage of non-agricultural expenditures is less than 4 percent. Only 45 percent of the capital expenditure on agriculture (or less than 2 percent of non-agricultural expenditures) is on farm implements. It seems that limited access to capital markets have a profound effect on on-farm investment and thus affect the level of efficiency observed from one farm to another.

The main capital assets in many communal farms are draft animals. Communal agriculture is highly dependent on draft power. More than 74 percent of the households surveyed in 1989/90 season owned cattle. For those who own cattle, each household, on average, has of six animals. This would appear sufficient for the provision of draft power if we do not take into account that this number may include non-draft power providing animals such as calves. A survey of cotton farmers in 1995 showed that the farmers in most areas have less than the required four draft providing animals and in one case the number of draft animals was less than two (Mudhara, Anandajayasekeram, Kupfuma and Mazhangara, 1995).

Thus although most of the households surveyed owned cattle and donkeys for draft power, a shortages of draft power at the household level exists. Farmers often resolve the shortage of draft animals by combining and sharing spans while those who do not own draft animals rely on borrowing from close relatives or hiring from neighbors (Mudhara, et al, 1995). Thus access to draft power is an important factor in communal agriculture[26].

The other important group of capital assets is farm implements. The implements of interest here include ploughs, ox-drawn scotch-carts, cultivators, harrows and wheel barrows. In both HP and LP areas, a majority (over three-quarters) of communal farm households own the ox-plough which is used primarily for land preparation and planting. The other reasons why the plough is the most common farm tool is its low price and ease of maintenance (MLAWD, 1993). Motorized farm implements are less common because of the high costs and the limited versatility (Moyo, Matanyaire and Norton, 1992). Most farmers in both the LP and HP areas own scotch carts for farm transportation and cultivators for weed control and to some extent marking of planting furrows. The absence of even a single farmer who owns motorized farm implements such as tractors testifies the degree of under-capitalization in communal areas[27]. The percentage of farmers owning these implements are shown in Table 3.3.

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[26]But access to draft power should be interpreted with caution. Access to draft power is not equivalent to draft animal ownership. Extensive family ties allow households which do not own draft animals varying degrees of access to draft power. Some households which do not own draft animals behave like those who own because of the extended family ties which are difficult to capture using a survey instrument.

[27] In 1987, of the 24,000 tractors used for agricultural production country-wide, only 1,500 (6.25%) were used by communal farmers (Moyo, et al, 1992).

Table 3.3: Farm Implements Ownership in Communal Areas of Zimbabwe, 1990/91

Farm Asset	Low Potential		High Potential	
	% Owning	N° Owned	% Owning	N° Owned
Plough	75.7	0.9	77	1
Scotch Cart	30.2	0.7	26	0.4
Cultivator	12.3	0.1	43.9	0.5
Harrow	12	0.1	9.7	0.1
Wheelbarrow	41.5	0.3	2.7	0.3

Source: MLAWD, 1993

There are no major significant differences in the farm implements ownership pattern between the HP and LP areas as shown in Table 3.3. The implements shown in Table 3.3 are appropriate for small farms that are labor intensive. But it has been shown above that the average family labor force of between three and four adults may not be enough to provide the labor required on the more than four hectare farms in the absence of major capital implements. The ownership of farm implements is expected to affect the level in farm-level economic efficiency.

In summary communal farmers in both high and low potential areas do not have the resources they would require to operate their farms adequately on a commercial basis. Land is of poor quality. The capitalization of communal farms is almost nonexistent. Farm implements are not up to the modern standards as the absence of tractor use seems to suggest. Even the labor that many have said communal farmers have in abundance might be on the low side (more than a hectare per adult residing full-time on-farm). It can be safely concluded that there are genuine resource constraints (quality and quantity) on communal farms in Zimbabwe.

3.3.4 Crop Production Enterprises

Communal agriculture consists of both crop and livestock enterprises. The major crops in communal areas are maize (*Zea mays*), groundnuts (*Arachis hypogaea*) and cotton (*Gossypium spp*). These crops' average share of the national total value of crop production during the ten-year period 1982 to 1991 was more than 75 percent. There are eight major crops grown in the sample areas. They can be categorized as follows:

•**Main Food Crops**: - Mainly maize and groundnuts grown by most farmers and a large portion of the harvest are retained for domestic consumption. However, these crops also serve a double function as food and cash crops.

•**Main Cash Crops**: - The main cash crops include cotton, tobacco (*Nicotiana tabacum L.*) and sunflower (*Helianthus annuus*) grown solely for sale. Cotton, unlike sunflowers, is grown in specific areas notably where soils are clays or loams. Tobacco is also grown in special areas.

•**Other Crops**: - The crops in this category are either not very popular with the farmers or they are grown on a very small-scale basis in terms of the proportion of the land on which they are grown. Most of these crops, which are mainly food crops for domestic use, include small grains such as sorghum (*Sorghum bicolor*), pearl millet (*Pennisetum americanum*), finger millet (*Eleusine coracana*) and bambara nuts (*Vigna subterranea*).

The main livestock enterprises are cattle, goats and poultry. Livestock enterprises on their own seem to contribute very little to the farm income other than acting as store of wealth and insurance against unforeseen cash demands (Ndlovu, 1994). However, livestock enterprises are closely linked to the crop enterprises (Shumba, 1992). Crops benefit from livestock enterprises through the provision of draft power and manure. In many communal areas crop residues are fed to livestock particularly cattle, goats, sheep, and donkeys. The relationship between the two enterprises can be considered highly symbiotic.

The popularity of maize and groundnuts in communal areas is shown by examining both the area under and the number of farmers growing the crop. This pattern is the same in low potential and high potential areas as shown in Table 3.4. However, farmers in high potential areas use a larger portion of their land to produce maize than farmers in the low potential areas (42% versus 25%, respectively). The main reason for this pattern could be that farmers in the low potential areas have access to larger pieces of arable land as pointed out before. This seems to imply that there is more land pressure in the high potential areas though this land may be more productive than that in low potential areas[28]. There is very little difference between the HP and LP areas when it comes to other conventional crops listed in Table 3.4 in terms of the proportion of farmers growing the crop and the proportion of the area planted to the crop.

It has been argued that farmers in low rainfall areas should concentrate on growing drought resistant crops. The pattern shown in Table 3.4 indicates that this recommendation is not fully followed. Farmers in LP areas still grow drought-susceptible crops such as maize. The choice of crops to grow is clearly not a function of amount of rainfall alone. Farmers

[28] The other possible explanation for this phenomenon is that LP area farmers put a larger proportion of their arable land to drought-resistant crops such as sorghum and millet as a way of managing the risk associated with crop production in these areas.

have other factors to consider in their choice of an enterprise mix that include potential crop yield and consumption patterns. Maize has taken the place of sorghum and millet as a staple in low rainfall areas because of its higher yield, better taste as food and easy processing (Kupfuma, et al, 1992). Farmers grow maize alongside sorghum and millet in low rainfall areas so that if the maize crop fails they can always depend on the small grains (Shumba, 1992). However, if the maize crop succeeds, then the sorghum and millet harvested is either sold or used for making beer. This point should not be ignored when considering programs to alleviate poverty in the low rainfall areas of Zimbabwe.

Table 3.4: Crops Grown on Communal Farms in Selected Areas in Zimbabwe, 1990/91

Crop Grown	Low Potential Areas		High Potential Areas		All Areas	
	% Farms Growing	%Area Cropped	%Farms Growing	% Area Cropped	%Farms Growing	% Area Cropped
Maize	92.6	25.2	96.3	41.6	93.5	29.3
Groundnut	80.6	11.7	61.7	12.0	75.9	23.3
Cotton*	7.2	21.1	66.7	27.7	66.7	23.3
Sunflower	24.8	15.6	24.9	13.2	25.2	15.0
Pearl millet**	37.3	15.0	n/a	n/a	37.3	15.0
Finger millet	42.3	9.2	27.1	12.1	38.5	9.9
Sorghum***	23.3	11.3	n/a	n/a	23.2	11.3
Bambara nut	40.6	6.9	8.3	7.2	32.5	7.0

NOTES

* The cotton data in from enumeration areas where cotton is grown

** Pearl millet is not grown in high potential areas (Chiweshe and Kandeya)

*** Sorghum is not grown in high potential areas and the data reported exclude these areas

Source: MLAWD, 1993

Although cotton is the second largest agricultural foreign currency earner it did not show up as a major crop in the sample in terms of area planted and/or the number of farmers growing it because cotton is grown in specific agro-ecological zones. The crop does well on heavy clay and loam soils. Thus cotton is grown in specific areas such as the north-central Middleveld and *Lowveld* and the south eastern *Lowveld*[29]. Because of its high value its contribution to total communal agricultural value is significantly high to be considered a major crop. This is also true for tobacco which is grown in specific areas. But even in areas where the two cash crops are grown, maize and groundnuts are still major enterprises (Mudhara, et al, 1995). In the 1990/91 survey cotton did not show up as a popular crop with farmers because the enumeration areas were not major cotton growing areas (see Table 3.4).

Table 3.4 shows the average farm's mix of crops in terms of the proportion of the area devoted to each crop. As expected topping the list is maize which takes up close to a third of the cropped area. The proportion devoted to other crops is close to even at around 10 percent with the exception in areas where cotton is grown. Here the area occupied by cotton is close to a quarter of the total area under crops. The communal farming system is primarily maize-based. Other crops do not have the same importance that farmers attach to the maize crop

Table 3.4 also shows that the main differences in crop mixes between LP and HP areas is in the form of the proportion of arable area under sorghum and pearl millet. The two crops

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[29] Zimbabwe is divided into three broad altitudinal planes/plateaus. The first is a T-shaped plateau that lays above 1,200 meters above sea level (masl) called the Highveld occupying 25 percent of the country; the Middleveld is a plateau laying between 900 and 1,200 masl and covers about 40 percent of the country's land; the third plateau is the Lowveld laying below 900 masl made up of the Zambezi basin to the north and the Limpopo and Save basins to the south and south-east, respectively.

are not grown extensively in HP areas. In LP areas pearl millet and sorghum together take up a quarter of the arable land that is available. It is, however, interesting that finger millet is grown in all areas enumerated with more than 40 percent and 27 percent of the sampled farmers growing the crop in the LP and HP areas, respectively. The same can be said of bambara nuts raising the question on how best to promote the production, processing and marketing of the crops or their by-products such that they graduate from being the "forgotten" crops to enterprises that are beneficial to a wider spectrum of small-scale farmers.

We have already noted the effect of agro-ecological conditions as the main factor that influences the choice of crops farmers grow (Chasi and Shamudzarira, 1992). But agro-ecological factors cannot explain why maize is still the dominant crop in the semi-arid zones. There are other factors that explain these production patterns. A simple analysis of the average yields and prices[30] of the different crops in the two zones can provide some answers. In Table 3.5 the average area planted, the average yield and the returns to the farmers own labor is shown for each crop for the two zones.

[30] The producer prices of sorghum and millets were equated to that of maize during most of the 1980s.

Table 3.5: Crop Area, Yields and Return to Labor in Selected Areas of Zimbabwe

Crop Grown	Low Potential Areas			High Potential Areas			All Areas		
	Area (ha)	Yield (t/ha)	Labor RoR* ($/hr)	Area (ha)	Yield (t/ha)	Labor RoR* ($/hr)	Area (ha) ***	Yield (t/ha) ***	Labor ROR* ($/ha)
Maize	1.38	0.99	0.46	1.28	3.59	0.7	1.73	1.45	0.52
Groundnuts	0.6	0.19	0.13	0.33	0.64	0.44	0.49	0.33**	0.2
Cotton	1.52	0.14	0	1.16	0.73	1.85	1.41	0.56	1.85
Sunflower	0.82	0.14	0.19	0.39	0.49	0.54	0.69**	0.25**	0.28
Pearl millet	0.81	0.8	0.12	n/a	n/a	n/a	1.49**	0.17**	0.12
Finger millet	0.5	0.25	0.19	0.36	0.44	0.19	0.66**	0.33**	0.19
Sorghum	0.59	0.1	0.11	n/a	n/a	n/a	0.7	0.17	0.11
Bambara nuts	0.33	0.06	0.49	0.2	0.2	0.72	0.46**	0.18**	0.53

NOTES

* RoR stands for rate of return per man-hour of labor

** These averages have a coefficient of variation that is greater than 30 percent.

*** The averages are computed from three years data 1988/89, 1989/90 and 1990/91.

Source: MLAWD, 1993

In terms of area planted and yield, maize is dominant in both LP and HP areas. As shown by the three-year average data, only the area under cotton and pearl millet is close to that of maize (cotton area higher than maize area in the LP areas). But the average yield for pearl millet is way below that of maize. This is not surprising given the research effort that maize has received over the years relative to other food crops and the attention farmers give to their maize crop relative to other crops (Shumba, 1992). It is only close in the low potential zones (maize average yields are 0.99t/ha to 0.8t/ha for pearl millet). However, when it comes to returns to an hour of family labor, cotton dominates as shown in the All Areas columns and the HP area column that represent some real cotton growing areas. Returns to labor for maize are almost equal to those from bambara nuts even though the latter have a very low average yield and demand more labor. If this crop is developed from production all the way up to marketing then there is a good chance that farmers will be richly rewarded from growing the crop. In the same light, the returns to labor for millets, sorghum and groundnut are low compared with those from maize, cotton and bambara nuts.

The higher maize yields in comparison to other crops particularly cereals is because, as the main staple, a lot of research work has been done to improve the crop[31]. Maize is the only cereal crop to which communal farmers in the selected areas apply chemical fertilizer.[32] The levels of fertilizer application on maize in the two zones are shown in Table 3.6.

Table 3.6: Fertilizer Application Rates on Maize in Selected Areas of Zimbabwe, 1990/91

Type	Low Potential Areas	High Potential Areas
Basal Application (kg/ha)*	24	204
Top Dressing (kg/ha)**	29	181
Total Amount Applied (kg/ha)	53	385

NOTES: * This is Compound D fertilizer (7%N, 14%P, 7%K)
** This is Ammonium Nitrate (34.5%N)
Source, MLAWD, 1993

The fact that more fertilizer is applied to maize grown in the high rainfall areas partly explains why maize yields in the HP zone are higher than the yields in the LP zone. In Table

[31] Numerous studies in Zimbabwe show that almost all farmers, including communal farmers, use improved hybrid maize seed.

[32] Cotton farmers are also reported as users of chemical fertilizers (Mudhara, et al, 1995)

3.6 farmers in the high potential areas apply more than seven times more fertilizer than farmers in the semi-arid zones. This is driven by the high returns farmers get from growing the crop as compared with the returns obtained in the semi-arid areas. They buy more inputs and more households use AFC loans. This means that the farmers in these areas are relatively more integrated into the monetary economy. In the LP zone, lower but more variable expected yields discourages communal farmers from using fertilizers and chemicals on their crops. However, the small-scale farmers in the HP areas occupy only a quarter of the total small-scale farming area. The other three-quarters of the small-scale areas are relatively less integrated into the market economy and is cause for concern.

3.3.5 Livestock Production Enterprises

Communal farmers own the bulk of the national cattle, sheep, pigs and goats herds as shown in Figure 3.1. The five-year average numbers of livestock owned by the communal and commercial farmers clearly show the dominance of the communal farmers. Communal farmers owned more cattle, sheep, pigs and goats. However, communal farmers do not sell their animals because in per capita terms the number of animals owned is too small. For instance, the off-take, in terms of animals sold through formal markets, from communal farms is less than 3 percent compared with 23 percent for commercial farmers (Ndlovu, 1994). The offtake for the other smaller stocks is far less than that of cattle in communal areas. Livestock play a role in small-scale agriculture that is different from that it plays in large-scale commercial agriculture (providing draft power, store of wealth, insurance and food).

In small-scale agriculture livestock is an important input in crop production. Cattle and donkeys are an important source of draft power for land preparation and other field operations. Farmers who have access to draft animals can plough their fields early enabling them to benefit from the higher yields associated with early planting (Shumba, 1992). Those farmers without access to draft animals have to wait for those who have to finish planting their fields before they can hire and/or borrow. As a result they end up planting late and thus get poor yields. In addition livestock is also an important part of the nutrient cycle. Livestock provide manure used to improve soil fertility and structure. Crop residues are an important feed for livestock especially during the dry season. Efficiency in communal agriculture is dependent on how best farmers exploit the crop-livestock interactions.

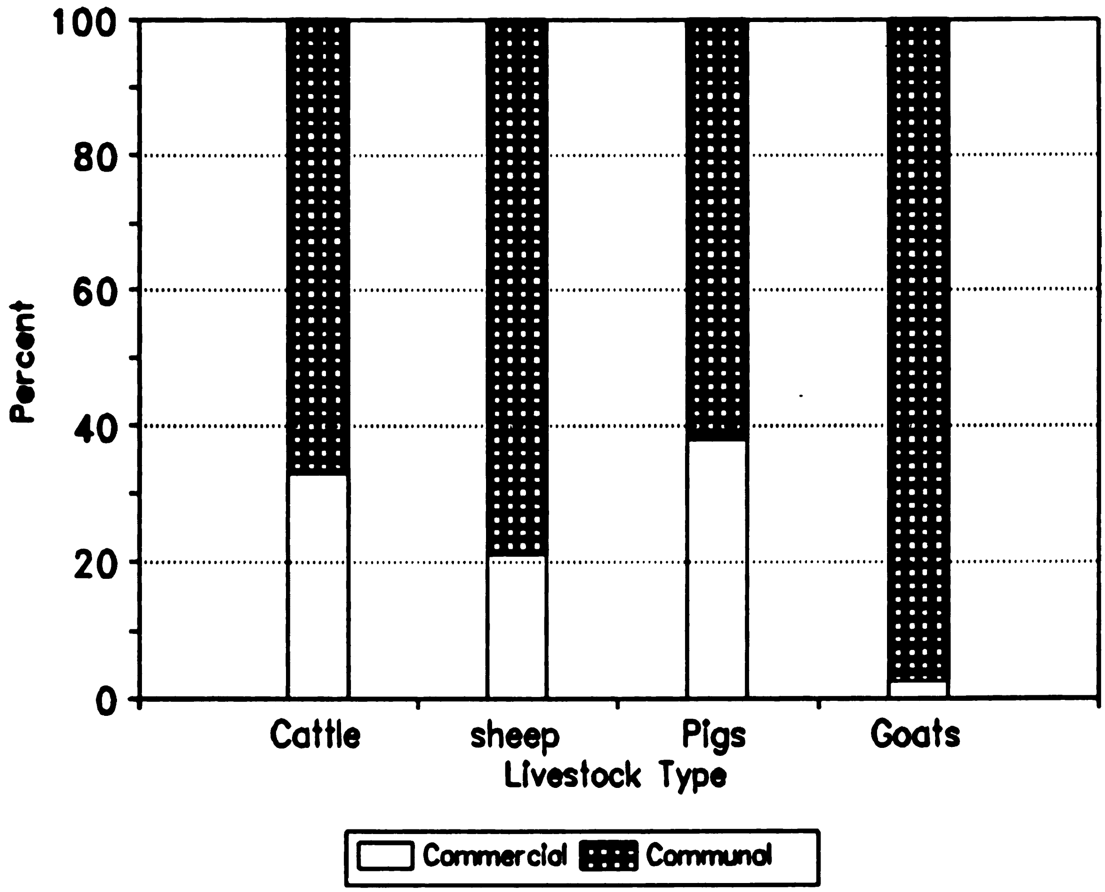

Figure 3.1: **Distribution of Livestock by Sector in Zimbabwe, 1987-1991**

Although communal farmers own the bulk of the national cattle, sheep and goat herds, not every one of them own all these species of animals. Furthermore those who own livestock, do not own them in numbers large enough for commercial livestock rearing and neither do they keep livestock for the same reasons commercial farmers do. Table 3.7 shows that a quarter of farmers sampled in the 1990/91 season did not own cattle. It also shows the ownership patterns for donkeys (which supply draft power in the semi-arid regions) and goats.

Table 3.7: Livestock Ownership Patterns in Selected Areas of Zimbabwe, 1990/91

Item	Low Potential Areas	High Potential Areas	All Areas
% Owning Cattle	74.4	74.4	74.4
Number Owned	6.1	4.9	5.8
% Owning Donkeys	20.2	2.9	15.9
Number Owned	0.7	0.1	0.5
% Owning Goats	77.5	52.5	71.2
Number Owned	6.7	2.6	5.6

Source: MLAWD, 1993

Other surveys in communal areas have reported higher percentages of communal farmers who do not own cattle[33]. However, the average number of cattle owned is close to other findings. The major point of interest is that while the percentage of cattle owners is the same for both the HP and LP zones, the average number of cattle per household in HP areas is less than that in LP areas by one animal. Fewer farmers in HP areas own donkeys and goats when compared with LP area farmers. The farmers who own donkeys and goats in HP

[33] For instance, Shumba (1985) reported that about 48 percent of farmers survey in Mangwende, a high rainfall area, did not own cattle. Mudhara et al (1995) reported from a survey of cotton farmers that about 40 percent of the farmers were non-cattle owners.

areas own far less of these animals when compared with owners of donkeys and goats in the LP areas. This pattern could be because there is more land per capita in the LP areas though this land is of limited potential. In addition the LP areas are more suited to livestock rearing than the HP areas according to the Vincent and Thomas's 1961 study (Chasi and Shamudzarira, 1992).

To summarize the communal farmers operate a system of crop-livestock enterprises that has weak links with the market economy relative to large-scale commercial farmers. The production system is heavily dependent on rainfall. Livestock are an important input into the crop enterprises such that it can be viewed as a capital input. Livestock provide crops with manure and draft power services. The value of livestock changes in either direction depending on the quality of the season and reproduction (appreciate or depreciate). Livestock and human labor are the major inputs in crop production. It is only maize and cotton that receive fertilizer and chemical inputs on a significant scale. The production system in communal areas is therefore less dependent on inputs from the market economy. It follows that if these inputs are to be used to revolutionalize agricultural production in these areas then some significant changes in the delivery of these inputs have to be implemented.

3.4 The Communal Areas in the 21st Century

There is no doubt that improving living standards in Communal Areas remains a major challenge to policy makers as the new millennium approaches. Despite substantial investments in improving small scale farmers' access to markets and support services and improvements in the rural infrastructure, the majority of communal area farmers remain impoverished. The main beneficiaries of these investments have been the small scale farmers in the high potential areas (Shumba, 1990). Nevertheless, even for these farmers in high potential areas the "independence dividend", caused by the improvements in access to support services and markets, has proved short lived because of financial sustainability problems. Designing new initiatives to eradicate poverty in communal areas and integrate the communal area population into national economic and political markets remains an elusive goal for all concerned.

This chapter has characterize the communal production systems in order to put the issue of eradicating poverty in the country-side into focus. By determining whether communal agriculture is efficient or not one is then able to screen the options that can be employed to wipe out rural impoverishment. If communal area agriculture is efficient, then new technologies could be developed to shift the efficiency frontier outwards. The other option is to expand the land frontier through redistributing underutilized and/or idle land. If, on the other hand, communal area agriculture is not efficient then living standards in these areas can be improved substantially by a program that focuses on changing the agricultural management systems. The role of extension, crop management research, input delivery systems and infrastructural development in such a program would be crucial. The characterization has shown how urgent the rehabilitation of Zimbabwe's country-side is to ensure sustainable and peaceful development.

3.5 Summary

The production systems are described in terms of the demographic characteristics of the households, household resource endowments and the production practices and patterns that farm household use. Characterizing communal area production systems does not only put the study into context but can be helpful when identifying factors that can be used to explain the differences in efficiency in the use of available resources at farm-level. Ultimately this characterization would help in identifying the critical areas where policy reform has a potential of achieving gains toward the goals of creating an egalitarian society in and rehabilitating the degraded communal lands of Zimbabwe.

In this chapter a communal area household, on average, consists of about nine members with over 70 percent of them headed by males who have completed about eight years of education. However, only three to four members reside and work full time on farm after adjusting for members attending school and/or working off farm. These four family members work on between 3 to 5 hectares of arable land, on average. Most households (88%) do not use formal credit sources to purchase inputs. Communal area production systems are low-input systems that are heavily dependent on ox-drawn implements. Most communal area farmers own cattle (74%), an ox-plough (over 76%) and a few other farm implements.

Communal area farmers devote over 29 and 23 percent of their arable area to the main crops, maize and ground nuts, respectively. The rest is used for other crops such as small grains and cash crops depending on agro-ecological zones. Because of its position as a staple food maize receives almost all of the fertilizer used on communal farm while other crops, with the exception of cash crops like tobacco and cotton, receiving next to nothing. In addition the improvements made on the maize crop through years of research have resulted in farmers from low potential areas growing maize instead of the more drought-tolerant small grains. As a result crop production in Zimbabwe's communal areas is dominated by maize.

Livestock is an important enterprise in communal areas not only on its own but more as an input into the crop production system. Livestock enterprises provide draft power and manure to crop production and make use of crop residue as a source of food. It became clear in this chapter that there was need to strengthen the low-input crop-livestock production system in communal areas. In doing so there is need to ensure that the benefits thereof are as equitably distributed as is possible without sacrificing efficiency.

CHAPTER IV: METHODOLOGICAL ISSUES: A LITERATURE REVIEW

4.1 Introduction

The main objective of this study is to measure the economic efficiency of communal area agriculture in Natural Regions II, III, IV and V. Measuring economic efficiency at the farm-level is preferable, so that a relationship between the estimated indicators of economic efficiency and variables that characterize communal area farm households can be specified. Having explained the variation of the estimated indicators of economic efficiency from one farm to the other, one can go on to draw policy implications and gain some insights into what factors should be considered when crafting programs to rehabilitate communal area agriculture in Zimbabwe.

Measures of farm-level efficiency are estimated from production, cost or profit frontier functions. These functions specify relationships between inputs and outputs. Since it is possible to produce several output levels using the same bundle of inputs the production, cost and profit functions have often been defined frontier functions. Production (profit) frontiers map the relationship between input bundles and the maximum level of output (profit) that these bundles can generate. Cost functions, on the other hand, are loci of the cheapest input bundles that can be used to produce given output levels. The notion of duality links production, profit and cost functions[34]. The best farm-level economic efficiency measures are estimated using the best models of the production technology.

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[34] Duality theory specifies that all the information that is contained in a production function is embodied in the cost function such that by estimating a cost function one can recover all the parameters that are in the production function. In other words the cost function is dual to the underlying primal production function. The dual cost function allows one to assume that firms choose inputs quantities so as to minimize the cost of producing a certain level of output given exogenously determined input prices.

In this chapter the main thrust is to review the literature on the methods of estimating production and cost functions and therefore economic efficiency indicators. The first section deals briefly with how to specify the relationship between outputs and inputs with emphasis on flexible functional forms. An important aspect of the input-output relationship addressed in this section is whether to use a cost function as opposed to a production function. The second section reviews recent developments and the extension of the original production or cost functions to make them more general and flexible. Special emphasis is placed on the use of a multi-product function versus a single product function and extensions that deal with short run asset fixities . Endogenization of pricing to take into account the existence of imperfect markets and the modeling of the impact of technical progress while important are not covered here. In the third section, the focus turns to how to use the estimated cost functions that take into account these generalizations and extensions to estimate indicators of economic efficiency.

4.2 Modeling the Production Technology

The economic concept of production functions, as it describes the technical process through which inputs are transformed into outputs, has preoccupied the discipline of economics for nearly two centuries. The advances made in the theoretical analysis of the relationship between the levels of inputs and outputs, starting in the mid-nineteenth century, were not matched by developments in empirical analysis (Berndt, 1993). The first attempt to empirically analyze input-output relationships occurred in the 1928 with the development of the Cobb-Douglas (C-D) function. Much of this early work focused on the use of production functions as devices for macroeconomic studies on the distribution of income between the two major inputs, capital and labor. But it was only after 1951 that Dean and others started work on the empirical estimation of microeconomic production functions (Greene, forthcoming). Most of the work on estimating the production function has involved the modification of the C-D functional form to make it more flexible and realistic. This discussion on modeling the production process through a standard production function is used here as a means to draw some insights on the estimation of frontier production functions. The latter concept is an extension of the former. The extension involves imposing the microeconomic theory-based constraint that a production function should be the maximum output that is possible from a given bundle of inputs. As will be shown later, by not allowing observations to lie above the production frontier (or below a cost frontier), this constrained estimation of the production function naturally leads to the measurement of efficiency as the difference between the observed and the estimated theoretical ideal.

4.2.1 Flexible Functional Forms

With the original C-D function, researchers could only estimate input value shares. The main force behind the modification of the C-D function into a constant elasticity of substitution (CES) function was to enable researchers to estimate input substitution elasticities (Berndt, 1993). Both the C-D and CES functions, however, proved restrictive as they assumed constant returns to scale. The development of the Generalized Leontief function and the Transcendental Logarithmic (Translog) functions made it possible for analysts to estimate input-output relationships without having to restrict the magnitude of the input substitution elasticities.

Conflict exists between structured and flexible production technology models. The more structure imposed on a model the better the estimates, as long as the imposed structure is correct. The correct structure is usually not known. In such a situation, it is better to estimate a sufficiently flexible model and then test possible restrictions.

In this study a choice of what structure to impose on production technology has to be made. As shown in the last chapter, communal agriculture farm-level technology is not easy to characterize. The generalized translog structure that will be used to model communal agricultural technology is a result of careful consideration of the data and characteristics of the communal farmers. In reaching such a decision one should recognize that stronger assumptions generate stronger results but strain one's conscience more (Bauer, 1990).

4.2.2 Dual Versus Primal Models

Very often researchers are interested in firm-level production issues rather than the issues for the whole industry. In competitive industries, prices are more exogenous than are quantities. Entrepreneurs cannot choose prices when maximizing profits in a competitive market. Everyone is a price-taker. Instead, they choose input quantities to produce a given level of output. Thus output levels and prices are exogenously determined. But when primal functions, such as production functions, are used output, being the dependent variable is endogenous and input quantities are exogenous. Thus these functions do not accurately reflect what takes place in competitive markets. The dual functions (mainly cost functions[35]) became popular because their ability to reflect the relationships generated by competitive markets. In addition the availability of disaggregated firm level data contributed to the growth in the use of dual functions in empirical analysis of production technology.

However, there is debate on the appropriateness of primal versus dual function estimation (Mundlak, 1996). The main issue of contention is the exogeneity of output

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[35] With dual functions output and prices are exogenous.

quantities. In this study the dilemma is whether communal area agricultural production systems are competitive given, on one hand, the large number of production units and, on the other, input and output markets that are not completely competitive. If markets are competitive all small farms would produce the same level of output, qe=Q/N[36]. In this case the output level is exogenously determined. The cost function treats output as exogenous as it would be under perfect competition scenarios.

But communal farmers usually face imperfect input and output market. It has been long recognized that neoclassical framework does not adequately capture the decision making process that characterize many small-scale semi-subsistence production systems (Ellis, 1993). It appears plausible to assume that communal area farmers choose how much to produce and then pick the cheapest input bundle to produce the chosen output level. The input and output level decisions are endogenous. But the input prices are still exogenously determined. The debate on the primal versus dual approaches thus is inconclusive in as far as it applies to communal area agriculture[37].

The dual function approach is used in this study because of its advantages when estimating economic efficiency. Because a production function specifies a theoretical maximum output given the observed input choices by producers, one can only estimate technical inefficiency. Technical inefficiency is specified as the extent to which output falls below the theoretical maximum output given by the production function. By definition the production function does not provide a framework from which one can estimate the extent

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[36] Q is the industry output determined by the equilibrium between the aggregate demand and supply. N is the optimal number of producers/suppliers.

[37] Simultaneous systems, which are used to handle cases with endogeneity problems, will not be used because output (being endogenously determined on communal farms) is expressed as the value of output. The endogenous output level is combined with exogenously determined product prices.

to which observed input choices diverge from the optimal levels dictated by cost minimization or profit maximization. Thus using cost functions provides a framework for addressing the question of optimal input choices or allocative efficiency. In addition, these dual functions allow the specification of multiple product technologies and the estimation of economically efficient sets of input choices through the use of Shephard's and Hottelling's lemmas for cost and profit functions, respectively. The second order conditions of a production function do not indicate farm-level input choice decisions.

4.2.3 Transcendental Logarithmic (Translog) Cost Function

One of the most significant developments in the generalization of the highly restrictive C-D and CES production functions, using duality theory, took place around 1961 when Heady and Dillon published a functional form that had second-degree polynomials with quadratic and cross-terms added to the C-D function.[38] Heady and his colleagues at Iowa State University were using experimental data to estimate input-output relationships using different functional forms. When they included input combinations that are in stage III of the production function (where the marginal products are negative) they found out that the C-D type functions became impractical. The third stage of production does not exist in C-D and CES functions because of the constant returns to scale assumption. The first-order derivatives (marginal products) of these functions are always positive. As a result the team headed by Heady had to develop a generalized functional form that allowed for all stages of production. Experiments with Taylor's series expansions as polynomial approximations to

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[38] This functional form was also developed independently by Christensen, Jorgenson and Lau ten years later and became known as the Transcendental Logarithmic (Translog) function.

unknown algebraic forms of the production process yielded what became the transcendental logarithmic or translog function (Berndt, 1993).

A non-homothetic translog cost function is presented here since it is very general because the ratio of cost minimizing input demands can depend on the output level. Assuming that there are 'k' input prices (P_i) for the input quantities (X_i) used by a producer to produce a single output (Y), and that P_i and Y are exogenous while X_i and the total cost of production (C) are endogenous, a non-homothetic translog cost function is specified as follows:

$$\begin{aligned} \ln C = \ln\alpha_0 &+ \sum_{i=1}^{k}\beta_i \ln P_i + \frac{1}{2}\sum_{i=1}^{k}\beta_{ii}(\ln P_i)^2 + \sum_{i=1}^{k}\sum_{j=1}^{k}\beta_{ij}\ln P_i \ln P_j \\ &+ \alpha_Y \ln Y + \frac{1}{2}\alpha_{YY}(\ln Y)^2 + \sum_{i=1}^{k}\delta_{iY}\ln P_i \ln Y, \quad \forall\ i \neq j \end{aligned} \tag{1}$$

The symmetry conditions are imposed by letting $\beta_{ij} = \beta_{ji}$. The translog cost function is nicely behaved[39] if it is homogeneous of degree 1 in input prices for a given output level. For this to apply the following restrictions must be imposed:

$$\sum_{i=1}^{k}\beta_i = 1, \ \sum_{i=1}^{k}\beta_{ij} = \sum_{j=1}^{k}\beta_{ji} = \sum_{i=1}^{k}\delta_{iY} = 0$$

If the underlying production technology dictates that the cost function is homothetic then an additional parameter restriction has to be imposed by letting the parameter δ_{iY} in the translog function to be equated to zero for all inputs. Constant returns to scale can also be imposed if the parameter restrictions $\alpha_{YY}=0$ and $\alpha_Y=1$ are made besides the homotheticity restriction.

[39] This means that all the parameters of the underlying production function can be derived from such a cost function.

The translog function is reduced to a Cobb-Douglas function if all the β_{ij} parameters are restricted to zero.

The translog cost function can be estimated directly after creating the cross products and quadratic variables. However, there are some efficiency gains if the optimal cost-minimizing input demand equations are estimated and transformed into cost share equations (Berndt, 1993). The translog cost function in equation (1) is differentiated with respect to input prices. Employing Shephard's Lemma yields the optimal cost-minimizing input demand equations and the cost share equations:

$$\frac{\partial \ln C}{\partial \ln P_i} = \frac{P_i}{C} \cdot \frac{\partial C}{\partial P_i} = \frac{P_i X_i}{C} = \beta_i + \sum_{j=1}^{k} \beta_{ij} \ln P_j + \delta_{iY} \ln Y = S_i \qquad \textbf{(2)}$$

The sum of S_i's for all inputs should equal unity. This is known as the "Adding-Up Condition" which implies that with n inputs, k-1 cost share equations are linearly independent. This condition has several important econometric implications.

The number of parameters to estimate from these cost share equations can be reduced by imposing restrictions. Among the most common restrictions are symmetry in parameter estimates, homogeneity, homotheticity and constant returns to scale conditions. Because residuals from the translog cost function and the cost-share equations that are used to estimate farm-level economic efficiency are related, there is considerable debate about how best to represent this relationship (O'Donnell, 1996). This additional problem has been christened after Greene (The Greene Problem) will be briefly discussed later on in this chapter.

In the estimation of production and cost functions many researchers are interested in estimating elasticities of substitution and own-price and cross-price elasticities. The elasticities of substitution from a non-homothetic translog cost function are estimated as follows:

$$\sigma_{ij} = \frac{\beta_{ij} + S_i S_j}{S_i S_j}, \ \forall\ j \neq i; \quad \sigma_{ii} = \frac{\beta_{ii} + S_i^2 - S_i}{S_i^2} \tag{3}$$

The cross-price and own-price elasticities from a non-homothetic translog cost function are, respectively, estimated as follows:

$$\epsilon_{ij} = \frac{\beta_{ij} + S_i S_j}{S_i}, \ \forall,\ j \neq i; \quad \epsilon_{ii} = \frac{\beta_{ii} + S_i^2 - S_j}{S_i} \tag{4}$$

These elasticities are used for testing input substitution and effects of price changes. Because the issue of input substitutions is outside the scope of this study, this subject will not be pursued in detail with the exception of the elasticity of costs with respect to output (λ). The inverse of λ is a measure of returns to scale and is estimated as follows;

$$\lambda = \frac{1}{\epsilon_{CY}}; \quad \textit{where} \quad \epsilon_{CY} = \frac{\partial lnC}{\partial \ln Y} = \alpha_Y + \sum_{i=1}^{k} \delta_{iY} \ln P_i + \alpha_{YY} \ln Y \tag{5}$$

Estimating the elasticity of costs with respect to output allows one to test hypotheses about the returns to scale. This returns to scale indicator is closely related to the measure of returns to size as will be demonstrated later.

The other area of interest to researchers is to check whether the estimated translog cost function is consistent with economic theory. Two of the most crucial conditions are to find out if the function is monotonic and if it is strictly quasi-concave in input prices. If the cost function increases monotonically then all fitted cost shares must be positive. Strict quasi-concavity exists if the $k \times k$ σ_{ij} matrix is negative semi-definite for each observation. It is also important that the condition that all cross-price elasticities sum up to zero is fulfilled to ensure homogeneity as required by economic theory.

4.3 Further Extensions of Cost Functions

Modeling the production process has undergone substantial changes ever since the Cobb-Douglas function was introduced around the 1930's. These changes came out of a desire by several researchers to model the process of production without having to impose, *a priori*, restrictions on the functional form or the parameters to be estimated. The Generalized Leontief (GL) and the Translog Cost functions are products of these efforts and are more flexible and general than the original C-D functional form. However, the GL and translog functional forms, though general and flexible, cannot adequately handle real world empirical work. Several extensions to the original formulations should be made to improve their ability to reflect real world situations.

A translog cost function is used in this section to illustrate that there are some important extensions to these generalized and flexible functional forms that can improve their capability to more accurately reflect real world situations. The extensions considered include using multi-product versus single product specifications and handling fixed inputs instead of assuming that all inputs can be instantaneously transformed into output. The incorporation of imperfections in input and output markets and the handling of the effects of technical progress on factor demands and costs are also important considerations in the empirical specification of the production process. They are not reviewed in this section, not because they are considered inconsequential, but because, when handling technical progress, a long time series is essential.[40] Endogenizing pricing in the product market to handle imperfect competition may not be necessary since the large numbers of small-scale farmers (producers) and the reforms taking place in agricultural commodity markets suggest a movement toward competitive markets.

4.3.1 The Multi-Product Cost Function

Since the 1930s, models of the production process have been presented as single output functions. Yet firms do not always produce a single product. Many firms produce more than a single product from a given bundle of inputs. Some firms producing a single product cannot maintain uniform product quality characteristics and therefore have a production function that is in many ways similar to that of a firm producing more than one product. Thus, there are two types of multi-product firms; those that produce more than one product, and those that produce a single product that is not uniform in terms of quality and other physical product characteristics.

Failure to take into account the variation in physical output with respect to quality attributes often results in specification errors. Some researchers have solved this problem by constructing hedonic measures of output as a function of the quality attributes of the product in question. This is essentially transforming the output variable into a quality-adjusted variable. The use of quality-adjusted output variable is most beneficial when estimating factor demand elasticities and economies of scope. The use of quality-adjusted output variables applies to firms that produce a single product but with different quality attributes.

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[40] Most researchers assume that the effects of technical progress are independent of the temporal composition and characteristics of capital inputs implying that technical progress is disembodied.

The quality-adjusted output variable cannot be used for a firm that produces more than one product. Here a multi-product cost/production function should be specified. The multi-product cost function recognizes the inherent danger of confusing economies of scale and economies of scope[41]. The major advantage of a multi-product formulation is that it allows more in-depth analysis of the effects of the various changes in the composition (scope economies) and levels (scale/size economies) of output on the costs and factor demands. This form of the multi-product specification has become the most preferred in empirical work.

The total cost of producing 'm' outputs using 'k' inputs is generally expressed as C(Y,P) where Y in a $m \times 1$ column vector of output levels and P is a $k \times 1$ column vector of input prices. C(Y,P) is defined to satisfy regularity conditions[42] so that it is dual to a transformation function T(Y,X), where X is a $k \times 1$ column vector of input levels. This duality condition between C(Y,P) and T(Y,X) ensures that the two functions contain the same information about the production process. The function C(Y,P) is assumed to be a translog technology specification. The multi-product translog cost function is a straightforward extension and generalization of the single output case. The translog form of the multi-product cost function can be represented as follows:

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[41] Economies of scale and size are concerned with the absolute size of the production unit while economies of scope refer to the advantages or disadvantages associated with the number of products that a single firm produces. It is not possible to separate the effects of scope economies from scale/size economies without employing a multi-product function.

[42] The regularity conditions in C are that (i) it is non-negative; (ii) it has real values, (iii) it should be non-decreasing, (iv) it is strictly positive for nonzero Y, and (v) it be linearly homogeneous and concave in X for each Y.

$$\ln C = \ln\alpha_0 + \sum_{i=1}^{m}\alpha_i \ln Y_i + \frac{1}{2}\sum_{i=1}^{m}\alpha_{ii}(\ln Y_i)^2 + \sum_{i=1}^{m}\sum_{j=1}^{m}\alpha_{ij}\ln Y_i \ln Y_j$$
$$+ \sum_{i=1}^{k}\beta_i \ln P_i + \frac{1}{2}\sum_{i=1}^{k}\beta_{ii}(\ln P_i)^2 + \sum_{i=1}^{k}\sum_{j=1}^{k}\beta_{ij}\ln P_i \ln P_j \qquad (6)$$
$$+ \sum_{i=1}^{m}\sum_{j=1}^{k}\delta_{ij}\ln Y_i \ln P_j$$

The main problem with equation (6) is that, because outputs are expressed in logarithmic values, it does not permit output values to have zero values. If there are zero values, the translog multiproduct cost function does not have finite representation (Caves, Christensen and Tretheway, 1981). Caves et al (1981) proposed a Box-Cox metric as a way to handle this problem. This metric replaces ln Y_i in equation (6). Box and Cox specified the metric (λ) such that $f_i(Y_i) = (Y_i^\lambda - 1)/\lambda$, for all $\lambda \neq 0$ and $f_i(Y_i) = \ln Y_i$ for $\lambda = 0$, where λ is always positive. Thus $(Y_i^\lambda - 1)/\lambda$ would replace $\ln Y_i$ in equation (7)[43]. The result is a generalized translog multiproduct cost function (Caves, et al, 1981). Eakin and Kniesner (1988) developed a similar model which they termed "hybrid translog" multiple output cost function. The extension to this model done by Atkinson and Cornwell (1992, 1993) will not be considered here because it requires the use of panel data.

One way to accommodate observations for which outputs are zero in to define the logarithms of output not as log(Y) but log(Y+1). When output is zero the logarithmic value computed this way will be zero. This study uses this approach because it is simpler than the Box-Cox metric.

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[43] The limiting case of the Box-Cox metric is the natural log metric i.e. $\lim_{\lambda \to 0}\frac{(Y_i^\lambda - 1)}{\lambda} = \ln Y_i$

Following the way cost share equations are derived for single output translog cost functions and using Shephard's Lemma, the cost share equations of the generalized translog multiproduct cost function are as shown below:

$$\frac{P_i X_i}{C} = \frac{\partial C}{\partial P_i}\cdot\frac{P_i}{C} = \frac{\partial \ln C}{\partial \ln P_i} = \beta_i + \sum_{j=1}^{k} \beta_{ij} \ln P_j + \sum_{j=1}^{m} \delta_{ji} \ln(Y^*) \qquad (7)$$

where $\ln(Y^*) = \ln(Y+1)$

Once the cost share equations have been specified then the elasticities of substitution, own-price and cross-price elasticities and other parameters can be estimated.

4.3.2 Incorporating Input Fixity

This discussion has implicitly assumed that all input can be instantaneously adjusted to their long-run, full equilibrium levels. This assumption does not hold for many real world situations. It is not always possible to change the level of inputs instantaneously in response to changes in other variables such as input and output prices. This realization has lead many researchers to develop a framework that recognizes that total costs consist of variable and fixed and/or quasi-fixed costs. Quasi-fixed costs correspond to inputs that cannot be completely adjusted to their full equilibrium level within one production period. Making this distinction is similar to differentiating between short-run cost functions (with some of inputs being fixed at levels that are not at their long-run full equilibrium) and long-run cost functions (with all inputs being used at their full equilibrium levels).

In specifying the generalized translog multiproduct cost function two transformations take place. First the total cost is replaced as a dependent left-hand side variable by the variable cost variable and second the logarithms of the price of fixed inputs, such as capital, are replaced by the logarithm of the actual amount of the fixed input used in production (for example ln K_i replaces ln P_i for capital in equation (6)). The result is a generalized translog multiproduct variable cost function. Thus the cost share equation derived from the generalized translog multiproduct variable cost function, using Shephard's Lemma, can be written as shown in equation (8) below:

$$\frac{\partial lnVC}{\partial lnP_j} = \frac{P_jX_j}{VC} = \beta_j + \beta_{jj}\ln P_j + \sum_{i=1}^{k-1}\beta_{ij}lnP_i + \sum_{i=1}^{h}\gamma_{ij}lnK_i + \sum_{i=1}^{m}\delta_{ij}\ln(Y_i^*) \qquad \textbf{(8)}$$
$$given\ that\ k = h+l.$$

In equation (8) the number of fixed inputs (denoted K) is h and the number of variable inputs is still k. This equation can then be used to estimate the elasticities and other parameters that the researcher is interested in.

The generalized translog multiproduct variable cost function has the advantage that one can calculate the shadow value of the fixed inputs by differentiating this variable cost function with respect to the fixed inputs, i.e., ∂VC/∂K. This shadow value is a one-period reduction in variable costs when the quantity of K is increased by one unit everything else being equal. In the short run this value is not expected to equal the market price of the fixed input that represents the long-run full equilibrium price level for this fixed input. Because it is possible to define the full equilibrium level of the fixed inputs as that amount that prevails when the shadow value of the fixed input equal the market value, distinguishing short-run functions from the long-run function is feasible. This property also makes it possible to distinguish between short and long term input substitution and own-price and cross-price elasticities. By treating some inputs as fixed and/or quasi-fixed, the generalized translog multiproduct variable cost function is sometimes called the generalized translog multiproduct restricted cost function.

The case for a generalized translog multiproduct variable cost function as a potential model of communal agricultural production technology in Zimbabwe has been made. It clearly does not take into consideration all the extensions proposed because of data problems and sometimes the inapplicability of the situation that lead to these extensions to the situation in Zimbabwe's communal areas. It is hoped that the generalized translog multiproduct variable cost function is general and flexible enough to reflect the diverse production processes in Zimbabwe's communal farming areas adequately. In the next section the focus turns to how to use the generalized translog multiproduct variable cost function to estimate indicators of economic efficiency.

4.4 Estimating Economic Efficiency

The preceding sections have highlighted the problems associated with modeling the production process. The main problems relate to the numerous choices that have to be made. Some of the important decisions include whether to use dual (cost or profit) or primal (production) functions, structured or flexible functional forms and the best mix of assumptions for the modeling of the production process to be as realistic as is possible. The availability of data have a decisive bearing on the final choices to make when modeling the production process. Once the decision on how to model the production process is made, the next step is to consider another set of decisions concerning the estimation of economic efficiency using production technology models.

It is important at this stage to reiterate the importance of distinguishing between production or cost functions and frontiers when estimating indicators of efficiency. Conventionally production or cost functions are estimated by fitting an "average" function over observations using techniques such as ordinary least squares. Even though this procedure allows the representation of interesting technical aspects of production such as economies of scale, size and scope, input substitution and input demand elasticities, the "average" function is not adequately constructed to capture the theoretical definition of a production or cost function. Theoretically a production (cost) function expresses the maximum (minimum) amount of output (cost) obtainable from a given bundle of inputs using a given technology (Aigner, Lovell and Schmidt, 1977). As such no producer can operate above (below) a production (cost) function. The development of production or cost frontiers provided a way to bridge the gap between theoretical and empirical work[44]. Production (cost) frontiers are regressions that take into account the theoretical constraint that producers cannot operate above (below) the frontier (Greene, forthcoming). It is from this constrained estimation process that measures of economic efficiency naturally emerge as representations of the distance between what producers do and the theoretical ideal that is defined by the frontier function.

4.4.1 Economic Efficiency

Economic efficiency holds whenever technical and allocative efficiency conditions are satisfied. A technically efficient farm cannot produce more output than the efficient level from a given input bundle. Thus there is no way of producing the current output level using fewer inputs than currently employed. Allocative efficiency holds whenever a farm maximizes profits by equating the values of the marginal product of inputs to their respective input prices. Thus one farm can be more economically efficient than another due to differences in technical and/or allocative efficiency.

[44] Lau and Yotopoulos (1971) used a "meta" cost function to approximate a cost frontier in line with economic theory.

The measurement of efficiency was popularized in a classic paper by Farrell (1957) who noted that quantifying productive efficiency would enable empirical testing of theoretical propositions about the relative efficiency of different economic systems. This process involved modeling the transformation of inputs into outputs (the production technology). As noted above, the production technology is normally described by means of a production or cost frontier both of which are not known. The observed input and output data can be used to construct the unknown production or cost frontiers empirically. Following the pioneering work of Debreu (1951) and Farrell (1957) figure 4.1 graphically illustrates these two components of economic efficiency using a conventional isoquant/isocost framework where two inputs (X1 and X2) are used to produce a single output.

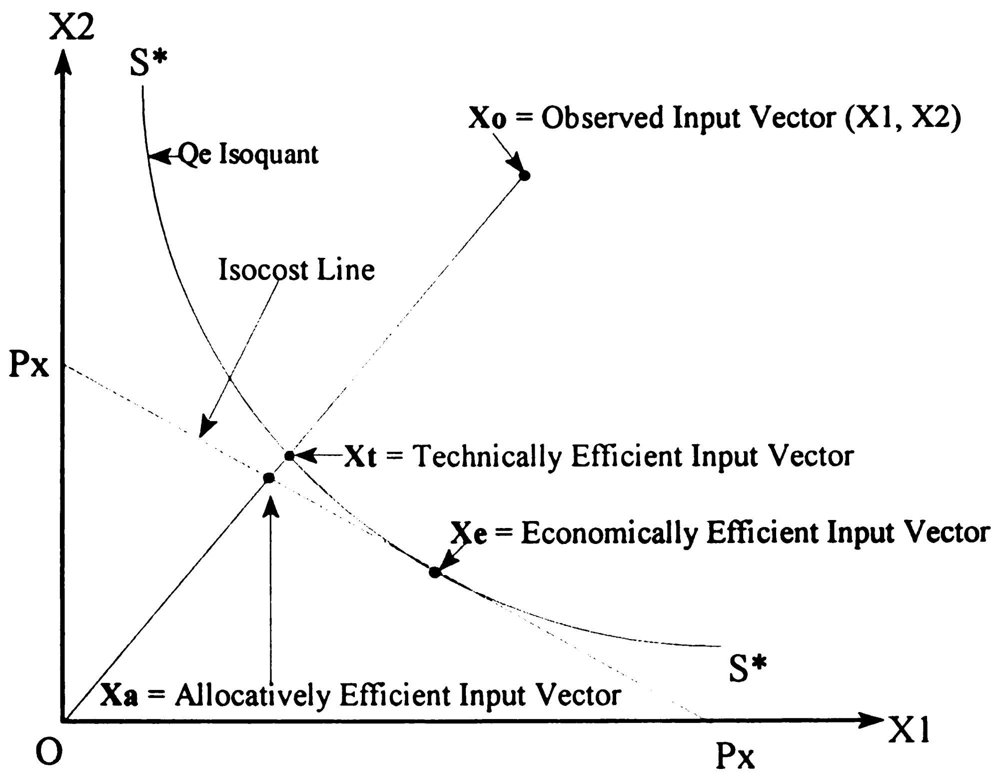

Figure 4.1: Illustration of Relative Economic Efficiency

Figure 4.1 shows an inefficient input vector X_o used to produce some given level, say Q_e, of output that is mapped by an isoquant S^*S^*. An isocost line PxPx from given input prices when combined with the isoquant yields a unique least cost combination of inputs to produce the given output level. Debreu and Farrell measured technical efficiency using this framework as shown below.[45];

$$\theta(t) = \frac{|X_t|}{|X_o|}$$

But although input vector X_t is technically efficient, because it lies on the isoquant, it is not economically efficient. Output Q_e can be produced using an input vector X_e which costs less than X_t. Any producer who uses X_e to produce Q_e is both technically efficient (located on the isoquant) and allocatively efficient (produces Q_e at least cost). Because input vector X_a costs the same as input vector X_e, a measure of allocative efficiency can be represented as follows;

$$\theta(a) = \frac{|X_a|}{|X_t|}$$

Allocative efficiency can be measured only when price information is available. Thus the measure of economic efficiency/total efficiency is a product of the two components of firm-level efficiency; $\theta(e) = \theta(t) * \theta(a)$. Thus $\theta(e)$ can also be expressed as shown below;

$$\theta(e) = \frac{|X_a|}{|X_o|}$$

[45] $|x|$ denotes the length of the input vector x.

These measures of efficiency, as shown in figure 4.1, represent the distance between the observed input bundle X_0 and the theoretical ideal X_a.

Estimating economic efficiency involves using available input use information (X_0 and P_{Xi}) to derive X_e, X_a, X_t and the associated measures of the components of economic efficiency. This can be done in two ways. We will outline parametric and non-parametric approaches to estimating economic efficiency (technical and allocative efficiency).

4.4.2 Parametric Measure of Economic Efficiency

One of the two main paradigms to estimate the production and/or cost frontiers is the parametric approach. This is the most common and conventional approach that involves the econometric estimation of a production or cost frontier. A generalized translog multiproduct variable cost frontier function is an example of this approach where producers use n inputs (X_i), purchased at given prices (P_i) to produce m outputs (Y_i) under an environment dictated by h fixed and quasi-fixed factors (K_i). While the producer's objective is to produce at minimum cost, success is often elusive.

In the estimation process there is need, first, to impose restrictions on the cost frontier to account for regularity conditions, and, second, to specify an error structure that accounts for the mistakes producers commit as they try to minimize costs. In the latter case, the error structure is normally specified as consisting of two terms with an *a priori* distribution[46]. Following Ferrier and Lovell (1990) if the cost frontier is a generalized multi-product

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[46] Aigner, Knox-Lovell and Schmidt (1977) suggested a two-part error term composed of (a) the pure random noise, assumed to be normally distributed, and(b) an inefficiency term that has a one-sided distribution. This one-sided distribution can be half-normal, exponential, truncated normal or a two-parameter Gamma distribution.

translog, then the producers' commonly observed total variable cost and observed input variable cost shares can be written as follows;

$$
\begin{aligned}
\ln VC_t = {} & \ln\alpha_0 + \sum_{i=1}^{m}\alpha_i \ln Y_{it}^{*} + \sum_{i=1}^{k}\beta_i \ln P_{it} + \sum_{i=1}^{h}\gamma_i \ln K_{it} + \frac{1}{2}\sum_{i=1}^{m}\alpha_{ii}(\ln Y_{it}^{*})^2 \\
& + \frac{1}{2}\sum_{i=1}^{k}\beta_{ii}(\ln P_{it})^2 + \frac{1}{2}\sum_{i=1}^{h}\gamma_{ii}(\ln K_{it})^2 + \sum_{i=1}^{m}\sum_{j=1}^{m}\alpha_{ij}\ln Y_{it}^{*}\ln Y_{jt}^{*} \\
& + \sum_{i=1}^{k}\sum_{j=1}^{k}\beta_{ij}\ln P_{it}\ln P_{jt} + \sum_{i=1}^{h}\sum_{j=1}^{h}\gamma_{ij}\ln K_{it}\ln K_{jt} + \sum_{i=1}^{m}\sum_{j=1}^{k}\delta_{ij}\ln Y_{it}^{*}\ln P_{jt} \\
& + \sum_{i=1}^{m}\sum_{j=1}^{h}\rho_{ij}\ln Y_{it}^{*}\ln K_{jt} + \sum_{i=1}^{n}\sum_{j=1}^{h}\lambda_{ij}\ln P_{it}\ln K_{jt} + \epsilon_t
\end{aligned}
\tag{12}
$$

The k-1 input variable cost share equations are as follows;

$$
\frac{\partial lnVC}{\partial lnP_j} = \left(\frac{P_j X_j}{VC}\right)t = \beta_j + \beta_{jj}\ln P_{jt} + \sum_{i=1}^{k-1}\beta_{ij} lnP_{it} + \sum_{i=1}^{m}\delta_{ij} lnY_{it}^{*} + \sum_{i=1}^{h}\lambda_{ij} lnK_{it} + \mu_{jt}
$$

Where the error terms are defined as follows, $\varepsilon_t = \pi_t + \omega + \nu_t$ and $\mu_{jt} = \Omega_j + \upsilon_{jt}$ (Ferrier and Lovell, 1990).

The above definition of error terms suggest that observed costs differ from efficient costs for three reasons. First, there is technical inefficiency captured by the term, $\pi_t \geq 0$ and is assumed to have half-normal distribution ($\pi_t \sim |N(0,\ \sigma_\pi^2)|$) then allocative inefficiency represented by a scalar, $\omega \geq 0$, and random noise which producers cannot control, ν_t and has zero mean ($\nu_t \sim N(0,\ \sigma_\nu^2)$). There are two components on the error term obtained when the observed input share equations were estimated. Thus input shares diverge from the efficient input shares because of allocative inefficiency in the way producers use inputs as shown by, Ω_j which can be either positive or negative. The influence of factors beyond producers' control in input use causes random variations in observed input cost shares which is represented by υ_{jt} with a zero mean and constant variance. Thus μ_{jt} does not have a zero mean and is assumed to have the following normal distribution; $\mu_{jt} \sim N(\Omega_j\ ,\ \sigma_{\mu_j})$.

The relationship between the cost function and cost share equation error terms remains an unresolved issue and hence a subject of intensive research effort. Greene (1980) was the first to realize the problem when he found out that treating the two error terms as independent was an unsatisfactory restriction from a theoretical as well as practical point of view. It is reasonable to expect that whenever there are errors in the way producers use inputs then producers will not be able to produce at minimum cost. In other words higher costs are a result of mistakes in the use of inputs. This problem has been christened the "Greene Problem".

Ferrier and Lovell's solution to the Greene Problem was to assume that allocative efficiencies were the same for all observations. They also assumed a close positive correlation ω between and Ω_j so that whenever there are errors in the way inputs are utilized producers end up with higher costs. Their specification takes care of the fact that costs are a result of mistakes in the use of inputs and that those producers who commit relatively larger errors end up with higher total variable costs. Thus when Ω_j has a higher variance, the value of ω is expected to be correspondingly higher. This relationship between ω and Ω_j's was defined as follows;

$$\omega = \sum_{j=1}^{n} \psi_j \Omega_j^2$$

where ψ_j are weights. Note that since ω is a scalar, it is not possible to obtain producer-level estimates of allocative inefficiency from such a formulation.

Maximum-likelihood techniques are usually employed to estimate the observed cost frontier and input cost share equations. The procedure yields not only the set of parameters that describe the efficient cost frontier and input cost share equations, but also a set of parameters that shows the extent of divergences between the efficient cost frontier and the observed attempts by producers to minimize production costs. These include Ω_j and their variances, the weights, ψ_j and the variance of π_t. After computing the estimate of allocative efficiency, ω, as shown above, technical efficiency estimates, π_t, can be calculated as follows;

$$\hat{\pi}_t = (\hat{\varepsilon}_t - \hat{\omega}) \times \left(\frac{\hat{\sigma}_\pi^2}{\hat{\sigma}_\pi^2 + \hat{\sigma}_v^2} \right)$$

Where the hat-notation denotes an estimated parameter. This approach will yield farm-level estimates of technical efficiency and an average measure of allocative efficiency. To explain variation in farm-level efficiency only measures of technical efficiency will be employed.

Kumbhakar (1991) extended Ferrier and Lovell's formulation by imposing the conditions of Shepherd's lemma on the cost function residuals as shown below;

$$\Omega_{jt} = \frac{\partial \varepsilon_t}{\partial lnP_{jt}} = \frac{\partial \pi_t}{\partial lnP_{jt}} + \frac{\partial \omega}{\partial lnP_{jt}}$$

After imposing this relationship, Kumbhakar then formulated the log-likelihood function that takes into account the implications of this relationship on the efficiency components of the cost function residuals (ie, $\pi_t + \omega$). This formulation specifically applies to translog cost functions that correspond to non-homothetic production functions. Although this extension in itself is not restrictive, it is not grounded in economic theory. The question is in what ways can the level of input prices be related to inefficiency? Because the derivative of economic inefficiency with respect to input prices, or Ω_j, can be negative or positive, the direction of causality is ambiguous.

The formulation of the relationship between the efficiency parameters in the cost frontier function and the cost share equations that allows allocative efficiency to vary across observations and is derived from economic theory remains a challenge to practitioners working on frontier models. The other challenge is to formulate this relationship in a way that minimizes complexities during empirical estimation and biases in the resultant parameter estimates. In this study separate measures of technical and allocative efficiency will not be estimated because of the problems associated with their separation during estimation.

The advantage of the parametric approach is that it provides a consistent framework for the econometric investigation of the indices measuring technical, allocative and scale (scope and size) efficiency (Chavas and Aliber, 1993). However, the assumed functional form cannot be tested statistically[47] and may introduce specification errors (Färe, Grosskopf and Kraft, 1987). The other problem with parametric estimation of production functions is the inconsistency between the theoretical definitions of the function as a maximum (or a cost function as a minimum) coupled with the use of methods based on zero mean errors in the estimation process (Hall and LeVeen, 1978).

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[47] For example, whenever a Cobb-Douglas production function is imposed, homotheticity is prejudged even though no homotheticity test is performed. The same can be said of the use of input and output price and quantity data as if the data was generated by perfect competition when a dual function is employed. (Hanoch and Rothschild, 1972)

4.4.3 Non-Parametric Measure of Economic Efficiency

The two main non-parametric approaches to measuring economic efficiency are deterministic frontier models and data envelopment analysis (DEA). They both use mathematical programming as an algorithm to generate the measures of efficiency and closely resemble each other. The main difference between the two non-parametric approaches is that DEA does not impose an *a priori* parametric restriction on the production technology as occurs when deterministic frontiers are employed. DEA procedures yield a piecewise, quasi-convex hull around the observed data points in input space. The procedure strictly compares observations to some observed best practice.

In non-parametric models observations deviate from the theoretical optimum due to mistakes by producers only. Random errors are not taken into account. Both non-parametric approaches rationalize observed data by a closed and convex production possibility set if the input, output and price data are consistent with profit maximization[48]. Thus the production technology can be bounded without imposing restrictive parametric functional forms (Varian, 1984). In deterministic frontier models technology is parameterized, but the absence of stochastic variation makes statistical inference impossible.

The non-parametric approach is an easy method to measure relative productivity that can also handle production technologies with disaggregated inputs and multiple outputs (Chavas and Aliber, 1993). When economic (technical and/or allocative) inefficiencies exist, then the observed data are inconsistent with profit maximization. Here there is no production possibility set that rationalizes the observed data (Banker and Maindiratta, 1988). The

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[48] An observed input, output and price data set Θ of n farms is rationalized by a production possibility set Υ, if every input-output vector is contained in set Υ and is consistent with profit maximization relative to all other sets in Υ, for a given price vector (Banker and Maindiratta, 1988).

measures of the levels of inefficiency depend on the production possibility set to which they are evaluated. The tightest, lower and upper bounds of measures of inefficiencies represent the best description of the production frontier that can be constructed without imposing structural restrictions such as a specific functional form. This production (cost) frontier is obtained by floating a linear surface (hyperplane) on the "top" (bottom) of the observations.

The nonparametric approach's main weakness is that its estimates of economic efficiency cannot be subjected to tests of statistical significance. The procedure does not yield hypotheses tests (Cox and Chavas, 1990). This is because the model does not provide for statistical noise, measurement errors and omitted variables errors. All deviations of observations from the efficient frontier are attributed to inefficiency. In addition the linear hyperplane is sensitive to extreme points thus rendering most of the observations inefficient.

4.5 Methodology Cross-Checking

The main objective of this study is to analyze the structure and efficiency of communal agriculture in Zimbabwe. This can be done using parametric and nonparametric techniques. Which technique is best? Is it necessary analytically to compare the capability of the two techniques to reveal consistently the same story about economic efficiency using the same data set? The two techniques have different strengths and weakness. By comparing their performance in estimating economic efficiency we shed light on the relative weights to attach to their differences.

Ferrier and Lovell (1990) compared the ability of econometric and mathematical programming (MP) techniques to reveal the structure of cost efficiency in banking accurately. They compared the rankings of firms based cost efficiency estimates using the two techniques. Technical efficiency rankings from the two techniques were positively correlated but were insignificant. One reason advanced for this finding was the inability of the MP technique to exclude statistical noise. Linear programming is a non-stochastic technique. The econometric approach used in the Ferrier and Lovell study was stochastic. Unlike the MP technique, the econometric approach can account for pertinent institutional variables plus random noise. The difference in the efficiency estimates from the two techniques can be attributed to the difference in both structure and implementation of the two estimation techniques (Ferrier and Lovell, 1990).

The question is can a stochastic MP technique produce results comparable to those from a stochastic econometric model. Bjurek, Hjalmarsson and Forsund (1990) showed that the differences in measures of structural efficiency using deterministic (non-stochastic) parametric and nonparametric specifications were "surprisingly small". Finding out if small differences exist between measures of economic efficiency using stochastic parametric and nonparametric specifications is an important analytical exercise. The problem has been how to develop a stochastic nonparametric model of production technology. LP models are hyperplanes fitted on top of observations and cannot be compared with stochastic frontier models that allow some observations to lie above and below the fitted hyperplanes.

This study will not pursue the analytical goal of comparing parametric and nonparametric frontier models due to two main reasons. First stochastic nonparametric models have not been adequately developed. Developing a stochastic nonparametric model comparable to the stochastic parametric model would be a major exercise that a separate study can handle. Second, the similarity between the results from deterministic parametric and nonparametric models coupled with the positive (though insignificant) correlation between rankings based on a stochastic parametric model and a deterministic nonparametric model (Ferrier and Lovell, 1990) suggests that stochastic parametric and nonparametric models are likely to produce comparable results. This study will, therefore, concentrate on the estimation of measures of economic efficiency using a stochastic parametric model - the generalized translog multiproduct variable cost frontier function.

4.6 Summary

This chapter briefly reviewed the relationship between factors of production and output. Duality theory lead to the development of Translog Cost functions. These functions are based on the theory that a cost function, by being dual to the production function, captures all the information that is in the transformation function itself. The major advantage of a cost function is that the way it is specified more accurately reflects the process which farmers use to maximize profits. In competitive markets farmers are often faced with a set of output and input prices and have to produce a given level of output. Thus, they have to minimize the costs of producing this output by choosing input quantities.

The first extension discussed in this chapter covered the fact that farms like most production units do not produce a single product. They have multiple outputs and have to be modeled as multiproduct firms. The second extension discussed in some detail is to allow for the fact that not all inputs can be instantaneously be transformed into the final product over the production period. In other words some inputs are fixed in the short run. The dependent variable was therefore changed into a variable cost variable and the amount of the fixed inputs used replaced the price of this input on the right-hand side. The final product was a generalized translog multiproduct variable cost function.

Generalized translog multi-product variable cost functions and frontiers were used as the best representation of the relationship that characterizes the production process. To estimate economic efficiency using this function an error term was added. A special feature of this error term is that it can be decomposed into its constituent components. The normally distributed component represents variability outside the farmer's control. The other is due to inefficiency at the farm-level. Measuring economic efficiency therefore involves decomposing the error term into its constituent components. The other method of measuring economic efficiency is the non-parametric approach that employs linear programming techniques to fit a hyperplane on the observed data points. This hyperplane becomes an estimate of the cost frontier so that those farms that are above the hyperplane are considered inefficient. Efficient farms are those that are on the hyperplane.

Results obtained from the two approaches of estimating economic efficiency are only comparable if a stochastic nonparametric model is developed. The main intent of this study is not to develop such a model but to analyze the structure and economic efficiency of communal agriculture in Zimbabwe. The next chapter goes into the details of how to measure the economic efficiency of small-scale farms in Zimbabwe by specifying the necessary data transformations required when estimating a generalized translog multiproduct variable cost function.

CHAPTER V: CHARACTERISTICS OF COMMUNAL AGRICULTURAL PRODUCTION DATA

5.1 Introduction

This chapter describes the characteristics of the data used in this study to estimate cost functions and frontiers from which farm-level efficiency measures are derived. Measures of spread are presented for each of the variables that is included in the estimation of cost functions and frontiers. As pointed out in the third chapter, the data were collected from communal farmers by the Farm Management Section of the Economics Division of the Ministry of Agriculture. The main purpose for collecting this data was to develop a data base from which informed general policy decisions could be made.[49] It must be noted that these data were not collected primarily for the measurement of economic efficiency. However, the data are detailed and comprehensive enough to permit the estimation of multi-product translog cost functions and frontiers. But there are other techniques to estimate relative economic efficiency, both modern and old, that cannot be used in this study because they require specialized data which is unavailable.

This chapter is organized as follows: The first section briefly reviews the generalized multi-product translog variable cost function. This is followed by sections describing the variables used to estimate the cost functions and frontiers. These are output values, variable input prices, quantities of fixed and quasi-fixed inputs and environmental variables[50]. The

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[49] The data collection program was designed when mechanisms for moving from a controlled to a market-oriented economy were being debated with a view to implement them. Information from communal areas was considered essential in managing the new economic system.

[50] The two environmental variables that are included in this study are soil quality and the location of the farms in terms of natural regions.

quantities of variable inputs were used to calculate the total variable costs. The main focus of these four sub-sections is to look at general patterns and variability across farms and across seasons. The last section consists of a brief discussion of the Ministry of Agriculture data collection instrument. The main intention is to identify the potential data gaps as well as provide an overall assessment of the suitability of the data set for estimating translog multi-product variable cost functions and frontiers

5.2 The Cost Function Data

The generalized translog multi-product variable cost function (GTMVC), as specified in the previous chapter, is made up of the total variable cost (TVC_i) as the dependent variable; output quantities (Y_i), input prices (P_i), amounts of fixed inputs (K_i) and environmental variables (L_i) as independent variables. The GTMVC function is been specified as shown below to illustrate the manner in which the above-mentioned variables make up the cost function and cost frontiers.

$$\begin{aligned} \ln VC_t = {} & \ln\alpha_0 + \sum_{i=1}^{m}\alpha_i \ln Y^{*}_{it} + \sum_{i=1}^{k}\beta_i \ln P_{it} + \sum_{i=1}^{h}\gamma_i \ln K_{it} + \frac{1}{2}\sum_{i=1}^{m}\alpha_{ii}(\ln Y^{*}_{it})^2 \\ & + \frac{1}{2}\sum_{i=1}^{k}\beta_{ii}(\ln P_{it})^2 + \frac{1}{2}\sum_{i=1}^{h}\gamma_{ii}(\ln K_{it})^2 + \sum_{i=1}^{m}\sum_{j=1}^{m}\alpha_{ij}\ln Y^{*}_{it}\ln Y^{*}_{jt} \\ & + \sum_{i=1}^{k}\sum_{j=1}^{k}\beta_{ij}\ln P_{it}\ln P_{jt} + \sum_{i=1}^{h}\sum_{j=1}^{h}\gamma_{ij}\ln K_{it}\ln K_{jt} + \sum_{i=1}^{m}\sum_{j=1}^{k}\delta_{ij}\ln Y^{*}_{it}\ln P_{jt} \\ & + \sum_{i=1}^{m}\sum_{j=1}^{h}\rho_{ij}\ln Y^{*}_{it}\ln K_{jt} + \sum_{i=1}^{n}\sum_{j=1}^{h}\lambda_{ij}\ln P_{it}\ln K_{jt} + \pi_1 L_{1t} + \pi_2 L_{2t} + \epsilon_t \end{aligned} \qquad (16)$$

The characteristics of the main components of cost function above are described in the next sections. Although the variables are expressed in logarithmic form, the characteristics discussed are for the original values of these variables.

5.2.1 The Output Variables (Y_i)

The output variables in the GTMVC function is expressed in monetary values. To avoid degrees of freedom problems, farm outputs were grouped into four categories. These are maize, legumes, small-grains and cash crops[51]. Output amounts and prices used to construct this vector were obtained from the survey data. The prices used were either the farm-gate (selling price less transport costs) for quantities marketed formally or the local selling price for quantities sold locally and/or retained for family consumption. The price indices for the legumes, small grains and cash crops are a summation of individual crop prices weighted by the ratio of the value of that crop to the total value of the crop category. The descriptive statistics of the total farm output levels (in nominal monetary terms) are shown in Table 5.1 below.

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[51] Farm output, Y, is a 4×1 vector (m=4). The legumes category consist of groundnuts, bambara nuts, field beans and cowpeas. Small grains include sorghum, pearl millet and finger millet. Cash crops aggregates sunflower, cotton and tobacco. These crop categories, with the exception of cash crops have similar uses, yield, price and production patterns.

Table 5.1: Descriptive Summary of Values of Farm Output Per Farm (Yi).

Crop Values	1989			1990			1992		
	Mean (Z$)	Max (Z$)	CV (%)	Mean (Z$)	Max (Z$)	CV (%)	Mean (Z$)	Max (Z$)	CV (%)
Maize	$622	$11,711	143	$430	$2,728	113	$2,224	$26,857	116
Legumes	$291	$12,895	258	$142	$2,236	176	$191	$3,540	217
Small Grains	$87	$850	159	$75	$1,177	162	$259	$5,730	211
Cash Crops	$137	$5,739	370	$57	$1,747	317	$339	$17,900	358
All Crops	$1,137	$13,266	118	$704	$4,050	102	$3,012	$28,088	109

Farm output values vary considerably from one category to the other and from one year to the other as shown by both the mean and maximum values in Table 5.1. The relatively high coefficients of variation (CV) show that the value of farm output also varies from one farm to another. The variability is a combination of farm-gate price variation and the variation in the physical output harvested. The values of farm output are more variable than the output farm-gate prices. For instance, the CV's for maize output for the three years are 112.8%, 113.4% and 106.2%, respectively. The CV's for maize farm gate prices fro the three years are 19.5%, 27.9% and 27.4%, respectively.

There are several reasons for the above pattern of variability. Physical farm output varied from one farm to the other mainly due to the differences in agro-ecological conditions[52], crop management and access to service institutions. On the other hand, the year to year variation in physical farm output is due to differences in rainfall and macroeconomic conditions. Because output prices were determined by the government, they are expected to be close to uniform from one farm to the other. The differences in prices from one farm to the

[52] This refers mainly to differences in amount of rainfall, although differences in soil type are also very important.

other could only be due to differences market access in terms of distance to markets and mode of transportation used. The price indices of crops marketed through informal channels like legumes and small grains are more variable across farms because of the high variability associated with these markets. The cash crops price index is more variable than the maize price because of the mix of cash crops varies widely from one farm to the other. In addition the unit prices of the three cash crops, cotton, sunflower and tobacco, are very different from one another. Farmers also marketed their cash crops through different channels giving rise to differences in the price that is realized at the farm-level. The resultant price index exhibits this variability.

5.2.2 Prices of Variable Inputs (P_i)

The main variable inputs used by communal farmers are labor and seed. Fertilizer and chemicals are selectively used depending on region and crops grown. The prices of these inputs are calculated at the farm-gate. The pattern of input use affects the farm-gate input price indices. Chemicals are rarely used on crops other than cotton and tobacco. Thus chemicals as an input are insignificant in communal agriculture because very few farmers grow these two crops. Fertilizer is mainly used on maize in high rainfall areas and by the few farmers who grow cotton[53] and tobacco. Thus the fertilizer and chemical price index is dominated by the fertilizer price.

Seed is a major input on communal farms. Farmers purchase maize, cotton and tobacco seed from formal sources consistently. The prices of these seeds are easily calculated as purchase price plus the transport costs. In the case of other crops retained seed is used.

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[53] Mudhara et al (1995) found out from a survey of cotton farmers that the majority of cotton growers do not use fertilizer.

The price of retained seed is calculated as the output price in local markets at planting time plus the local transport costs involved.

The price of labor is difficult to determine because of the poor state of communal area labor markets. In this study the price of labor is calculated as a shadow wage rate equal to either the rate at which family members permanently staying on-farm are paid when they find temporary work locally or the wage rate paid to hired labor. The price of labor, thus depends on what kind of off-farm work family members were able to get or the task for which hired labor was sought. Different types of work entail different wage rates for both family members working off-farm and hired labor. The determination of the price of labor is further complicated by a myriad of kinship relationships and community arrangements that sometimes determine what to pay for the bulk of farm work. The variability, shown in Table 5.2, in the price of labor from one farm to the other reflects the difficulty of calculating a farm-specific shadow wage rate.

Table 5.2: Descriptive Summary of Prices of Variable Inputs, (Pi).

Input Type	1989			1990			1992		
	Mean	Max	CV (%)	Mean	Max	CV (%)	Mean	Max	CV (%)
Labor ($/hr)	$0.68	$3.34	43	$0.89	$3.13	63	$1.18	$5.31	53
Fertilizer* ($/kg)	$1.01	$55.60	45	$0.57	$0.95	8	$0.33	$1.64	93
Maize Seed ($/kg)	$1.17	$6.71	34	$1.64	$3.60	19	$1.40	$3.82	61
Legume Seed ($/kg)	$1.45	$8.00	47	$1.14	$2.75	19	$2.74	$10.57	42
Small Grain Seed ($/kg)	$1.21	$3.00	27	$1.31	$2.15	11	$1.47	$10.00	58
Cash Crop Seed ($/kg)*	$1.18	$64.00	265	$0.95	$9.16	97	$5.56	$250.00	513
All Seeds Index ($/kg)	$1.18	$6.07	39	$1.44	$3.60	21	$1.54	$3.60	46

* Notes:

-Fertilizer also includes chemicals.

-The high variability in cash crop seed prices is because of the differences in per unit prices of tobacco, cotton and sunflower as well as the fact that farmers grow these crops using different combinations.

The mean shadow wage rate for communal farms increased consistently across the years as shown in Table 5.2. But the price of purchased inputs like fertilizer and chemicals and maize seed did not exhibit such a consistent trend. Fertilizer and chemical mean price index fell from $1.01 during the 1988/89 season to $0.57 the following season and $0.33 three seasons later. The all seeds price index showed a consistently increasing trend masking the irregular pattern exhibited by the constituent seed price indices. It is interesting to note that farmers paid less for purchased inputs (mainly fertilizer and maize seed) in 1992/93 as compared to what they paid three years before (1989/90). This is clearly due to the drought relief program implemented after the 1991/92 season. Under this program, farmers received close to free seed and fertilizer from the government and other non-governmental organizations. The program had the effect of reducing the average prices since "free" inputs are valued at the cost the farmers incurred to get them[54].

Table 5.3 also reveals an interesting trend on wage rates. The wage rate variation across farms (CV) did not change across the years as did that of other input price indices. For instance the three season CV for the fertilizer and chemicals index was 45%, 8% and 93%, respectively compared to 43%, 63% and 53%, respectively for the labor price. The fertilizer and chemical price index CV has the same variation as that of the cash crop price index. This similarity could be due to the differences in season samples. The 1989/90 season excluded farmers from cotton growing areas (Kandeya).

5.2.4 Quasi-Fixed and Fixed Inputs (K_i)

The other set of factors of production are the quasi-fixed and fixed inputs. Quasi-fixed input levels can be altered in a period which is shorter than that required for fixed costs. Livestock can be considered a quasi-fixed input in communal agriculture while land and farm assets (buildings and farm implements) are fixed inputs. Land is expressed in hectares and livestock and farm assets are expressed in terms of current Zimbabwean dollars. The data for farm assets and livestock for 1992/93 were not available. The cost function for this season will be devoid of these crucial variables with the exception of land planted to the different categories of crops. The descriptive summary of the quasi-fixed and fixed inputs used in this analysis is provided in Table 5.3, shown below.

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[54] The cost of acquiring "free" inputs was set at the time involved in attending the meetings and the transport costs. While data on transport costs were collected from the farmers, the time spent at the meetings (political party and village/ward development committees) could not be determined.

Table 5.3: **Descriptive Summary of Quasi-Fixed and Fixed Inputs, (Ki)**

Input	1989			1990		
	Mean	Maximum	CV (%)	Mean	Maximum	CV (%)
Farm Assets	$2,713.80	$30,592.50	145	$1,248.65	$12,177.00	135
Livestock	$2,406.60	$12,237.00	82	$2,632.34	$20,281.00	108
Maize Area (ha)	1.56	7.40	64	1.77	8.70	74
Legume Area (ha)	0.50	3.60	109	0.70	5.33	111
Small Grain Area (ha)	0.71	20.90	198	0.74	8.20	145
Cash Crop Area (ha)	0.36	5.30	191	0.25	3.10	218
All Crop Area (ha)	3.12	23.40	71	3.46	16.93	77

The main observation from Table 5.3 is that there is more farm-to-farm variation in the value of farm assets compared to the value of animals owned by respondent farmers. The seemingly significant difference in ownership of farm assets between the two years could be explained by the absence of farmers from Kandeya (a cotton growing area) in the 1989/90 sample. Being predominantly cotton farmers they are likely to own more farm assets than the average non-cotton grower. It is not that they need special implements for growing cotton but because of the higher farm income earned from cotton which allows them to acquire more and/or improved farm assets.

The area under crops does not exhibit any major deviation from expectations. Particularly interesting is the lower farm-to-farm variation in the area under maize compared to other crop categories. The higher across farm variance in area under other crop categories could be due to the fact that not all farmers grow all the crops making up the respective categories . This is especially true for cash crop area where cotton and tobacco can only be grown in areas with specific agro-ecological conditions. Generally the area under all crops does not show major variations across farms.

5.2.5 Environmental Variables (L_i)

Because agricultural production is a biological process, it is dependent not only on quantity and quality of factors of production but also the quality of a number of environmental variables. These variables determine the potential levels of output that can be obtained. The main ones include the type of soil, topography, climatic factors (rainfall, temperature, humidity, etc) and management. Because of data limitations it was not possible to include all these variables in this study.

Soil type and location in terms of natural regions are the only two environmental variable that are considered in this study. They are both presented as binary/dummy variables where one stands for "favorable" soil type or natural region and zero otherwise. Red clays, clays, clay loams, black clays, black and red loams and loams are categorized as favorable soils. Sands and sandy loams constitute the less favorable soils category. Natural regions I and II constitute favorable locations while natural regions III, IV and V are less favorable locations for agricultural production.

The soil data are only available for the 1989/90 season and there is very little to say about the proportion of farms that have favorable soils over the years. As a result maize yield is used as a proxy for soil type. Although yield data reflects management quality, it is the best available variable to use as a proxy for soil type. The percentage of farms that have favorable soils and are located in favorable natural regions during the three agricultural production seasons are shown in Table 5.4 below.

Table 5.4: The Percentage of Farms With Favorable Soil Types and Located in Favorable Natural Regions

Season	soil types*	natural regions	Sample size
1988/89	na	48.2%	425
1989/90	44.4%	30.8%	331
1992/93	na	43.5%	368

Notes:
* na denotes cases were data is not available.

As shown in Table 5.4 the number of farms with good soils and located in favorable natural regions are high enough to permit empirical analysis. Although the location of farms in natural regions was predetermined in the design of the surveys which tried to mirror the national distribution of the farming populations by natural regions, the percentage of farms that are located in favorable regions is higher than the national average of around 25 percent. The percentage of farms in favorable natural regions was closest to the national average during the 1989/90 season. During the other two seasons the proportion of farms in these regions is almost double the 25 percent national average. This over-representation of farms in favorable natural regions is partly due to a disproportionate dropping of farms in the less favorable regions from the study due to incomplete information. More farms in these areas were left out of the analysis because low rainfall resulted in most of them producing negligible agricultural products. They did not, as a result, have all the data that was required for this study and were therefore dropped. But this over-representation does not have a significant impact on the results.

5.2.6 Total Variable Costs (TVC_i)

The dependent variable of the cost function is a summation of labor, seed, fertilizer and chemical costs incurred on farm. Each variable cost item is a product of the amount of input used and the input's farm-gate price. Table 5.5 below summarizes the farm-by-farm

Table 5.5: Descriptive Summary of Total Variable Costs (TVC_i)

Season	Minimum	Maximum	Average	CV (%)
1988/89	$68.49	$5,909.85	$1,212.90	80.2%
1989/90	$99.20	$7,748.08	$1,631.69	84.3%
1992/93	$84.68	$16,014.43	$2,060.05	89.1%
Overall Mean	$84.12	$9,890.79	$1,634.88	84.5%

The effect of the government-led drought relief program that provided farmers with free seed and fertilizer is not as apparent in Table 5.5 as it was with prices of variable inputs shown in Table 5.2 because variable costs are expressed in current terms. But the free seed and fertilizer provided to farmers during the 1992/93 growing season did translate into lower total farm variable costs if the total variable cost figures are expressed in real (inflation-adjusted)[55] terms. In 1989 dollars farmers paid $820.00 for farm inputs in 1992/93 compared to $1212.90 in 1988/89. In other words, the $2060.05 used to buy inputs in 1992/93 bought inputs that were worth only $820.00 in 1988/89. What might also have happened is that farmers stopped buying the inputs they normally acquire because of a combination of the availability of free inputs and large year-by-year increases in input prices. The impact of these

[55] The year-by-year inflation after 1990 rose to over 40 percent due to the 1991/92 drought and the initiation of the World Bank/IMF economic reform program, ESAP (Economic and Structural Adjustment Program) in 1991.

changes in the macroeconomic environment on the use of purchased inputs and hence farm-level economic efficiency will be explored later on in this study.

Table 5.5 also shows that farm-to-farm variation in the amount spent on farm inputs remained close to constant over the three seasons. The CV only increased slightly from 80.2 percent in 1988/89 to 89 percent four season later. However, the farm-to-farm variation that is shown by the variable costs CV is not as large as those for other variables discussed before.

5.3 The Data Collection Instrument

The questionnaire used to collect the data described in this chapter is reproduced in summary form in the Appendix. As an instrument of data collection this questionnaire is fairly detailed and comprehensive enough to cover the important farming and farming related activities. But a good questionnaire does not generate an equally good data set without the aid of the adequate planning of the data collection exercise itself. This starts with good selection and thorough training of enumerators. During field work there is need for frequent monitoring of enumerators not only to ensure that the data is collected as planned but to solve problems as soon as they occur and before they start to affect the quality of the survey output. Given that the enumerators resided in the study areas for the whole season, monitoring and evaluation became an expensive but essential input. Like all other public institutions, the farm Management Section (FMS) did not have unlimited supply of funds at its disposal to carry out this study. But the FMS team went all the way to ensure that the data collected was as accurate as possible within the limits of the human and financial resources available (MLARR, 1990).

The survey questionnaire has three sections. The first section, the Pre-season questionnaire, captured demographic and household resource endowment data. It also included an assessment of the farmers' performance in the previous season. The next section comprises the mid-season questionnaire that covers all farm-level operations from ploughing to weeding. It also includes information on livestock transactions. The last section is a questionnaire that seeks detailed data on harvesting and marketing activities, non-farm income, overhead activities and livestock movements. The administration of these questionnaires was the responsibility of carefully chosen and trained enumerators (research assistants) who were permanently stationed at each site. Each enumerator collected data from around 30 farmers, visiting each household once every four to six weeks. The crucial question here is whether four to six weeks is not too long for farmers to recall accurately the data as detailed as indicated by the questionnaires. A shorter turn-around period would have been more appropriate if resources had permitted.

Again like most public institutions, the FMS had its fair share of professional staff turnover and had to rely on the services of fresh graduates, mainly from the local university (MLARR, 1990). The FMS tried to fill the gaps by using the services of technical advisers who were experienced agricultural economists. Thus although frequent staff changes could have affected the quality of the output of the surveys there was enough professional expertise to ensure that the data collected was the best that could possibly be assembled.

5.4 Summary

The data set used in this study generally exhibit wide across farm and season variability. This characteristic reflects on the nature of communal agriculture even if one controls for geo-physical (rainfall and soil type) and socio-economic factors. As pointed out in Chapter II communal farmers are not a homogenous group. There are differences in resource endowment and agricultural practices.

The first four subsections examined the variability of the independent variables. The variability of output values, being a combination of physical output variation and farm-gate price variation was high with CV's above 100 percent. This was mainly due to the variation in physical output as output prices were controlled by the government. However, the variation was similar across seasons. The variation in input prices was, in most cases, low with CV's around 30 percent. The exception was cash crop seed prices and the fertilizer and chemicals price index during the 1992/93 season when there was a significant change in crop combinations in communal areas. The variation of quasi-fixed and fixed inputs from one farm to the other is in many ways similar to that of output values. This indicates significant differences in household resource endowment levels. The two environmental variables, soil type and natural region, were expressed as dummy variables. The was an insignificant over-representation of farms with good soils and/or located in favorable natural regions.

The dependent variable in this study is the total variable costs at the farms. After adjusting for inflation, it was evident that farmers spent less on inputs during the last two seasons (1989/90 and 1992/93) than they did in 1988/89. Otherwise farm to farm variation in nominal total variable costs remained relatively the same over the seasons. The main conclusion is that all this variation in variables is as expected of cross-sections of such breadth. There is sufficient quality in the data sets to continue with the proposed analysis.

CHAPTER VI: THE COST FUNCTIONS AND ECONOMIES OF SCALE.

6.1 Introduction

The focus in this chapter is on estimating a generalized "hybrid" translog cost function and obtaining measures of economies of scale. In the next section results of the estimated cost function are presented. Then the econometric problems that are associated with the empirical estimation of the cost function are examined next. This section covers econometric problems such as heteroskedasticity, multicollinearity, errors-in-variables[56] and measurement errors. The cost functions should also conform to economic theory. These are discussed next and include homogeneity, homotheticity and constant returns to scale. This leads us directly into the discussion on economies of scale and the implications of the estimates to communal agricultural policy in Zimbabwe specifically and agrarian reform in general. Measures of economies of scale provide important information on the question of optimal farm sizes. The chapter closes traditionally with a short summary.

6.2 Estimating the Cost Function: The Results

The generalized translog multi-product variable cost function (GTMVC) was estimated using ordinary least squares after all the variables were converted to logarithms. Following Sil and Buccola (1995) Cowing and Holtmann (1982) Binswanger (1974) and many others the input prices and total variable costs were normalized by the fertilizer/chemicals price index to impose homogeneity in input prices. A different choice of input price for normalization does produce different results but this issue is not pursued here.

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[56] This includes the problems of omitted variables and measurement errors and the different methods of correcting for these problems.

The estimated cost functions are presented in their entirety in the appendix (Tables A2-A4) because of the large number of variables that were used to estimate these functions. This section will summarize and highlight the main characteristics of the estimated parameters.

6.2.1 Model Explanatory Power

Generally the independent variables provide a reasonable degree of explanation of the variability in total variable costs as shown by the unadjusted and adjusted coefficients of determination, R^2 and $\check{R}^2$, respectively. These are shown in Table 6.1. The adjusted coefficient of determination ($\check{R}^2$) takes into account the number of independent variables used. As expected, R^2 is greater than $\check{R}^2$. Using $\check{R}^2$ one can conclude that, on average, the independent variables explain well over 66 percent of the variation in total variable costs.

It is surprising that the 1992/92 costs function had higher $\check{R}^2$ than the cost functions estimated with data from the other two seasons. The 1992/93 cost functions did not include two important fixed inputs in communal area agriculture (farm asset and farm animals). Fertilizer and seed use was distorted by the government drought relief program which provided farmers with free seed and fertilizer. As mentioned earlier it was difficult to assign values to these "free" inputs. The higher $\check{R}^2$ for this season while puzzling could be due to higher quality data as the team became experienced.

Table 6.1: Unadjusted and Adjusted Coefficients of Determination (R^2 and $\check{R}^2$)

Season	R^2	$\check{R}^2$
1988/89	78.6%	72.6%
1989/90	75.6%	66.1%
1992/93	89.6%	87.3%

Translog cost functions have more independent variables because of the inclusion of cross terms. Coupling this with multi-product formulations, which also increases the number of independent variables, results in a very large number of variables on the right-hand-side.[57] Because $\bar{R}^2$ takes care of the problem of numbers of independent variables, the reasonably high explanatory power is not simply due to the large number of right-hand-side variables. However, other considerations should be taken into account for one to conclude that an estimated model has sufficient explanatory power.

6.2.2 Significance of Parameter Estimates

Parameter estimates are of econometric importance if they are both statistically significant and have the expected sign. Because of the large number of independent variables used to estimate the cost functions, Table 6.2 does not show the significance levels of the α_{ij}, β_{ij}, γ_{ij} and λ_{ij} parameters. In fact Binswanger (1974) pointed out although α_{ij}, β_{ij}, γ_{ij} and λ_{ij} are related to variable elasticities of substitution and of factor demand, they have little economic meaning of their own. Since this study's focus is not on elasticities of substitution, little is lost by their omission from the discussion, especially at this diagnostic stage.

The purpose of table 6.2 below, and the accompanying discussion, is to highlight the extent of parameter significance for the estimated cost functions. It is also important to point out that the parameter estimates, α_i, β_i, γ_i and λ_i, shown in table 6.2 are not elasticities of substitution. Elasticities of substitution in a translog formulation are variable and dependent on other variables due to presence of cross terms. Thus the discussion here is limited to just comments on the significance of the individual parameters. Little can be said about their signs

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[57] In this study the GTMVC function with four crop categories, five variable inputs, three fixed inputs and two environmental variables had a total of 92 (1988/89 and 1989/90) and 67 right-hand-side variables (1992/93).

or can economic significancy be determined. Detailed and complete sets of results are presented in the appendix (Tables A2-A4).

Table 6.2: Level of Significance of Selected Coefficients

Variable	1988/89		1989/90		1992/93	
	β-value	t-value	β-value	t-value	β-value	t-value
Constant	4.70	1.61	8.92	1.33	**1.38**	**2.06**
Labor Price	2.18	1.16	1.20	0.47	**1.83**	**3.26**
Maize Seed Price	0.33	0.19	**-14.63**	**-2.72**	0.39	0.99
Legume Seed Price	1.84	1.47	5.39	0.89	-0.26	-0.62
Small Grain Seed Price	-0.20	-0.11	9.09	1.12	0.06	0.09
Cash Crop Seed Price	-0.36	-0.28	2.95	1.37	0.63	1.41
Value of Maize	0.24	0.75	-0.39	-0.90	0.11	1.04
Value of Legumes	<u>0.28</u>	<u>1.72</u>	0.19	0.70	0.01	0.15
Value of Small Grains	0.23	1.37	**0.93**	**2.88**	**0.18**	**2.48**
Value of Cash Crops	-0.11	-0.68	0.36	1.12	-0.05	-0.52
Total Crop Area	1.30	0.86	**-4.45**	**-3.15**	**2.74**	**6.07**
Value of Farm Assets	-0.25	-0.72	0.06	0.09	na	na
Value of Livestock	**-0.94**	**-2.57**	-0.56	-1.04	na	na
Soil Type	**0.24**	**2.64**	0.03	1.00	**0.27**	**4.43**
Natural Region	-0.12	-1.27	**0.42**	**2.18**	-0.10	-1.50

Notes: Significant coefficients are bolded (ρ=5%) and underlined (ρ=10%); na=not available.

The parameters shown in Table 6.2 above are not estimates of elasticities of costs with respect to the specified right-hand-side variables. The magnitude of each parameter cannot tell us the percentage change in total variables cost that is brought about by a one percent change in the independent variable. The fundamental inequality of cost minimization, which states that if input prices increase total variable costs cannot decrease, cannot be determined by simply looking at the sign of coefficients on input prices. The additional effect from cross-term must also be taken into account if one is to discuss the state of input substitution by farmers. These partial effects can be represented as follows:

$$\frac{\partial lntvc}{\partial lnP} = \beta_i + \beta_{ii} lnP_i + \sum_{j=i}^{m} \beta_{ij} lnZ_j$$

. The fact that input prices have negative coefficients (labor is an exception) in one of the three seasons is not a serious violation of the principles of the fundamental inequality of cost minimization. But the change in coefficient signs across seasons could be an indication of the existence of data-related and/or econometric problems.

If homotheticity is assumed then all inputs are normal so that costs are non-decreasing in output. Output increases always increase variable costs. An increase in the value of output is expected to increase variable costs, more so if the increase is due to change in the physical output as compared to output price. If the increase in output value is due to an increase in the product price, total variable costs can either increase or decrease depending on farmers' objectives.[58] In this exercise farmers are assumed to be profit optimizers and the coefficients on the output variables are all expected to be positive. Table 6.2 shows that the coefficients on the value of maize (1989/90) and value of cash crops (1988/89 and 1992/93) are negative. The validity of the profit maximization assumption when dealing with communal area agricultural production data is challenged by these results. Maybe the fact that communal farmers pursue other goals such as meeting family food requirements can explain these results where a price increase may not significantly alter the production mix.

There is no theoretically valid basis on which to predict the sign of the coefficients on fixed inputs. Increases in fixed inputs can either reduce variable costs if there is an

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[58] If farmers pursue profit maximization only then an increase in prices will result in an increase in output and hence total variable costs. But if farmers pursue other goals other than profit maximization then it is reasonable to expect other outcomes.

improvement in efficiency (less inputs are used) or increase costs if the input bundles are unaffected. The coefficients on farm assets and livestock are almost all negative except the value of farm assets during the 1989/90 season. For increases in total area planted the fundamental inequality of cost minimization should be expected to apply implying that the coefficient on total area planted should be positive. The results for 1988/89 and to some extent 1992/93 conform to this expectation. But the coefficient on total area planted for the 1989/90 season is negative and statistically significant.

Despite the reasonable explanatory power shown by the coefficients of multiple determination, very few coefficients are statistically significant as shown in Tables 6.2 for the selected parameters and the appendix (Tables A2-A4) for the quadratic and cross terms. Only 6, 12 and 9.6 percent of the coefficients of the 1988/89, 1989/90 and 1992/92 multi-product cost functions are significant at 5 percent level, respectively. Similar percentages for 10 percent level of significance are, respectively, 16, 18 and 25. However, there are coefficients that are economically significant. For instance, table 6.2 shows large coefficients, especially for labor and the seed prices. But a percentage change in any one of these variables is not determined by the magnitude of these coefficients alone. Coefficients from cross terms have some influence as well.

Other than the observation that there was a large number of variables used to estimate the GTMVC function and the assignment of crops grown into four categories to avoid degrees of freedom problems[59], there are other areas of concern. As a result the data will be

[59] Initially about 7 main crops were identified in communal areas. A translog function involving 7 crops, seed prices and crop areas, a fertilizer and chemicals price index, a labor wage rate and two fixed input levels would end up with 350 independent variables. The 1988/89, 1989/90 and 1992/93 seasons have 425, 331 and 368 observations, respectively.

examined for the existence of econometric problems that should be taken care of when estimating the cost functions and frontiers.

6.3 Testing for Econometric Regularity

The main purpose of this section is examine if the data presented in the last chapter can be used to estimate a "well-behaved" cost function. The estimation of the cost function employs a combination of least squares and maximum likelihood estimation techniques. A function estimated using least square is "well-behaved" if does not violate the basic least squares assumptions. Four econometric issues that will be examined include testing for the presence of multicollinearity, heteroskedasticity, errors-in-variables and misspecification errors. Particular attention is given to how the presence of econometric problems affects the residuals used to estimate farm-level economic efficiency. These issues are separately discussed in detail below.

6.3.1 Multicollinearity Problems

Least squares estimation assumes that there is no relationship between independent variables. If some independent variables are perfectly correlated then the significance of the parameter estimators of the collinear variables cannot be accurately determined. Collinear independent variables result in large variances of the parameter estimates on these variables making it possible that t-tests on these parameter estimates may turn out insignificant when they should be significant. The estimators themselves are neither biased nor inconsistent.[60]

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[60] Because there will always be substantial correlation between independent variables, multicollinearity is considered a problem when the correlation is perfect.

Multicollinearity often occurs in time series data where variables have a common trend. This is not possible in this study. What is likely to result in multicollinearity is the cluster sampling which was used to pick out the farmers involved in this study. Collinearity in variables occurs in cluster sampling because of the proximity of respondents to each other. But extra care was taken during cluster sampling to ensure that the problem of multicollinerity is avoided (MLAWD, 1993).

There are informal and formal tests for collinearity in independent variables. The informal tests include checking what happens to the significance tests on coefficients when variables are added or subtracted and calculating a correlation matrix and "correcting" for collinearity whenever the correlation coefficient (ρ) is greater than 0.8.[61] If the overall regression coefficient (R^2) is larger than the R^2 obtained from regressing an independent variable on another then multicollinearity is not serious. If multicollinearity is found to be serious the simple options available include collecting more data or dropping the offending variable. Principal component approach can also be used to correct for this problem. Otherwise very little can be done to correct for multicollinearity.

In this data set an effort was made to avoid multicollinearity. For instance, the prices of fertilizer for the four crop categories were combined into a single index. Without this index, problems would arise because the four prices for fertilizer corresponding to the four crop categories would be highly correlated. Fertilizer types, compound D and ammonium nitrate, are used in varying proportions in almost all crops. Because these two fertilizer types comprise the bulk of fertilizer used by farmers on any crop their prices would dominate the fertilizer price indices for the four crop categories.

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[61] The significance of multicollinearity as a statistical problem is diminished by the fact that it does not affect the error term. As a result there is no absolute number that can be cited as proof for the existence of multicollinearity and 0.8 is an arbitrary threshold.

Simple correlation coefficients are used to test for the likelihood of multicollinearity problems among the original independent variables. The quadratic and cross-terms were omitted from the calculation of correlation coefficients. Figure 6.1 shows the distribution of absolute values of correlation coefficients (ρ) between pairs of independent variables for each of the three seasons. Figure 6.1 shows that there is insignificant correlation between variables. Over 65 percent of ρ-values are less than 0.2 in the last two seasons. The variables for the 1988/89 season show a different pattern of correlation. While the distribution of correlation coefficients peak in the 0.0-0.1 range for the last two seasons, the 1988/89 ρ-values pick in the 0.2-0.3 range. But generally correlation between variables is insignificant because the percentages of ρ-values that are greater than 0.4 are, in all cases, below 15 percent.

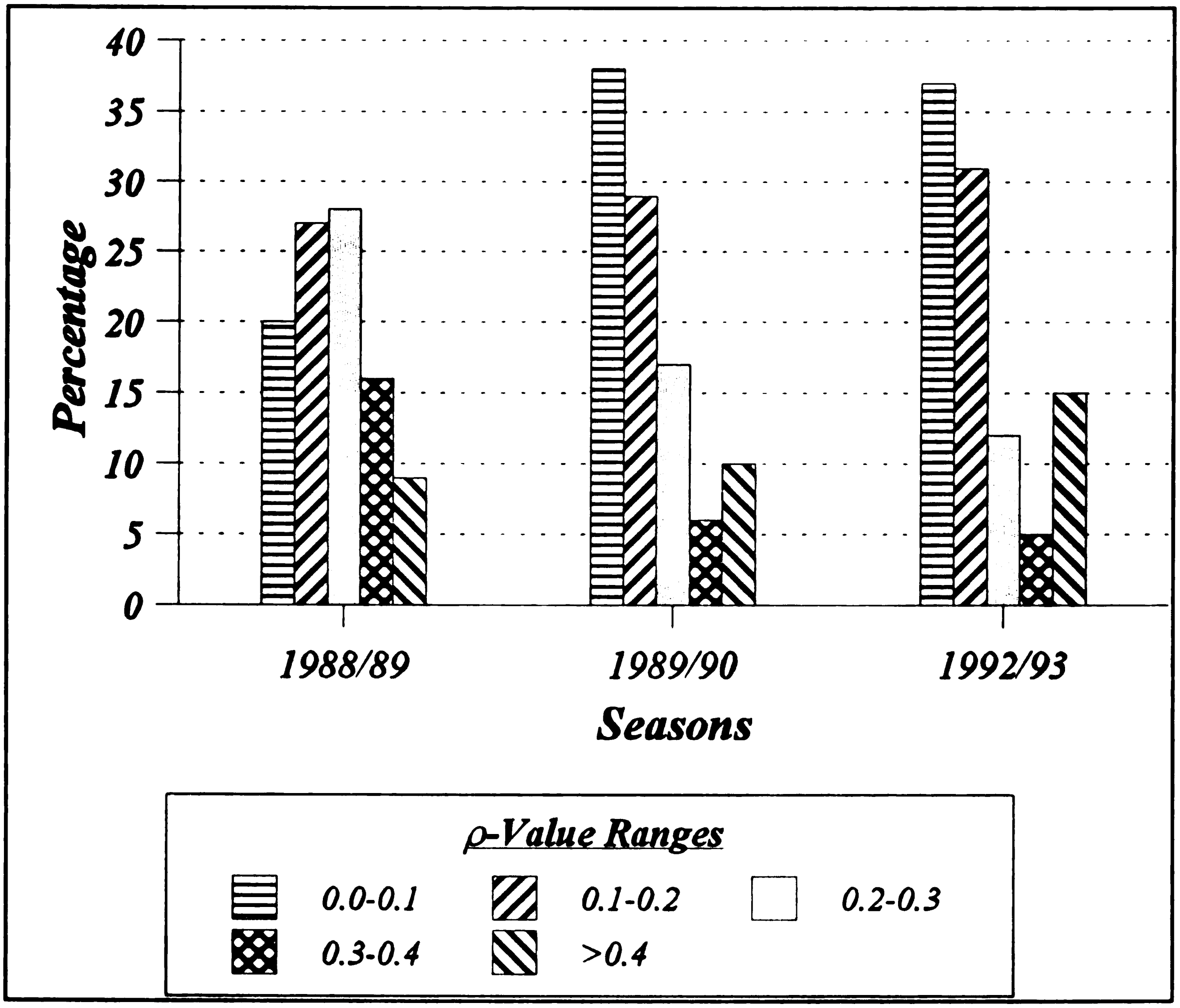

Figure 6.1: Percentage Frequency Distribution of Correlation Coefficients

The pairs of independent variables with at least one correlation coefficient ρ, that is greater than 0.4 are presented in Table A5 in the Appendix. Table A5 shows that input prices have quite a number of ρ-values that are greater than 0.4 against each other. Small grains, legumes and cash crop seed prices have ρ-values greater than 0.4 in at least one of the seasons with all other input prices. This leaves the maize seed and labor price pair as the only one without ρ-values greater than 0.4 in any of the three seasons. But all input price pairs have ρ-values that are, however, below the 0.8 threshold. In addition there is no pair of input prices that have ρ-values greater than 0.4 for all the three seasons. Only three out of the nine pairs listed on Table A5 have ρ-values that are greater than 0.4 in two of the three seasons. As a result there is little danger that input prices could pose serious multicollinearity problems. Input prices were, therefore, left as they are.

There is only one pair of independent variables that exhibit significant correlation. As shown in Table A5 the ρ-values of cash crop area and cash crop value are 0.8 and 0.82 for 1988/89 and 1989/90, respectively. In fact, for all crop categories, the ρ-value for area and value of output is greater than 0.4 in all seasons, with the exception of the maize area and value of maize combination in 1989/90. Crop areas also have ρ-values that are greater than 0.4 against each other. All this indicates a high likelihood of a multicollinearity problem involving the area planted variable. This emanates from the fact that land is defined here as the area planted while the value of a particular crop category is a product of the area planted and the price of the final output. Because the output price may be relatively uniform across farms high correlation between area planted against value of output harvested or area planted to other crops becomes highly likely.

Even though the easiest remedy to multicollinearity problems is to drop the offending variables, we retain the land variable but modify it so as to minimize the probability of multicollinearity. Land will be defined as an aggregate value to eliminate correlations between area planted and crop value, area planted to other crop categories and input prices. The areas planted to crop categories and the value of the different crop categories harvested appear to be the variables most likely to trigger multicollinearity problems.

6.3.2 Heteroskedasticity Problems

In this study heteroskedasticity problems deserve more attention than multicollenearity because they affect the error terms. Heteroskedasticity exists when at least one of the independent variables in correlated with the error term. The least squares assumption of residuals having a constant variance is violated. While the consistency of the parameters estimated using least squares is not affected, it is not possible to subject these least squares parameters to significance tests, such as t-tests. Inference is less accurate because, although the parameter estimates are unbiased, they are not the best parameter estimates in terms of variance. In addition, the error terms do not exhibit the preferred form of constant variance.

Correcting for heteroskedasticity allows one to obtain unbiased parameters with the lowest variance (i.e. best estimate). In this study we hypothesize that producers with higher levels of farm assets, livestock and arable land are less risk averse and thus make decisions that are likely to result in larger deviations from the economically optimal cost function. For instance they are more likely to produce higher outputs than farmers who are less endowed and hence are prone to commit bigger "mistakes" because of factors beyond their control as well as inefficiency . We therefore hypothesize that least square residuals are correlated with the quasi-fixed and fixed input variables. A simple test for heteroskedasticity is simple visual inspection of a plot of residuals on the independent variables.

Figures A1 to A7 in the Appendix show plots of residuals on total arable area, value of farm assets and value of livestock. The bulk of the observations on total arable area fall between 2 to 10 hectares (or 0.7 to 2.3 in logarithmic terms) as shown in figures A1 to A3. There is no clear pattern between total arable area and the residuals. "Mistakes" appear to be uncorrelated, in any way, with size of holding. The same conclusion also hold for the relationship between residuals and the value of farm assets and livestock.

The Cook-Weisberg test for heteroscedasticity was performed to further test for the presence of heteroscedaticity. This procedure involves the modeling of the variance using the fitted values of the dependent variable. It produces a χ^2 statistic that is used to test the null hypothesis that the model has constant variance. The results are presented in Table 6.3.

Table 6.3: The Cook-Weisberg Test for Heteroscedasticity

Season	χ^2-Statistic	ρ-value
1988/89	5.88	0.02
1989/90	0.19	0.66
1992/93	0.19	0.66

The null hypothesis specifying the presence of constant variance can only be rejected in one season; 1988/89. The other two seasons' data does not have the heteroscedasticity problem. The peculiar case of 1988/89 is difficult to explain and goes to show that there are other factors at work other than simple seasonal variations. On the whole, and in spite of the 1988/89 anomaly, the Cook-Weisberg test adds weight to the results of informal tests for heteroscedasticity.

6.3.3 Omitted Variables Problem

This is the most serious problem that often arise in empirical analysis[62]. In this case an important explanatory variable is omitted from the regression, for instance, because it is difficult to observe and hence cannot be easily measured. This omitted variable is subsequently thrown into the error term affecting the t-tests on regression coefficients. The

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[62] Most regression analysis begin with the omitted variable test and nothing else can be done before the omitted variable problem have been solved if it is found to exist.

problem is not merely the preciseness of t-test on regression coefficients. First, there is an endogeneity problem if the omitted variable is correlated with other independent variables. The often cited example in production economics is the difficulties of representing the unobserved management and labor quality in estimating a production or cost function. Management and labor quality are often correlated with observable inputs that are part of the production or cost functions.

The second problem with omitted variables is that they "contaminate" the residuals making it difficult to ensure that only random noise and inefficiency are in the residual. In the example given above the variation in output or variable costs that is explained by the quality of labor and management should be taken out whenever possible. But this would not be as serious a problem if the intention is to measure economic inefficiency and if the quality of management and labor were not correlated with farm input choices. What is crucial at this stage is to find out whether there is a problem of omitted variables.

The problem of omitted variables in this study can only be a result of errors in defining the cost function. Theoretically a short-run cost function similar to the one estimated in this study, relates total firm costs to variable input prices, levels of fixed costs and quasi-fixed inputs and output levels. There are few other possible explanatory variables that can be considered omitted in this specification other than the quality of labor, management (incorporating education and experience), technology and other shifter variables. Since management and labor quality are directly correlated with observable inputs levels, they cause less problems when a cost function is used. A cost function does not have input levels as independent variables. The indirect relationship between the unobserved management and labor quality and output levels (that is, through input choices) can be ignored because other factors affect output level more than management and labor quality. In addition, it is hard to find a proxy for management and labor quality that is not correlated with input levels and hence indirectly to output levels.[63] The technology used in the communal area production system can be assumed to the same across farms (rainfed agriculture based on animal draft power) as outlined in Chapter III.

The Ramsey Reset test for omitted variables estimates a regression model by augmenting it with the second, third and fourth powers of the dependent (or independent variables, if so specified) variable. In the absence of omitted variables the coefficients on these powers of fitted values are hypothesized to be zero. The results of the test that the coefficients on the second, third and fourth powers of the dependent variable are all equal to zero are presented in Table 6.4 below.

Table 6.4: Results of the Ramsey Reset Test for Omitted Variables

Season	F-value	ρ-value
1988/89	1.83	0.14
1989/90	2.59	0.06
1992/93	0.82	0.48

From Table 6.4 we note that we cannot reject the null hypothesis (that the regression model/cost function has no omitted variables), at 5 percent significance level, in all three seasons. At 10 percent significance level there is evidence that there is an omitted variable problem in the 1989/90 cost function. This is a surprising result in that exactly the same variables are used in the first two seasons. Could this omitted variable problem be attributable to unobservable seasonal traits? There is nothing particularly striking about the 1989/90

[63] The solution to this problem of unobservable variables is to find proxy variables which are as closely related to the unobservable variable as possible but not correlated to any of the other independent variables.

season that could be pointed out as the cause of the omitted variable problem indicated in Table 6.4. There is no variable in the 1989/90 cost function that is different from the 1988/89 model. If the problem of omitted variables is more a product of missing than unobservable variables one would expect to encounter this problem in the 1992/93 cost function. Data on value of farm assets and livestock is missing for the 1992/93 season. Table 6.4 does not show any evidence of omitted variables in the 1992/93 cost function. The problem of what was omitted in the 1989/90 cost function is difficult to resolve. We will look at specification of the dependent variable as a source of the omitted variable problem for the 1989/90 cost function in particular and as an econometric problem of its own for all the three cost functions.

It often occurs that when the dependent variable is mis-specified then the independent variables will also be incorrectly specified. Following the work of Tukey (1949) and Pregibon (1980) one can perform a test for model specification (link test) based on the dependent variable (StataCorp, 1997; Pregibon, 1980). A link test involves the regression of the dependent variable on two variables; the predicted values of the dependent variable and the square of the predicted values of the dependent variable ($\hat{Y}$ and $\hat{Y}^2$, respectively). The coefficient on $\hat{Y}$ is expected to be highly significant. But the coefficient on $\hat{Y}^2$ should not be statistically significant if there is no specification problems. The results of regressing Y on $\hat{Y}$ and $\hat{Y}^2$ are presented in Table 6.5 below;

Table 6.5: Results of the Specification Link Test.

Season	$\bar{R}^{2*}$	Constant		Pred. Value ($\hat{Y}$)		Pred. Value Squared ($\hat{Y}^2$)	
		Coef.	ρ-	Coef.	ρ-value	Coef.	ρ-value
1988/89	79%	-0.58	0.42	1.17	0.00	-0.01	0.40
1989/90	67%	-2.14	0.24	1.57	0.00	-0.04	0.24
1992/93	87%	-0.49	0.63	1.11	0.00	-0.01	0.63

* Note: $\bar{R}^2$ stands for adjusted-R^2.

All the coefficients on $\hat{Y}^2$ are not significantly different from zero at 5 percent significance level (that is at $\rho = 0.05$). Table 6.5 also shows that, as expected, the coefficient on the predicted value, $\hat{Y}$, is highly significant. There is, therefore, no problems in the way we specified the dependent variable, the total variable costs. Thus we cannot attribute the problem of omitted variables noted in the 1989/90 cost function to problems in the specification of the dependent variable.

Because omitted variables present a more serious econometric problem than that of heteroscedasticity, multicollinearity, and measurement errors the option of dropping the 1989/90 season's cost function was seriously considered, even if this conclusion is reached using 10 percent as the significance level. We recognize that all of the cost functions in general do not have all the variables that should be included (especially variables dealing with farmer experience and education, farm-level technology and other shifter variables). In one way or the other, there are missing variables in all cost functions because of the data problems outlined before. It is impossible to go back to the field to collect a new data set at this point in time. We, therefore, include the 1989/90 cost function in the analysis and take note that we should be cautious when interpreting the results that include this season. It also happens that this is the only season that has data on farmer characteristics and resource endowments which will be used to explain the variation in farm efficiency.

6.3.4 Problems of Measurement Errors

An endogeneity problem arises whenever one or more variables in a model are measured with error and the recording errors are correlated with at least one of the independent variables. When the recording errors are not correlated with independent variables (other than the independent variable that is being recorded in error) parameter estimates are unbiased and consistent. However, their large error variances result in imprecise statistical tests leading to the conclusion that measurement error is a major problem even when the recording errors are not correlated with other independent variables. Large error variances lead to large standard errors and thus imprecise t-tests on the estimated parameters.

The recording errors can be committed when recording both the dependent and independent variable. Unlike omitted variables, the problem of measurement error involves difficulties in recording variables. What is observed is the measured and not the actual variable because the latter cannot be observed. Recording errors may occur because of a variety of reasons. Enumerators may not ask the appropriate questions leading to wrong responses from the respondent farmers. On the other hand the questions may be appropriate but the responses are wrong because respondents, for one reason or the other, are not willing to provide the required information.

The measurement error problem deserves serious attention in this study because it affects the residual terms. One cannot guarantee that a particular data set was accurately recorded. Concern here is not about the measurement errors that occurred because of inadequate supervision and enumerator training, or the handling of recall data and sensitive information. Even though there is no guarantee that these errors were absolutely avoided, all imaginable means to minimize such errors were taken. This data set was extensively cleaned by the ministry staff and by the author. Observations that had obviously outrageous values were excluded from the data set. The measurement errors of concern are those emanating from the difficulties involved in accurately recording the variables by the respondents themselves. There is no way of handling this problem once the data has been collected. If the respondents cannot accurately record phenomena at their farms then there must be ways put in place before data collection starts to enable enumerators to anticipate such difficulties. It is hoped that the Farm Management Section of the Economics Division of the Ministry of Agriculture had enough experience and expertise to handle such data collection problems.

6.4 Testing for Regularity Conditions

To obtain a well-defined cost function requires the imposition of assumptions on the production technology (Chambers, 1986). The technology allows farmers to use factors of production to produce different output sets. As a result the cost-minimization problem is directly related to the production technology. Thus the properties of cost functions are derived from the production function properties and vice-versa if the functions conform to the regularity conditions that are based on economic theory. The main properties of production functions such as monotonicity, concavity, non-emptiness (feasibility), non-negativity and continuity give shape to cost functions. Chambers lists the following as properties for a well-behaved cost function:

a). Non-negativity (No output produced at zero cost - inputs that are positively priced lead to positive costs if positive outputs are to be produced)

b). Non-decreasing in input prices (An increase in input prices cannot reduce costs - the fundamental inequality of cost minimization or monotonicity)

c). Concavity continuity in input prices (This rules out the possibility of an optimal response to input price changes resulting in a decrease in costs and that the function be twice differentiable[64])

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[64] The Hessian or matrix of second order derivatives of costs with respect to input prices must be negative semi-definite.

d). Positive linear homogeneity (Proportional changes in input prices do not affect the level of cost-minimizing input bundles)

e). Non-decreasing in output (Minimum costs cannot be reduced by an increase in the level of output)

It is not necessary to test for or impose all six conditions on the cost function in this study. Some conditions, such as (c), are implicitly assumed to hold by design. The translog functional form is twice differentiable as it was developed primarily to capture all the three stages of production (Rask, 1994). The other condition (a) stated above will not be considered because it has a straight-forward interpretation. Homogeneity and homotheticity (that costs should not be decreasing in output) are implicitly assumed. Binswanger (1974) pointed out that one of the advantages of using a dual function, such as a cost function, is that the function is homogeneous in input prices by design. Thus an increase in input prices will always increase costs. In addition, the normalization of input prices and variable costs by the price of fertilizer and chemicals imposes homogeneity on the cost function. Having assumed the cost function to be homogeneous, it follows that it is also homothetic; for homogeneous functions are a special sub set of homothetic functions (Debertin, 1986). The monotonicity requirements (condition (b)) will not be examined because the cost functions are not estimated as a system of equations incorporating cost share equations.

6.5 Economies of Scale

Measures of economies of scale in a translog specification cannot be estimated at farm-level. The measures are a function of several independent variables depending on how the translog function is specified. These measures are calculated at the mean level of the independent variables. In this section these indicators are estimated and, on the basis of these estimates, implications are drawn on policy and program formulation for communal area farmers in Zimbabwe and other similar Southern African countries.

6.5.1 Economies of Scale Versus Economies of Size

The concept of economies of scale is often confused with economies of size to the extent that they are often used interchangeably. Economies of scale expresses the proportional change in output to proportional changes in all factors of production. In other words if all inputs are increased by a constant factor, π, output can increase by a factor less than, equal to, or greater than π, implying decreasing, constant and increasing returns to scale, respectively. But in the real world such proportional changes in input bundles are rare (Upton, 1996). Changes are normally not proportional due to the lumpiness or indivisibility of durable inputs and the difficulties in controlling and measuring inputs (Doll and Orazem, 1984). Economies of size is a measure of the output (cost) response to such non-proportional changes in factors of production (input prices) (Derbetin, 1986). This is a more realistic representation of what happens in the real world. But there are many non-proportional changes in input quantities (prices) which yield different output (cost) responses, making the measurement of economies of size difficult. Thus a measure of economies of size is only applicable to a particular non-proportional change in input quantities or prices. As a result most empirical work has been on estimating measures of the easy-to-define economies of scale (Derbetin, 1986).

While the two concepts are different it should be pointed out that these two concepts are very closely related. Chambers (1986) pointed out that "at cost-minimizing points, a firm exhibits increasing returns to scale .... if and only if it simultaneously exhibits increasing returns to size.." and vice-versa (p. 72). Measures of the two concepts coincide at the cost-minimizing points because indicators of returns to scale and returns to size represent the response of output and cost in input space, respectively. Their difference come from the fact that the two measures are based on different input combinations, with economies of size concerned about movements of costs along loci of cost-minimizing points. Measures of economies of scale are concerned with the response of output along the scale line from the origin (Chambers, 1986). The two measures are particularly close when the production function is homogeneous and homothetic.

6.5.2 Testing for Constant Returns to Scale

Agriculture, especially small-scale agriculture which does not use too many fixed or durable inputs (potential sources of scale economies), throughout the world is generally characterized by constant returns to scale (Upton, 1996; van Zyl et al, 1995). This explains much of the observed inverse relationship between farm size and efficiency (Barrett, 1993). It is important, therefore, that a test for the presence of constant returns to scale precede the calculation of the returns to scale parameters.

1. Constant returns to scale, according to Berndt (1993) can be imposed as follows;
2. Equating the sum of the input price (labor and seed) coefficients to unit.
3. Equating to zero the sum of coefficients on all cross terms involving input prices.
4. Equating to zero the sum of all coefficients on cross terms involving input prices and output variables.
5. Restricting to zero all the coefficients of cross-term variables involving output values, (that is, α_{ij}, ρ_{ij} and δ_{ij}).
6. Equating to one the sum of coefficients on the output value (Yi) variables (that is, $\Sigma\alpha_i=1$).

The null hypothesis for these restrictions can be represented as follows;

$$\sum_{i=1}^{k} \beta_i = 1; \ \sum_{i=1}^{q} \beta_{ij} = \sum_{i=1}^{p} \delta_{ij} = 0$$

{Where $q = \frac{k(k+1)}{2}$ and $p = \frac{m(m+1)}{2} + m(k - m)$ given that $k > m$.}

$$\alpha_{ij}, \rho_{ij} \text{ and } \delta_{ij} = 0$$

$$(\Sigma\alpha_i = 1)$$

These restrictions are tested together with the homotheticity restrictions. Table 6.6 below shows the results of the three tests outlined above.

Table 6.6: Tests for Constant Returns to Scale

Season	1988/89	
	F-value	ρ-value
1988/89	7.87	0.000
1989/90	24.46	0.000
1992/93	21.90	0.000

Table 6.6 shows the F-statistics and the associated significance levels (ρ-values) for testing the null hypothesis that the cost functions exhibit constant returns to scale (CRTS). It is clear from the results that communal agricultural production did not exhibit constant returns to scale during the respective three agricultural seasons. In all cases it is not possible to accept the null hypothesis of the presence of constant returns to scale. This is unlike the sugarcane case in Brazil which was tested for economies of scale by Kevin Rask (1995) using

a modified symmetric generalized McFadden cost function. Rask could not reject the constant returns to scale hypothesis. Using non-parametric methods, van Zyl et al (1995) found that only a little over 7 percent of farmers in the former South African homelands of KaNgwane, Lebowa and Venda were large enough to be scale efficient. But the later study did not test for the presence of constant returns to scale making it hard to compare findings.

The absence of constant returns to scale means that communal farmers cannot expect to double their outputs by simply doubling their input bundles. Without this option farmers have to look for other means of improving productivity. It is, however, important to have an idea about the direction of returns to scale in communal agriculture before delving into what these other productivity-improving options could be. The choice set facing farmers whose production system has increasing returns to scale is vastly different from the set available to farmers with a production system experiencing decreasing returns to scale. The next section presents the estimates of economies of scale.

6.5.3 Measures of Economies of Scale

Measures of economies of scale can be derived from the cost function by differentiating the log of costs with respect to log of output. The inverse of the elasticity of costs with respect to output is a measure of returns to scale, (λ). Using equation (16) and in the absence of sample-mean scaling, this measure is as shown below;

$$\lambda = \frac{1}{\varepsilon_{CY}}, \qquad \textit{where}$$

$$\varepsilon_{CY} = \alpha_i + \sum_{i=1}^{m} \alpha_{ij} lnY_j + \sum_{i=1}^{n} \rho_{ij} lnP_i + \sum_{i=1}^{h} \delta_{ij} lnK_i$$

Note that ϵ_{CY} stands for elasticity of costs (C) with respect to output (Y).

When the P_i, Y_i and K_i variables are scaled by their respective sample means prior to converting to logarithms then all the log terms in the cost elasticity equation drop out at the sample means. Thus the cost elasticity equation simplifies to the following representation:

$$\varepsilon_{CY} = \sum_{i=1}^{n} \alpha_i \rightarrow \lambda = \left(\sum_{i=1}^{n} \alpha_i \right)^{-1}$$

Increasing, constant or decreasing returns to scale exist when λ is greater than, equal to or less that one. It is important to note that λ, like its elasticity of cost components, is a local measure. These indicators of economies of scale are only applicable when the percentage changes in farm input prices are within the proximity of the sample means. In table 6.7 below, the economies of scale indicators calculated as the reciprocals of cost elasticity and after scaling the input prices, values of output and the fixed factors (P_i, Y_i and K_i variables) by their sample means are presented.

Table 6.7: Indicators of Economies of Scale (λ)

Season	Economies of Scale Indicator
1988/89	0.341
1989/90	0.245
1992/93	0.715

The measures of economies of scale that are displayed in table 6.7 indicate that communal production is characterized by decreasing returns to scale. Thus when communal farmers increase their scale of operation x-times the corresponding increase in output is less than rate x. The average over the three seasons, for instance, implies that a one percentage increase in all inputs will increase output by about 0.43 percent at the sample means. The average measure for returns to scale for the first two seasons at only 0.29 percent is much lower than the overall average. There is need to examine the behavior of economies of scale measures when sample means are changed so as to determine the optimal farm size at current technology levels. This research work is left for future initiatives.

The results shown in table 6.7 are best illustrated by a graph on the shape of the communal area cost functions. The possibility that it is a horizontal line is eliminated by the absence of constant returns to scale illustrated in the preceding section. Following Ferguson and Gould (1975), the U-shaped communal area cost function is presented in figure 6.2.

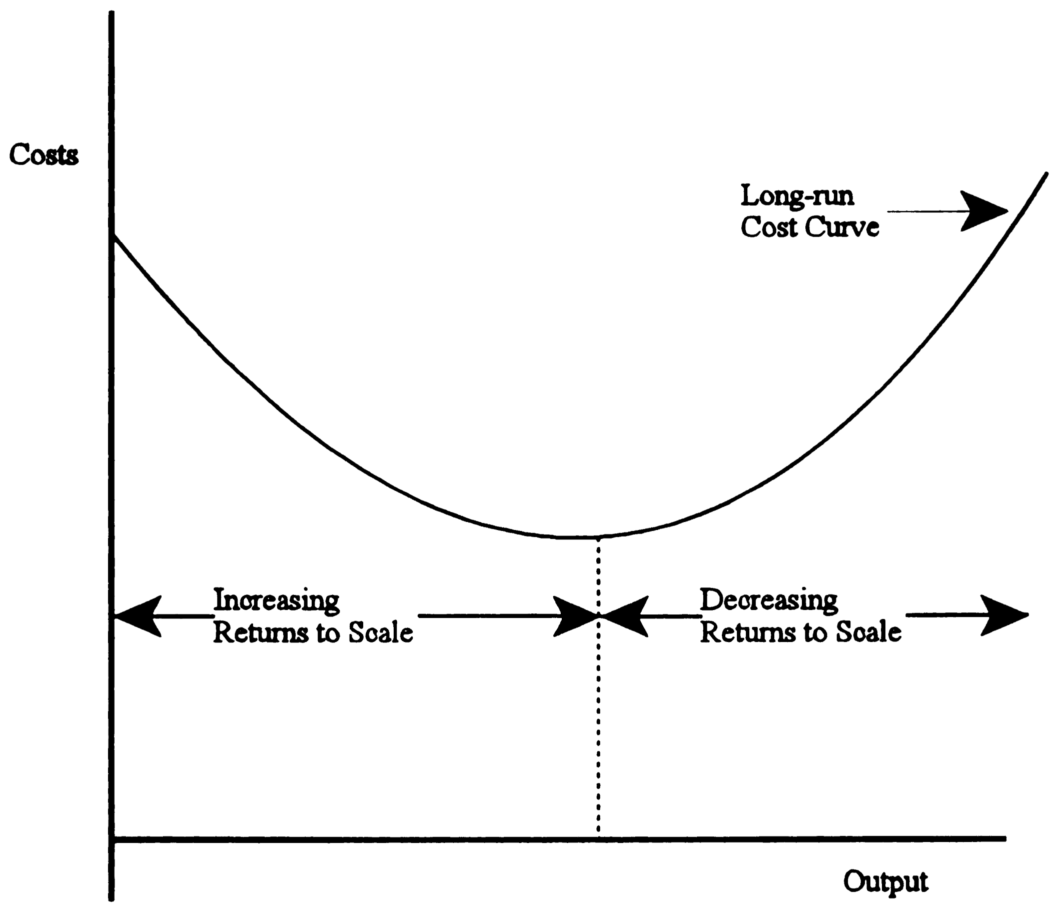

Figure 6.2 The Shape of the Long-run Cost Curve for Communal Areas

The measures of returns to scale shown in Table 6.7 suggest that communal farmers are operating in the decreasing returns to scale range that is shown in Figure 6.2 above. It appears as if they have already moved beyond the range of increasing returns to scale. If the farmers' motives were just to maximize profits then one would expect a downward adjustment in the scale of operation. But communal area farmers are semi-commercial, driven, first and foremost, by the need to produce enough food for the family (Shumba, 1985). In such situations farmers use inputs beyond the economically optimal level (Barrett, 1993; Zimmerman and Carter, 1996; Larson, 1997).

In addition communal farmers do not operate in a perfect market, making some of the predictions of economic theory incorrect. Facing decreasing returns to scale, communal farmers need to employ new production techniques which depend on the supply of modern inputs. But the input and output markets are not perfect. There is no market for communal land, for instance. Capital and labor markets are also imperfect. Thus institutional barriers could be among the important factors responsible for the observed agricultural production patterns in communal areas. This raises the question whether some "institutional midwifery" which hurries the birth of markets for land, labor and capital is necessary (Zimmerman and Carter, 1996).

Conditions in communal areas continue to change due to the demographic pressure and the changes in the external environment. New institutions are necessary to take full advantage of the changing environment. Expanding use of inputs such as seed, labor, fertilizer and chemical, land and capital inputs all can be instituted through markets regulated by both formal and informal rules. That these are not well defined for communal agriculture is part of the legacy of this system of farming that was meant to provide modern industry and commercial farms with cheap labor. The areas were never meant to be productive enough to support a reasonable standard of living (Potts and Mutambirwa, 1997). These may all explain why farmers operate in the decreasing returns to scale range when economic theory suggests otherwise. This could well be highlighting the desperation that characterizes communal agricultural production.

6.6 Summary

In this chapter estimates of translog cost functions were presented. The independent variables explained over 65 percent of the variation in farm-level variable costs. But less than a quarter of the total number of coefficients are significant at 10 percent. Little could be said about the signs of the coefficients given the specification of technology as a translog system. The partial effect of a variable, say P_i, when technology is specified as translog is a combination of P_i's coefficient and those of other variables (other input prices, fixed input and output), say Z_j, with which P_i forms cross-terms. To find out why such a small number of variables have significant coefficients the cost models were examined for existence of econometric problems.

The main econometric problems examined are multicollinearity, heteroskedasticity, errors in variable and measurement errors. The last issue was limited to a mere discussion as the measurement errors are unobservable and hence hard to handle. Multicollinearity was not found to be a major problem because precautions were taken to create indices of input prices such as fertilizer and chemicals and labor. Areas planted was found to be systematically correlated to values of output for the corresponding crop categories as well as with other variables and thus were collapsed into a single variable; total area planted.

Problems of heteroskedasticity were checked, first, by simple plots of residuals on all independent variables and then through the Cook-Weisberg (CW) test. The 1988/89 cost function was the only one showing evidence of heteroskedasticity after the CW tests. More attention was given to the problem of omitted variables. The Ramsey Reset test revealed that only the 1989/90 cost function could have this problem if the rejection levels for tests of significance is set at levels higher than the traditional five percent. The specification link test revealed no problems at all with the specification of the dependent variable.

The next set of tests covered economic regularity. Most of the regularity conditions were not tested because the translog cost specification implicitly assumes them to hold especially homogeneity and, therefore, homotheticity. Thus the cost functions will be used in this study and compared to estimates of cost frontier functions in the next chapter.

Measures of economies of scale were derived from the cost function estimated using variables that were scaled by their means prior to being converted to logarithms. The most striking finding was the presence of decreasing returns to scale in Zimbabwe's communal areas. This implies that, at current technology levels, an increase in the use of inputs only generates a change in output (or cost saving) that is less than the rate by which inputs quantities (prices) were changed. This has far reaching effects in terms of the recommendations for institutional change. Communal farmers will need programs that change more than just the input bundles. New technology will go a long way in ensuring that these farmers operate at the desirable tail end of the increasing returns to scale range.

The tests for econometric and economic regularity revealed that the three cost functions have differences. To estimate a 1988/89 cost function heteroskedastic-robust methods are best. Although the 1989/90 cost function has traces of the presence of the omitted variable problem, it is the most "nicely behaved" cost function of the three.

CHAPTER VII: THE COST FRONTIER FUNCTIONS AND ECONOMIC EFFICIENCY.

7.1 Introduction

The last two chapters described the data and the methods used to estimate translog cost functions. It was possible to calculate indicators of economies of scale from estimated cost functions. Although measures of returns to scale are important in determining economically optimal levels of production they cannot be used to estimate economic efficiency of communal farms at individual farm-levels. Farm-level measures of economic efficiency can be derived from translog cost frontier functions. This chapter presents estimates of farm-level economic efficiency and identifies the factors determining cross-farm variability in economic efficiency measures.

The chapter has three major sections. The first section covers issues related to the estimation of cost frontiers and measures of farm-level economic efficiency. The main focus of this section is the determination of the pattern of farm-level efficiency in communal areas of Zimbabwe. Regression analysis is used in the second section to identify the factors that cause variability in farm-level economic efficiency. The list includes household resource endowment and demographic variables. Whenever available, data on physical farm characteristics such as soil type are also used as possible explanatory variables for variation in farm-level measures of economic efficiency. The aim of this analysis is to provide insights to be used in the last chapter which draws implications on future policy making on communal area agricultural development. The chapter then closes with a short summary.

7.2 Estimates of Cost Frontier Functions and Economic Efficiency

The main issues related to the use of cost frontiers to measure economic efficiency have been reviewed in detail in Chapter IV. Economic efficiency indicators will be derived from the cost frontier by decomposing the error term into its constituent components of white noise and the one-sided distribution of inefficiency. The assumptions that are necessary for this process and the resultant estimates of economic efficiency are presented in this section.

7.2.1 Estimating Cost Frontier Functions

When estimating cost frontiers one must make an assumption about the distribution of the one-sided error term. Many studies have used half or truncated normal distributions for the one-sided error (Greene, forthcoming). This raises questions on what distribution should be considered as a reasonably adequate representation of the actual distribution of farm-level technical and allocative errors. Economic theory does not dictate that mistakes be distributed normally (Førsund, Lovell and Schmidt, 1980). It is legitimate to question why we should expect farm-level mistakes to be clustered near zero inefficiency. The same question can be posed for other alternative specifications of the distribution of farm-level errors. Economic theory does not provide enough light on such questions. Specifying the distribution of the one-sided error term is a major assumption in the use of frontier models to measure firm-level economic efficiency. Thus estimates of economic efficiency obtained assuming half-normal distribution for the one-sided error term will be compared to estimates when the one-sided error term is assumed to be distributed exponentially.

7.2.2 Cost Frontier Function Estimates

Cost frontier functions are different from those normally generated by least squares techniques because while the latter represent an "average" line fitted to minimize the sum of squares of residuals, the cost frontier function is a line fitted to map the observed least cost for given levels of output. The difference between the two manifests itself in the form of differences in coefficient estimates. Even though the frontier model is prone to the influence of outliers, it possesses strong intuitive appeal because of the assumption that economic agents aim to maximize utility by maximizing profits through minimizing the production costs. If producer behavior is so defined then a function that traces least cost observations is more representative than one which defines an average through minimization of residual sum of squares. The results from these two ways of representing production relations will be subjected to comparative analysis.

Tables A9, A10 and A11 in the Appendix present the parameter estimates of the translog cost frontier functions when the one-sided errors are assumed to be distributed as a half-normal for the 1988/89, 1989/90 and 1992/93, respectively. There is a slight difference (third to fourth decimal) between coefficients shown in Tables A9, A10 and A11 and those in Tables A2, A3 and A4. But the intercept term between the two sets of functions are significantly different. It is also interesting to note that cost functions have slightly more variables which have statistically significant coefficients than cost frontier functions, as illustrated in Table 7.1.

Table 7.1: Differences in Number of Statistically Significant Coefficients Between Cost Functions and Cost Frontier Functions.

Type	Cost function		Cost frontier (normal)		Cost frontier (expon.)	
ρ-level*	5%	10%	5%	10%	5%	10%
1988/89	10	12	8	10	9	10
1989/90	16	21	12	14	14	19
1992/93	15	19	9	13	9	13

*Note: ρ-level stands for level of significance.

In addition to the differences in numbers of statistically significant coefficients between the cost frontiers and cost functions shown in Table 7.1, there are also slight differences in numbers of variables which have statistically significant coefficients between half-normal and exponential cost frontiers[65]. The latter has more statistically significant coefficients than the former. However, the differences between coefficients on corresponding variables across the function types are almost negligible. This seem to suggest that the differences between traditional (or average) cost functions and cost frontier functions is far from being complex. Whilst the theoretical strength of the frontier model as a true representation of real world phenomena seem adequate for one to recommend it over the "average" models, more work needs to be done to close the gap which appears insurmountable theoretically but turns out otherwise empirically. That the coefficients in Tables A9, A10 and A11 have the same interpretation as those of cost functions shows that from both the theoretical and empirical standpoints these two concepts of representing the production process tend to show similar trends when it comes to characterizing the production process.

[65] The half-normal and exponential cost frontiers are estimated assuming that the one-sided error term has a half-normal and exponential distributions, respectively.

The discussion on cost frontier functions estimates would not be complete without an examination of the variances of the two part error terms which are shown in Tables A9, A10 and A11. The across season differences in the cost frontier estimates are also apparent in the variance of the random noise and the one-sided errors (σ_u^2 and σ_v^2 , respectively). The inefficiency errors dominate the random noise in terms of variance only in the first season, 1988/89 as shown by the ratio λ. The parameters σ and λ constructed from these variances are all statistically significant during the 1989/90 season. But σ is also statistically significant in the other two seasons while λ is insignificant in 1988/89 and significant at 10 percent level in 1992/93.

The cost frontier functions with the one-sided error term distributed exponentially are presented in Tables A12, A13 and A14 in the Appendix for the three seasons, respectively. In addition to the differences in coefficients and numbers of statistically significant variables noted above, the variances of the random and one-sided errors follow the same pattern as that of the half-normal cost frontier functions. Both σ_v and θ are statistically significant in 1989/90 while σ_v is statistically significant in the other two seasons and θ is only statistically significant at 10 percent level in 1992/93. These patterns should be taken into account when interpreting the measures of economic efficiency.

7.2.3 Estimates of Economic Efficiency

The variables described above were used to estimate levels of inefficiency in communal areas. Farm-level estimates of economic inefficiency, $E(e^{v}|\epsilon_i)$ assuming that the one-sided error term has a half-normal distribution are calculated as shown below following Jondrow et al (1982):

$$E[e^{v}|\epsilon] = \frac{\sigma_v \sigma_u}{\sigma} \cdot \left[\frac{f(\epsilon\lambda/\sigma)}{1 - F(\epsilon\lambda/\sigma)} - \frac{\epsilon\lambda}{\sigma} \right]$$

In the case of the one-sided error term having an exponential distribution Jondrow et al (1982) calculated $E(e^{v}|\epsilon_i)$ as shown below assuming $\alpha = \epsilon/\sigma_v + \sigma_v/\sigma_u$.

$$E(e^{v}/\epsilon) = \sigma_v \left[\frac{f(\alpha)}{F(\alpha)} - \alpha \right]$$

Other variables are defined as before. There are some differences between estimates of farm-level inefficiency when a half normal and a exponential distribution are compared. The descriptive statistics (mean, standard deviation, minimum and maximum) of economic inefficiency measures are shown in table 7.2.

Table 7.2: Descriptive Summary of Economic Inefficiency Estimates

Variable	1988/89		1989/90		1992/93		Average	
	Norm.	Exp.	Norm.	Exp.	Norm.	Exp.	Norm.	Exp.
Mean	0.114	0.110	0.218	0.206	0.143	0.137	0.158	0.151
Std. Dev.	0.003	0.002	0.034	0.031	0.013	0.010	0.017	0.014
Minimum	0.100	0.106	0.119	0.176	0.098	0.126	0.106	0.136
Maximum	0.121	0.126	0.284	0.460	0.166	0.210	0.190	0.265
Cases	425	425	331	331	368	368	375	375

Notes: 'Norm.'stands for the half-normal distribution case, 'Exp.' is the case when the exponential distribution is assumed and 'Std. Dev.' is the standard deviation.

Overall across-season average economic inefficiency estimates shown in Table 7.2 indicate that communal farmers are about 15 percent inefficient. Thus communal farmers can

Overall across-season average economic inefficiency estimates shown in Table 7.2 indicate that communal farmers are about 15 percent inefficient. Thus communal farmers can improve production by simply eliminating this 15 percent inefficiency. Although the average for the half-normal case is slightly higher than the average for the exponential case, the two methods seem to yield the same results on average. The variability of the average estimates, as shown by the standard deviations, is similar between the two methods. However, differences do occur when one considers the case of the most efficient and inefficient farmers. In the half-normal case the least efficient farmer would be 19 percent off the efficiency frontier as compared to 27 percent for the exponential case. On the other hand the most efficient farmer for the half normal case would be 11 percent off the efficiency frontier against 14 percent for the exponential case.

The real story is shown by the season by season measures of economic inefficiency. As expected there is some significant across season variation in farm-level efficiency as shown by the mean, minimum and maximum values in Table 7.2. The most inefficient farm for all the half-normal cases was off the efficiency frontier by 28.4 percent during the 1989/90 agricultural season. On the other hand the most efficient farm was only off the frontier by 9.8 percent during the 1992/93 season. Average seasonal inefficiency fluctuated between 11.4 and 21.8 percent. The variability of efficiency estimates from one farm to the other during the 1989/90 season was higher than that of the other seasons as shown by a higher coefficient of variation (CV) of 16 percent compared to 3 and 9 percent for the 1988/89 and 1992/93 seasons, respectively.[66] The efficiency measures for the 1988/89 season produced the lowest mean, standard deviation and maximum value. The 1992/93 are closest to the average values.

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[66] The coefficient of variation (CV) is obtained by dividing the standard deviation by the mean. A rule of thumb in social science research is that a CV of less than 30 percent indicates acceptable variability.

The exponential cost frontier functions produced estimates of economic efficiency that have a similar pattern in terms of descriptive statistics. Examining the exponential cases reveals the most inefficient farmer was off the efficiency frontier by 46 percent in 1989/90 as compared to 23 percent for the half-normal case during the same season[67]. The most efficient farm for the exponential cases was off the frontier by 11 percent in 1988/89. We also note from Table 7.2 that the 1989/90 estimates of economic inefficiency are not only higher than the overall averages but are more variable across farms. Variations in inefficiency from farm to farm followed the same pattern shown in the half-normal case with CV's of 2, 15 and 7 percent for the three respective seasons. Farm-to-farm variation, as measured by CV's, was lower than the variation in the half-normal case in all three seasons. This shows that the estimates from the exponential cases are clustered together more than those from the half normal case even though the former has the highest estimates of inefficiency.

Table 7.2 shows some differences in economic inefficiency estimates across the three seasons. To further explore the nature of the differences of economic inefficiency measures across seasons, we superimpose all three seasons into two plots, one for the half-normal case and the other for the exponential case. The economic inefficiency estimates were rearranged in ascending order for clarity of presentation. These plots are shown in Figures 7.1 and 7.2.

In both figures the 1989/90 estimates are notably higher than the other seasons while the 1988/89 estimates are not only the lowest but are consistently uniform. In the half normal case (figure 7.1) the 1988/89 estimates do not get beyond the half-way mark of the10 to 15 percent range. But the other seasons' estimates have a broader range especially the estimates for the 1989/90 season. The same pattern is evident in the exponential case with the 1989/90

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[67] The farm that was 28.4 percent inefficient in the half-normal case is not the same as the one that was off the frontier by 46 percent.

estimates having the widest range of all the three season estimates. Estimates for the 1988/89 season are again consistently within the narrowest range of between 11 and 15 percent. However, the exponential estimates have a flatter slope than the half-normal estimates implying lower across farm variability. The similarity in pattern once again indicates that the two methods of estimating economic inefficiency yield reasonably similar results.

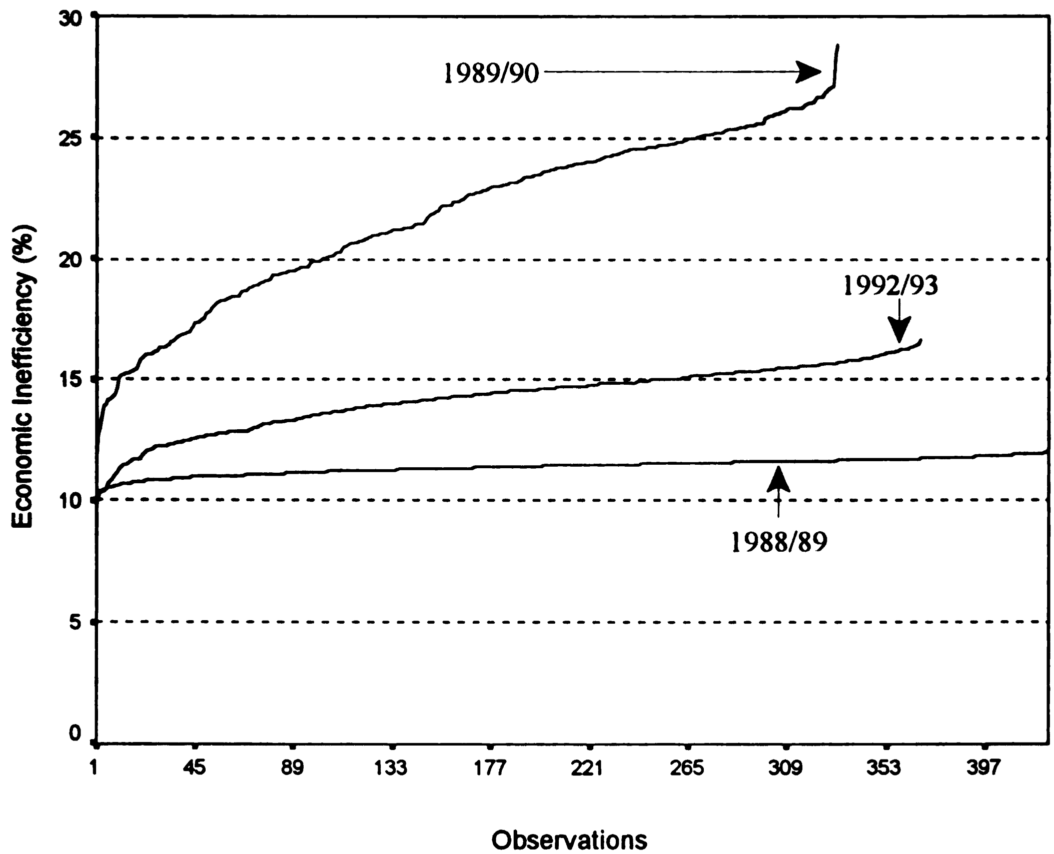

Figure 7.1: Measures of Economic Inefficiency for the Half-Normal Case

The differences in levels of estimates of economic inefficiency across the three seasons could be due to factors such as rainfall and other seasonal factors. The unpredictability of the rainfall season in Zimbabwe in general and communal areas in particular is considered to be one of the main factors affecting productivity (Chasi and Shamudzarira, 1992). False seasonal starts and mid-season droughts can eliminate whole plantings. Most farmers stagger their plantings as a way to hedge against the risk of false starts and mid-season droughts (Mudhara, et. al., 1995). The actual nature of the influence of rainfall cannot be pinpointed in the absence of data on rainfall and its distribution in the sample areas.

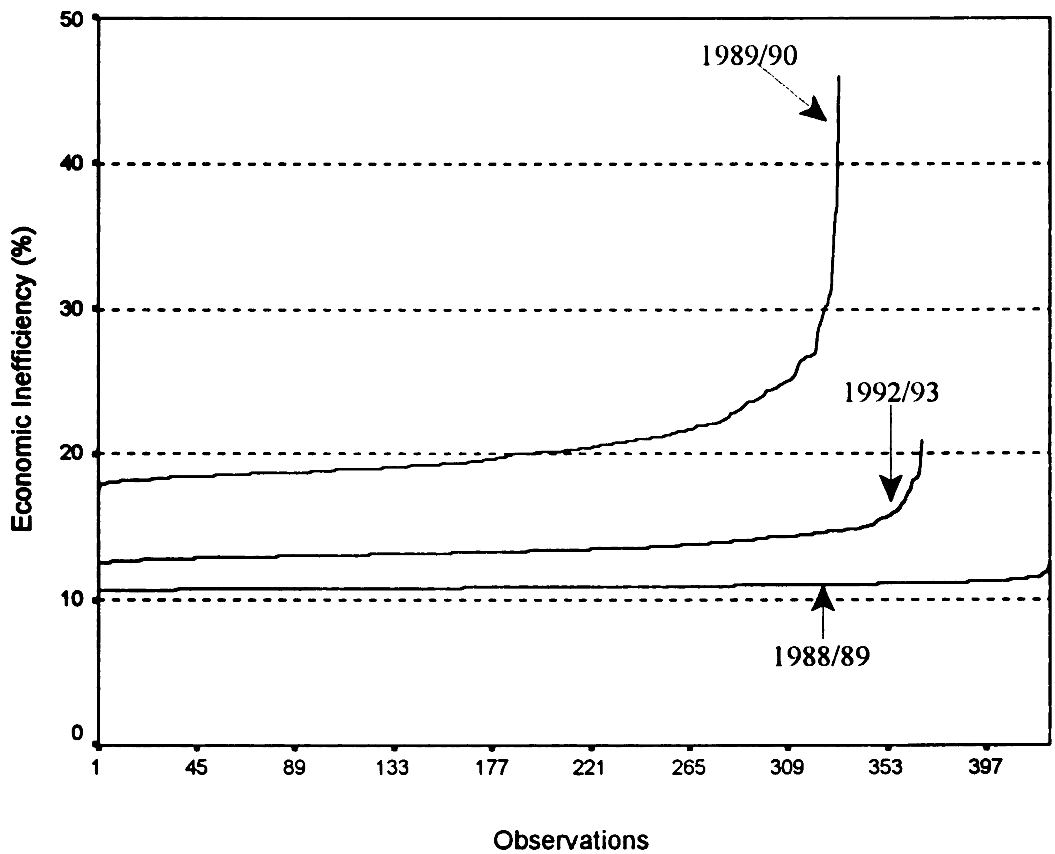

Figure 7.2: Measures of Economic Inefficiency for the Exponential Case

The above analysis has been based on measures of spread. Our next task is to examine the distribution of the economic inefficiency estimates. The histograms for both half-normal and exponential cases for each season are shown in Figures A8 to A13 in the

Appendix. These histograms allow us to examine whether there exists any difference in the distribution of economic inefficiency measures across the seasons and between the two cases.

What emerges from Figures A8 to a13 is that there is a difference in the nature of the distribution of estimates on the basis of method. The estimates from the half-normal cases all appear to have a distribution that is skewed to the right. The distributions are all approximately normal. On the other hand estimates from all exponential cases have distributions that are skewed to the left with a thinning right-hand side tail. The associated measures of skewness and kurtosis shown in Table 7.3 confirm that there is significant skewness and that the distributions are not normal. The thickness of the tails of the distributions shown in Figures A8 to A13 do not conform with those of a normal distribution.

Table 7.3: Test for Skewness, Kurtosis and Normality in the Distribution of Estimates of Economic Inefficiency

Season	Case	Skewness	Kurtosis	Test for Normality
1988/89	Normal	-0.78*	3.80*	34.21*
	Exponential	2.12*	11.67*	l.n.*
1989/90	Normal	-0.56*	2.43*	18.80*
	Exponential	3.40*	20.82*	l.n.*
1992/93	Normal	-0.77*	3.23	26.43*
	Exponential	2.84*	14.52*	l.n.*

* significant at 1 percent

l.n. stands for very "large number".

Table 7.3 confirms the pattern of skewness and kurtosis in the distributions of economic inefficiency measures. Unlike the exponential case, the half-normal cases' distributions have negative indicators of skewness. In addition all the indicators of skewness and kurtosis significantly indicate non-normality except for the kurtosis in the half-normal case of the 1992/93 season. The test for normality (joint significance of skewness and kurtosis) also confirms that none of the distributions have a normal distribution. These results show us that the two methods produce different distributions of inefficiency measures. What these distributions indicate is whether farmers are clustered towards the most efficient end or the inefficient end of the distribution. The distribution of exponential case estimates shows that farmers are clustered towards the efficient end. On the other hand, the distribution of the half-normal case estimates of economic inefficiency show that only a few farmers are on the most efficient end. Having said this one should note that the most efficient end for the exponential distribution start at level well beyond the medians of the distributions of the half-normal case estimates. In addition we have no theoretical background on which to base any expectations on what the ideal distribution of farm-level inefficiency should be.

7.2.4 Discussion of Results

The main highlight of this chapter is that on average communal farmers are between 11 and 22 percent inefficient as shown on table 7.2. Overally it was noted that farmers are off the economic optimum by between 10 and 46 percent. These rates are comparable to what other studies have found in other parts of the world. Van Zyl et. al. (1995) found the mean inefficiency relative to the best practice farms in the South African small-scale sector ranging between 52 and 64 percent. Bravo-Ureta and Evenson (1994) found out that on average peasant farmers in eastern Paraguay were economically inefficient by 60 percent for cotton and 48 percent for cassava. But in the North West Frontier Province of Pakistan, small farmers were 11.5 percent inefficient (Parikh, Ali and Shar, 1995). The Pakistan results are closer to those found in this study not only in terms of the average estimates but also in the wide variations in estimates from one farm to the other[68].

The average inefficiency ranging between 11 and 22 percent means that on average between 11 and 22 percent of the cost incurred could have been avoided without any loss in output. These observations on their own do not lead to any conclusion about the communal farmers' level of economic efficiency. Clearly it is not possible to expect zero efficiency in any production process. Some losses should always be expected even when the process is automated. The question then is what is acceptable level of inefficiency. There are no clear-cut answers to this question because this is equivalent to asking what is the expected or acceptable inefficiency attributable to random events which are beyond the control of the producers. With communal farmers some inefficiency is expected because of the importance that is given to meeting the family's subsistence needs. Farmers deviate from efficiency frontier because they use shadow values, based on family subsistence needs, to allocate resources at the farm. Again it is not easy to express this expectation in quantitative terms.

In chapter I it was hypothesized that communal farms would be considered efficient if the average inefficiency is below an arbitrarily determined figure of 10 percent. If this figure is accepted as a threshold for determination of economic efficiency, then we can conclude that communal farmers are efficient. Even though they can produce current levels of output at lower costs, the cost savings would be, on average, between 1 and 12 percent[69]. Thus, at current technology levels there are no significant gains for communal farmers if they

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[68] Parikh, Ali and Shar reported a range of between 3 and 42 percent for their estimates of economic inefficiency.

[69]The figures 1 and 12 percent are obtained from subtracting the hypothesized "acceptable" 10 percent from the means levels of inefficiency shown in Table 7.2 that range between 11 and 22 percent.

are to rearrange production so as to be closer to the frontier. In other words communal farmers are relatively close to the efficiency frontier.

The above conclusion does not change significantly if the distribution of the one-sided error term is assumed to be exponential. The three season average of economic inefficiency estimates ranges between 11 and 21 percent. Thus farmers would save about the same amount of costs that was found for the half-normal case if they take measures to produce at least 10 percent from the efficiency frontier. The cost savings of up to 12 percent are not economically significant. This change would not generate the changes in production that would result in revolutionary change in the lives of communal farmers and their families. But the change would still bring modest gains.

7.3 Determinants of Economic Inefficiency in Communal Agriculture

The next step is to identify factors responsible for the observed economic inefficiency. Most of the socio-economic factors are not taken into account in the estimation of the cost frontier function following the dictates of the two-step procedure of estimating economic efficiency[70]. The critics of this procedure argue that all variables should be incorporated directly into the frontier models (Bravo-Ureta and Evenson, 1994). But estimating the frontier models this way assumes that the variables directly affect efficiency and thus is at odds with those who contend that socio-economic variables have an indirect effect on production and hence efficiency (Kalirajan, 1991). Only further research can resolve this relatively new and developing controversy in the literature on the estimation of firm efficiency. In this study the estimated cost inefficiency are related to various farm-specific and nonphysical explanatory variables.

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[70] The two-step procedure involves measuring farm-level efficiency first and then estimating a regression model where efficiency is expressed as a function of socio-economic variables.

Because of unavailability of data it is not possible to relate cost inefficiency to farm-specific and nonphysical variables for all the three seasons. If one had a choice of the season that is representative of all the three seasons one would pick 1988/89. However, there is no data on the proposed explanatory variables for this season. But it is the 1989/90 season for which data on farm-specific and nonphysical data is available. As outlined in the preceding chapter, the only blemish on the 1989/90 data is that it produces a cost model that has evidence (at 6% significance) of problems of omitted variables. But the 1989/90 cost model, like the other models, is homogenous making it possible for us to make inference on the underlying primal function. In fact there is no season with a perfect cost model as illustrated in the last chapter. Thus there is no major loss in accuracy in identifying the determinants of cost inefficiency from the 1989/90 data.

7.3.1 Farm-Specific and Nonphysical Variables

Farm-specific variables that may affect inefficiency include farm size, farm assets, farm animals, annual cash remittances, soil type and location of the farm in terms of agro-ecological consideration. The hypothesized relationships between these variables and farm-level inefficiency are as follows:

- As argued throughout this study, farm size is expected to be positively related to farm-level inefficiency.
- The value of farm assets and farm animals are expected to be inversely related to farm-level inefficiency as these two would allow flexibility in farm operations.

- Families that receive remittances from relatives working elsewhere should also be more efficient because they have a reduced cash constraint. This contributes to farm working capital[71].
- Farms that have fertile soils and/or are located in good natural regions are expected to be closer to the efficiency frontier than those that are not. The soils variable is expressed as a dummy variable with all sandy soils classified as poor and red and black clays and loams classified as rich soils. Similarly location is presented as a dummy variable with farms located in natural regions II and III classified as good location and those in natural regions IV and V classified as poor location.

There are several nonphysical variables that could explain farm-level inefficiency. In this exercise three variables characterizing the head of the household are used as explanatory variables. These are age of the household's head, years of education and years of farming experience. The hypothesized relationship between these variable and farm-level inefficiency is specified as follows:

- The number of years of education for the household head is expected to be inversely related to inefficiency because farmers with more education are expected to commit less mistakes.
- The household head's years of experience in farming is also expected to be inversely related to farm-level inefficiency in similar fashion to the expected effect of the years of education on inefficiency.

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[71] This might appear to be at odds with the famous T.W. Schulz's "poor but efficient" hypothesis. But this hypothesis is an observation that farmers can be allocatively efficient without being technically (and hence economically) efficient. In this study the focus is on economic efficiency which implies both technical and allocative efficiency.

- There is no clear relationship to assign between inefficiency and age. Because age and experience should be positively correlated the former is dropped from the analysis.
- The other household variable included in this exercise is the size of the farm work force that includes adults and children[72]. Farms with more workers are expected to be more efficient than those with less.

The other nonphysical variables used in this exercise include access to input markets and use of credit. Access to input markets is represented by a dummy variable based on whether the farmer bought inputs or not. Use of credit is expressed as a dummy variable where one is assigned to farmers who used credit and zero to those who did not. An important nonphysical variable not used in this exercise, because of data unavailability, is access to extension.

- Farms that use purchased inputs are expected to be more efficient than those that do not rely on these modern inputs.
- Similarly farmers who use credit are expected to be more efficient that farmers who do not have access to credit.

We also look at two of the most common practices on communal farms; winter-ploughing and use of manure. While these two practices might appear as indicators of different technology at the farms, it is their dependence on farm resources and most probably farmer education and experience that persuade us to incorporate them in this analysis. Winter-ploughing allows moisture conservation and better germination in the event of early planting. Early planting have been shown to be associated with higher yields in the communal

[72] A family member aged between 15 and 70 years is taken as an adult-equivalent. A child aged between 5 and 15 years or an adult older than 70 years provides 75 percent of an adult-equivalent work.

areas (Shumba, 1985). Manure applications are known to improve the organic matter content of soils. The influence of manure could be affected by use of fertilizer. These two inputs have a synergistic effect. The use of manure and winter-ploughing are represented by dummy variables. The hypothesized relationships are as follows:

- The farmers who winter-plough their fields should be more efficient than the farmers who do not.
- Farmer who use manure as a source of organic matter to replenish soil fertility are expected to be more efficient.

7.3.2 Regression Results

The relationship between estimated economic (cost) inefficiency and the various explanatory variables is expressed as shown below:

$$
\begin{aligned}
EIE_i = \alpha_0 &+ \beta_1 EDUC_i + \beta_2 EXPE_i + \beta_3 WORK_i + \beta_4 AREA_i \\
&+ \beta_5 LNVA_i + \beta_6 LNLV_i + \beta_7 AREM_i + \beta_8 BUY_i \\
&+ \beta_9 AFC_i + \beta_{10} REG_i + \beta_{11} SOIL_i \\
&+ \beta_{12} WINP_i + \beta_{13} MANU_i + \epsilon_i
\end{aligned}
$$

Where the dependent variable, EIE is the estimated measure of economic inefficiency that is obtained when the distribution of the one-side error term is assumed to be either half-normal or exponential. In both cases EIE is expressed as a percentage.

The 13 independent variables are shown in the above equation are as follows:

1. EDUC = Years of education for the household head

2. EXPE = Years of farming experience for the household head

3. WORK = Number of adult equivalents working on-farm

4. AREA = Farm size (arable area)

5. LNVA = Logarithm of Value of farm implements and assets

6. LNLV = Logarithm of Value of farm animals

7. AREM = Amount remitted from relative working off-farm

8. BUY = Dummy variable for farmers who buy inputs

9. AFC = Dummy variable for farmers who use credit

10. REG = Dummy variable for natural agro-ecological regions

11. SOIL = Dummy variable for soil type

12. WINP = Dummy variable for farmers who winter-plough

13. MANU = Dummy variable for farmers who use manure

The two equations were estimated through ordinary least squares since the relationship. The estimated parameter coefficients (α_0 and β_i) and t-ratios are presented in tables 7.4 and 7.5.

Table 7.4: Relationship of Economic Inefficiency with Farm-Specific Variables; The Half-Normal Case

Variable Label	Variable Description	Coefficient	t-ratio
α_0	Constant	22.1159	18.153**
β_1	Years of Education for Household Head	-0.0563	-1.978**
β_2	Years of Farming Experience	-0.0082	-0.443
β_3	Number of Adult Equivalents Available	-0.1017	-0.917
β_4	Total Arable Area Available	-0.0990	-1.562
β_5	Logarithm of Value of Farm Assets	0.2799	1.429
β_6	Logarithm of Value of Farm Animals	0.1797	1.101
β_7	Amount Remitted	0.0004	1.260
β_8	Purchased Inputs	-1.5658	-2.932**
β_9	Use of Credit	-0.4138	-0.673
β_{10}	Natural Region	-0.5567	-1.016
β_{11}	Soil Type	0.0353	0.218
β_{12}	Winter-plough	-1.2871	-2.669**
β_{13}	Use of Manure	-0.4046	-0.827

Other Statistics: $R^2 = 0.091$; $\bar{R}^2 = 0.052$; $F(13, 305) = 2.35$**

Notes: ** = significant at 5 % level; * = significant at 10 % level

Table 7.5: Relationship of Economic Inefficiency with Farm-Specific Variables; The Exponential Case

Variable Label	Variable Description	Coefficient	t-ratio
α_0	Constant	21.2895	19.819**
β_1	Years of Education for Household Head	0.0409	1.630*
β_2	Years of Farming Experience	-0.0106	-0.650
β_3	Number of Adult Equivalents Available	0.0202	0.207
β_4	Total Arable Area Available	0.0750	1.343
β_5	Logarithm of Value of Farm Assets	-0.1812	1.049
β_6	Logarithm of Value of Farm Animals	-0.2447	-1.700*
β_7	Amount Remitted	-0.0002	-0.575
β_8	Purchased Inputs	1.1647	2.473**
β_9	Use of Credit	-0.1940	-0.353
β_{10}	Natural Region	0.7736	1.602
β_{11}	Soil Type	-0.1109	-0.776
β_{12}	Winter-plough	0.8752	2.058**
β_{13}	Use of Manure	0.5371	1.245

Other Statistics: $R^2 = 0.067$; $\bar{R}^2 = 0.028$; $F(13, 305) = 1.69$*

Notes: ** = significant at 5 % level; * = significant at 10 % level

The relationships represented by the coefficients shown in Tables 7.4 and 7.5 have low explanatory power. Collectively, the explanatory variables account for only 5 and 3 percent of the variation in economic inefficiency for the half-normal and exponential cases, respectively. However, these levels of explanatory power are typical of regression models involving cross-sectional data. Furthermore, out of the 14 estimated coefficients (13 variables and a constant), only 4 (constant, years of education, purchase of inputs and winter-ploughing) are statistically significant at 5 percent for the half-normal case. In the exponential case, on the other hand, 3 and 6 coefficients are statistically significant at 5 and 10 percent, respectively. Of those variables that are significant, the use of purchased inputs have the most economically significant coefficient even though use of these inputs only reduces inefficiency by 1.6 percent in the half-normal case. The coefficients shown in tables 7.4 and 7.5 are not significant economically even if they were statistically significant.

In addition the number of variables with the expected signs are low (8 and 7 for the half-normal and exponential cases, respectively). The signs on the variables differ between the half-normal and exponential cases. Only Years of Farming Experience and Use of Credit have the same signs in the two cases. Thus, the results shown in Tables 7.4 and 7.5 cannot be used to draw strong policy recommendations. These results are used with the caveat that they do not fully explain the relationship between farm-level efficiency and farm-level characteristics.

7.5 Summary

This chapter presented the cost frontier and measures of economic inefficiency. Economic inefficiency estimates were derived assuming the distribution of the one-sided error term to be either half-normal or exponential. The two cases produced results that were similar in terms of magnitude but different in terms of distribution. The main finding of this process was that, on average, communal farmers are 15 percent inefficient. All of the three seasons' measures of inefficiency were within a range of 10 to 46 percent. There was considerable across season variation.

Only the 1989/90 data was complete and detailed enough for an analysis of the relationship between measures of economic inefficiency and 13 farm-specific variables comprising of variables describing the household head, the resource endowment, and other farm-level nonphysical factors. As is typical of regression models involving cross-sectional data, the explanatory power of this relationship as shown by the coefficients of determination (R^2) was low. The signs on the coefficients were in line with expectations on 8 and 7 occasions for the half-normal and exponential cases, respectively. But only three of the 13 variables had coefficients that had the expected sign and at the same time were statistically significant at 5 percent level. The relationship was therefore found to be relatively insufficiently informative to be used for deductive purposes.

CHAPTER VIII: SUMMARY, RECOMMENDATIONS AND CONCLUSION

8.1 Introduction

The objective of this chapter is to summarize the main findings of this study and then draw some policy recommendations and conclusions. First, a summary of the main findings are provided. The outline of this section closely follows that of the study. Then policy recommendations that are based on the findings of the study are provided next. In the next section these recommendations are qualified by a short discussion on the theoretical and practical shortcomings of the study. The gaps identified in this section are the basis of the recommendations for future research work that are covered as part of concluding remarks in the last section.

8.2 Summary of Findings and Recommendations

Zimbabwe's agrarian structure is partly a creation out of the belief that large scale farms and estates are the best vehicle to transform an agricultural-based society into one dependent on industrial production. It is also a product of policies that sought separate development of the country's population on a racial basis. When the industrialization strategy failed to structurally transform the economy, the system was not adjusted accordingly. In fact policies were enacted to entrench large scale farming and reduce the competitiveness of small scale family farms. However, close to half of the land in Zimbabwe is under communal farming making any policy or program seeking to exploit the full productive potential of land unrealistic if it ignores what is happening in communal areas.

The second chapter presented the literature on the inverse relationship between farm size and economic efficiency. Small farms are often more efficient economically than large farms even if capital and land markets are distorted in favor of large farms. This inverse relationship between farm size and economic efficiency is due, mainly, to the dual nature of the agricultural labor markets which allows small family farms to use labor more intensively and incur less supervision costs than large, hired labor dependent farms. As shown in this literature review, there are few studies in Africa in general, and Southern Africa in particular, that address this issue even though farm size-efficiency issues are becoming increasingly important as the land frontier is closing due to rapid population growth. This was one of the motivation of this study. Data limitations, however, did not permit a comparison of communal and commercial farmers in Zimbabwe.

The third chapter is a presentation of the characteristics of communal agriculture. The description of communal area household demographic characteristics, household resource endowments and the production practices and patterns that farm household use helps identify the factors that explain the use of available resources at farm-level. This characterization revealed that communal farmers operate a low-input system of crop-livestock enterprises that have weak links with the market economy. Livestock and human labor are the major inputs of crop enterprises. Crop production, as the main occupation, is not dependent on the markets for inputs. The inputs that farmers purchase regularly are maize, cotton and tobacco seed and fertilizer. But fertilizer is not widely used and when used it is applied at levels lower than official recommendations.

The main purpose of the fourth chapter was to examine ways of expressing the relationship between factors of production and output which is important in the measurement of the efficiency of communal agriculture. From the review of models relating factors of production and output, duality theory afforded us an easier way of empirically estimating the input-to-output relationship. Chapter four made the case for using dual functions to reflect the process farmers use to maximize profits given a set of output and input prices and a level of output. The extension of the cost function to a generalized translog multi-product variable cost function allows the estimation of a more general and flexible function that does not involve imposing restrictive assumptions. It is this general and flexible translog multi-product variable cost functional form that was used to estimate frontier functions and, hence, the estimates of farm-level economic efficiency.

Before using the recommended general and flexible translog multi-product variable cost function to represent the relationship between factors of production and output in communal areas, the variables involved were described. As shown in the fifth chapter the variables used to estimate cost functions and frontier functions vary widely across farms and seasons. This reflects the inherent variability characteristic of communal agriculture due to geo-physical (rainfall and soil type) and socio-economic factors. The data, as shown in the sixth chapter, produced estimates of generalized multi-product translog variable cost function where the independent variables explained over 65 percent of the variation in farm-level variable costs. But only a few variables have significant coefficients suggesting that there could be some econometric problems.

The main econometric problems examined were multicollinearity, heteroskedasticity, errors in variable and measurement errors. Multicollinearity was not found to be a major problem because precautions were taken to create indices out of variables (input prices and area planted) which were found to be systematically correlated to values of output and with each other. There was no significant evidence of heteroskedasticity except in the 1988/89 cost function. The omitted variable problem appears to exist in the 1989/90 cost function only if the significance level is set above the standard five percent.

The conformity of the cost functions with economic theory is assumed by the way the translog cost function is specified. The most important conditions that are implicitly assumed include concavity, homogeneity and homotheticity.

Measures of economies of scale were calculated from cost functions derived from variables that were scaled by their means prior to being converted into logarithmic values. The most striking finding was the presence of decreasing returns to scale in Zimbabwe's communal areas. This suggests that communal farms need more than just an increase in input supply if they are to increase production significantly. New technologies are required so that farmers have an opportunity to produce outside the decreasing returns to scale region.

The main finding from estimating cost frontier functions and measures of economic inefficiency was that, on average, communal farmers are 15 percent inefficient. All of the three seasons' measures of inefficiency were within a range of 10 to 46 percent. But there was considerable across-season variation. Data availability only allowed the use of the 1989/90 data to relate measures of economic inefficiency to 13 farm-specific variables comprising of variables describing the household head, the resource endowment, and other farm-level physical and nonphysical factors. The explanatory power of this relationship was low and a significant number of coefficients were not statistically significant. The signs on the majority of the coefficients changed depending on whether the distribution of the one-sided error term was assumed to be half-normal or exponential.

8.3 Policy Recommendations

One of the major findings of this study is that there is economic inefficiency averaging between 11 and 22 percent and an overall range of between 10 and 46 percent in communal area agriculture in Zimbabwe. However, most farms are clustered around the mean range of 11 to 22 percent and an overall mean value of 15 percent. This means that current output levels can be produced using less resources or more preferably, more output could be produced using the same bundles of inputs that farmers currently use. If inefficiency is eliminated then, on average, production can be increased by up to 15 percent. This cannot result in significant changes in the living standards of the majority in communal areas. In aggregate terms this may be a significant change. But at the household level a 15 percent increase over an already small output level is unlikely to make much of a difference. Clearly the changes in production required for communal areas to break out of poverty will have to be more than that obtained from just eliminating the estimated inefficiency. This leaves unanswered the question of what is the most viable and appropriate mix of programs and policies that will rehabilitate communal areas and revolutionalize overall living standards.

8.3.1 Technology Development and Transfer

Technology transfer is recommended in cases where farmers are found to be economically inefficient. After finding levels of economic inefficiency ranging between 48 and 60 percent among peasant cassava and cotton growers in Paraguay, Bravo-Ureta and Evenson (1994) recommended extension programs to move farmers towards the efficiency frontier. Van Zyl et al (1995) also recommended intensification of extension efforts in the former homelands of South Africa when they found economic inefficiency levels ranging between 52 and 64 percent. In such cases extension specialists would provide farmers with information on the best use of existing technologies. If the extension programs succeed in transferring the technologies to the farmers then, at most, production at farm-level would increase by 60 percent. This could result in significant changes in income and subsistence levels.

Technology transfer may also be recommended in cases where farmers appear to be economically efficient but are unaware of the availability of new production technologies and/or how best to use them[73]. The low levels of inefficiency that are observed may be

[73] This occurs because the estimated frontier is basically a loci of the "best practices" by farmers using information available to them. The question of what is the true frontier will be discussed later on in this chapter.

reflecting a case where farmers are located on an efficiency frontier that is lower than the potential defined by the unknown technology. As a result care must be taken to ensure that frontier functions are estimated from samples of farmers that have access to information on how to use the best production technology available. Otherwise the estimates of economic efficiency may end up being used to recommend inappropriate policies and programs.

In cases where the estimated economic inefficiency level is relatively small, as is the case in the communal areas of Zimbabwe and the North West Frontier Province of Pakistan (Parikh, Ali and Shar, 1995), the impact of extension programs would be greatly reduced. Farmers are operating close to the efficiency frontier and can only significantly increase production if they move up to a new frontier. New agricultural technology developed for communal area conditions create new efficiency frontiers and allow farmers to use current resources to produce higher output levels. Investments in technology development have produced high payoff levels in the past. The rates of return to past investments in maize and cotton research and extension in Zimbabwe, averaging over 40 percent, were significantly higher than the opportunity cost of public funds (Kupfuma, 1994; Mudhara, et al, 1996). New technologies should be developed specifically for communal agriculture based on the faith that history will repeat itself as demonstrated by the fact that past well-planned technology development and transfer investments generated high rates of return. The main question is whether the success achieved from agricultural research approaches designed to solve commercial agricultural problems could be replicated using new agricultural research approaches that focus on the problems of semi-subsistence small family farms whose primary aim is providing sufficient food for the family

To develop new and appropriate technology and transfer it to farmers requires that sufficient financial and manpower resources be committed over a long period of time (20 to 25 years). The availability of resources and time constrain the process of producing new technology. Furthermore, the process is not definite as there is no guarantee that a new technology will be developed and when. The main question then is whether there is enough time to wait until science can accomplish all the tasks that society needs and expects. It is for this reason that the technology development planning process should be thorough and be managed by the best minds that agricultural sciences can provide. But science can provide more efficient and effective means to organize national resources in the process of production if investments in science are increased to enable the development of more comprehensive and better calibrated scientific models. Science, in various forms, has sustained and shaped the development of societies throughout the history of mankind even at times when popular belief on its utility was negative. Ultimately it is the political will and resolve of national governments that determine the ability of each nation to take full advantage of agricultural science as a tool for economic and social development.

8.2.2 Land Reform

In addition to technology development, land reform programs are often recommended when farmers are operating on or close to the efficiency frontier. Farmers are resettled on land taken from inefficient users or newly opened for agricultural use. The objectives of such a program include efficiency and/or equity. Without data from the other farm types in Zimbabwe it was not possible to identify the most efficient farm type raising the question of what would be foregone if other types of farms are transferred to communal farmers. Thus this study does not provide enough evidence for one to recommend land transfers in Zimbabwe. The efficiency of other farm types have to be established in order to give an indication of the opportunity costs of land reform programs. Furthermore, the economic and environmental cost of implementing land reform programs and the time it takes for the new settlers to restore current production levels should all be taken into account.

However, many land reform programs are often implemented for egalitarian purposes and to stem the political agitation that normally accompanies inequality in access to land. In Zimbabwe there is general agreement, even among the commercial farmers, that there should be some redistribution of land for the benefit of the landless and near landless residents of communal areas (Swanepoel, 1997). Power relations based on class play a major role here. Indeed the success of a land reform program is dependent on the balance of power between the new and old political coalitions. But these issues are beyond the scope of the economics discipline which offers limited insights into the process that is predominantly social and political (Zimmerman and Carter, 1996). Because a land reform program involves changing the land ownership structure, measures must be taken to change the social and political relations to minimize the inevitable conflict. But changing social relations and political coalitions is, admittedly, a difficult process to set in motion. Often it is the spontaneous emergence of strong socio-political coalitions that permits land transfers. In Zimbabwe reports of land invasions by communal area residents that began to appear in the popular press since June 1998, indicate that the pressure for a far-reaching land redistribution program is mounting. In fact, spontaneous settlements have been more successful than those that are planned and tightly managed (Kinsey and Binswanger, 1993).

8.4 Limitations of the Study

This study, like many others of its type, has a number of shortcomings despite considerable efforts to circumvent them. In this section we will resist the urge to address all identified shortcomings. We will concern ourselves with just two shortcomings (data quality and availability and methodological issues) that we believe to have significantly affected the outcome of this study. This does not in anyway mean that the shortcomings apparent in this study but not addressed here can be assumed away as insignificant. They do affect the study's outcomes, and all opportunities to avoid them were taken full advantage of.

8.4.1 Data Quality and Availability

As in many quantitative studies, there is always a problem of insufficient data. This study is no exception. The data used in this study were not collected specifically for this exercise. As a result some data that are specific to estimating measures of economic efficiency were not available. When data was retrieved from the Ministry of Agriculture data files, some important variables could not be obtained. For instance, we could not locate the 1988/89 and 1992/93 data on household characteristics. In addition, a lot of observations had to be thrown out because certain key variables were missing. This reduced the sample sizes significantly and affected the quality of the analysis.

Besides data availability problems, there are problems of data quality. The fact that we had no control over the data collection process leaves us with limited options to improve data quality. Because of the timing of this study, it was not possible to go back to the field to cross check the values which were found to be out of expected ranges. The only option at our disposal was to delete such observations from the analysis. Through this thorough data cleaning exercise, some control over data quality was exerted. Most of the quality control, such as in-field supervision and data entry, was performed by the Ministry of Agriculture staff.

The question often asked about poor data availability and quality is whether it is prudent to go ahead with the analysis. The answer is straight-forward when it is judged that no reasonable conclusions can be reached from analysis based on insufficient and/or poor quality data. But the line that separates when to and not to proceed with analysis using data with such problems is hard to draw. Most often the decision to use problem data is based on the realization that no other better quality data is likely to be available in the near future and that there is urgent demand for information that such an analysis would provide. Sometimes such analysis will provide important indications that can aid decision making. When decisions are being based on no information at all, there may be merit in proceeding with the analysis so as to provide the policy-making process with some information.

8.4.2 Methodological Issues

The other major weakness of the study has both methodological and philosophical dimensions that are hard to disentangle fully in a discussion like this. Following Førsund, et al (1980) this study raised the issue of what a cost frontier stands for as compared to an "average" cost function. The definition of a cost frontier as a loci of minimum levels of costs that can be attained to produce a given level of output, given a set of input prices, leaves us asking whether the minimum is with respect to the sample, the population or the technically feasible scenario. The first two define the best-practices observed and are used in the estimation of both deterministic and stochastic frontier functions. The question here is do these converge to or approximate the true cost frontier[74] as defined by the best available technology (or the third scenario). If farmers are not aware of the best available technology then the practice of using the observed best-practices as a basis for constructing a frontier function and calculating measures of inefficiency is clearly flawed. There are several obstacles that could prevent communal farmers from knowledge of the true frontier. Whatever these are, the bottom line is that we may end up using the 'wrong' frontier to evaluate the efficiency of a production system. Our inability to estimate frontier functions that incorporate 'known'

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[74] The true cost frontier must be defined by the minimum levels of costs with respect to the technically feasible levels which are well known by farmers as competitive markets do not have information asymmetries.

gaps between current practices and the best practices poses a methodological development problem that has to be resolved.

Somewhere in this study we pointed out the problem of assigning to the one-sided error term a known distribution without theoretical grounding. There is no way of knowing, *a priori*, how farm-level inefficiency is distributed. Even though alternative specification of the one-sided error term allows some form of sensitivity analysis, the question of the theoretical basis of the distribution assumption still remains. This study imposed these distributions without sufficient theoretical justification. There were differences in the distribution of economic efficiency estimates between the half-normal and exponential cases. When the two sets of economic efficiency estimates were regressed on farm-level variables they produced different results. These observations call for further investigation of the *a priori* distribution of farm-level economic efficiency to establish, on a theoretical basis, the distribution that best represents real world circumstances.

Several other methodological shortcomings are apparent in this study. In most cases methodological developments have lagged behind theory and desire. This is particularly true if one considers the "Greene Problem". Theory suggests that the errors made in using inputs translate into higher costs. But the development of a functional form that takes this relationship into account continues to this day, close to 20 years after Greene discovered this problem. In this study this problem was not taken into account because of the absence of appropriate methods. The separation of technical and allocative efficiency was thus not possible without adequately resolving the "Greene Problem".

8.5 Future Research Work

Given the data problems encountered in this study, there is need to collect new data sets specifically for estimating efficiency, and then to compare results. There is also need to estimate the efficiency levels of other farm types (resettlement areas, small-scale commercial and large-scale commercial) and, if possible, compare results across farm types. Estimates of economic efficiency obtained from panel data sets should be compared to estimates from cross-sectional data sets

The observed differences in estimates of economic efficiency when the assumption about the distribution of the one-sided error term changes is an issue that needs further investigation. Are mistakes made by agricultural producers distributed as half-normal, gamma or exponential? Under what circumstances would each of these distributions apply? Is there something that can be gleaned from production or economic theory in general to help identify the most appropriate distribution? Future methodological studies should try to answer some of these questions.

The suggestion that technology development and transfer and land reform programs are possible intervention tools to develop communal areas demands studies based on ex ante evaluations of the benefits and costs involved. There also should be in-depth evaluations of other agricultural and non-agricultural options. Most communal areas are located in areas not suitable for crop production at all. Maybe in these areas, agriculture is not the most viable option of using available resources. It may be that communal farmers could specialize in producing other types of goods and services from which they can earn sufficient income to meet their food and non-food needs through purchases. Studies that address this issue should pay particular attention to institutional reforms (especially food markets) necessary for this to work effectively and efficiently.

The other area that researchers have shied away from is the factors determining the formation and development of farmer organization and institutions. Interest should be on the dynamics of such organizations and institutions and how they can contribute to changes that are as complex as agrarian reform. One of the crucial issues is the different ways that can be employed to improve the effectiveness of organizations that are set up to serve many and geographically dispersed poor farmers. The economics discipline has tended to leave this area to political and other social science disciplines. But the developments in institutional economics offers the best promise for the discipline of economics to contribute significantly to a proper understanding of the political and social organizational issues that characterize small-scale farming.

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APPENDIX

A.1: THE MINISTRY OF AGRICULTURE SURVEY QUESTIONNAIRE

MINISTRY OF LANDS, AGRICULTURE AND RURAL RESETTLEMENT

(Farm Management Research Section - FMRS)

RECORD 050 - General Information

19. Enumerator -----------------------
20. Name of Head of Household -----------------------
21. Village -----------------------
22. District -----------------------
23. Number of Years Farming -----------------------

RECORD 100 - Socio-economic Characteristics

1. Ask for a full list of all the household members and indicate whether resident (R) or non-resident (N) next to name.

Name	R/N	Relationship to Head of Household	Age	Sex M/F	Attending School? Y/N	Highest Ed. Level	Principal Non-farm Occupation	Approx. Annual Remittance

RECORD 150 - Inventory of Assets

ASSET CODE	QUANTITY	AGE	ORIGINAL COST ($)	CURRENT SALE VALUE ($)

ASSET CODES

Ox-plough	PL	Spraying Equipment	SE
Harrow	HA	Hoes	HO
Ox-cultivator	CV	House (mud & thatched)	MT
Scotch cart	SC	House (brick & thatched)	BT
Wheel-barrow	WB	House (brick & corrugated)	BC
Water cart	WC	Storage facilities	SF
Chains	CH	Picks	PI
Axes	AX	Shovels	SH
Maize shellers	MS	Others (Specify)	OT

RECORD 200 - Farm Structure/Characteristics

Plot/Field Number	Last Year		Number of paces	Area (ha)	Approximate distance from homestead (km)	Soil type (ode)
	Main Crop (or fallow)	Minor Crop (if any)				
Garden	------------	--------				

Total Arable Area (ha) -------------- (NB 1 acre = 0.4 ha)

SOIL TYPE CODES:

Black Clayey	BC	Red Clayey	RC
Sandy Soils	S	Sandy Loamy	SL
Loamy Soils	L	Other (Specify)	

RECORD 250 - Livestock Composition

Type	Number of Animals	Health Condition	Uses in Order of Importance				Value per Animal ($)
			1	2	3	3	
CATTLE Bulls							
Cows							
Oxen							
Heifers							
Steers							
Calves							

HEALTH CODES:

01	Excellent	03	Average/Reasonable
02	Good	04	Poor

USE CODES:

DR	Draught	EX	Exchange of Animals	LO	Lobora (bride price)
MA	Manure	BR	Breeding	ME	Meat (home use)
SA	Sale of Animals	PR	Prestige/Status	EG	Eggs
SM	Sale of Meat	TR	Transport	Other (Specify)	

RECORD 350 - Pre-Rainy Season Operations

1. Did you do winter ploughing last season? Yes/No
2. Did you apply (a) manure? Yes/No
   (b) fertilizer? Yes/No
3. Did you purchase inputs such as seeds? Yes/No
4. Did you receive an AFC loan last year? Yes/No
5. If no, What are the reasons? ----------------------------

RECORD 300 - Cropping Patterns (Previous Season)

Plot No.	Crop (fallow)	Area hvstd (ha)	Sales		Gifts &/or Exchanges		Retention bags	Distance to point of sale (km)	Means of Transport	Cost of Transport per bag ($)	Soil Type
			Qty bags	Total value	Qty bags	Reason					

SOIL TYPE CODES:

Black Clay Soils	BC	Red Clay Soils	RC
Sandy Soils	S	Sandy Loams	SL
Loamy Soils	L	Other (Specify)	

Note: If inter-cropped show both crops on the same plot number.

RECORD 380 - Input Stocks

Crop	Input	Source Code	Quantity	Total Cost	Means of Transport	Transport Charge	Month & Year of Purchase	Comments

RECORD 400 - Land Preparations

Crop	Operation(s)	Mo.	Draft power Own/hired cost ($)	Adult labor hrs			Child labor hrs			Area Covered	Comments
				Own	Hired	Cost	Own	Hired	Cost		

RECORD 450 - Planting Operations

Crop	Mo. & No. of days	Draft Power	Adult labor hrs.			Child labor hrs.			Seed Used			Fertilizer Used		
		Own/hired Cost ($)	Own	Hired	Cost	Own	Hired	Cost	Type	Qty	Area Planted	Type	Qty	Area Fert.

RECORD 500 - Chemical Application

Crop	Fertilizer/ Chemicals		Month	No. of days	Area (ha)	Adult labor hrs.			Child labor hrs.			Comments
	Type	Qty				Own	Hired	Cost	Own	Hired	Cost	

RECORD 550 - Weeding Operations

Crop	Operation	No. of Days	Area covered (ha)	Draft power	Adult labor hrs.			Child labor hrs			Calculations
				Own/hired Cost	Own	Hired	Cost	Own	Hired	Cost	

RECORD 600 - Harvesting (up to grain preparation)

Crop	Operation	Mo.	No. of Days	Adult labor hrs			Child labor hrs.			Area	Quantity		Transport Home		
				Own	Hired	Cost	Own	Hired	Cost		Loads	Bags	Method	Dist.	Cost

OPERATIONS:

Millets, S/Flower, Rice	G/Nuts, R/Nuts, Cowpeas	Maize
1. Cutting heads	1. Lifting	1. Cutting
2. Transporting	2. Transporting	2. Stacking
3. Threshing	3. Plucking	3. Threshing
4. Winnowing	4. Drying	4. Bagging
5. Bagging	5. Winnowing	
	6. Bagging	

RECORD 650 - Marketing

Crop	Mo.	Sales		Gifts and Exchanges		Receptions		Transport to market		Market	
		Qty (bags)	Value ($)	Qty (bags)	Reason	Qty (bags)	Value ($)	Type/ Form	Cost ($)	Type	Distance (km)

MARKET TYPE CODES;

Local shop/store	LS	Local farmer	LF
Cooperative	COOP	GMB depot	GMB-D
GMB collection point	GMB-CP	GMB approved buyer	GMB-A
Others (Specify)			

RECORD 700 - Overhead Expenditures: Repairs and Maintenance

Operation	Items	Repairs Done	Material Costs	Labor hours		
				Own	Hired	Cost

RECORD 700 - Overhead Expenditures: Purchases and New Constructions

Operation	Items	Approximate useful life	Material Costs	Labor hours		
				Own	Hired	Cost

OVERHEAD ITEMS:

Equipment		Facilities	
1. Ploughs	5. Shellers	1. Fences	5. Contour ridges
2. Yokes & harnesses	6. Planters	2. Dams	6. Drainage ditches
3. Scotch carts	7. Harrows	3. Kraals	7. Houses
4. Cultivators	8. Others	4. Storage	8. Others

RECORD 750 - Non-Farm Activities

1. Ask the family whether they are in activities outside their normal farming business such as handicraft, cutting grass, being hired out, brewing and selling beer, etc.
2. Ask for the amount received as remittances.

Activity(ies)/Source	Family members involved*				Income generated (cash or in kind)	Uses/Comments
	M	F	m	f		

** MEMBER CODES:*

M	–	Male Adults	m	–	Male Children
F	–	Female Adults	f	–	Female Children

RECORD 800 - Changes in Livestock Numbers

Animal Type	Opening Stock (number)	Livestock Change Code	Number	Month	Value Received or Paid	Sale of Produce			Livestock Operation (specify)	Cost ($)
						Item Code	Qty	Value		
Bulls										
Cows										
Oxen										
Heifers										
Steers										
Calves										
Others										

LIVESTOCK CHANGE CODES;

S - Sales	B - Births	DO - Donations Out
P - Purchases	D - Deaths	DI - Donations In
SL - Slaughtered	O - Others (specify)	

APPENDIX

A2: FIGURES AND GRAPHS

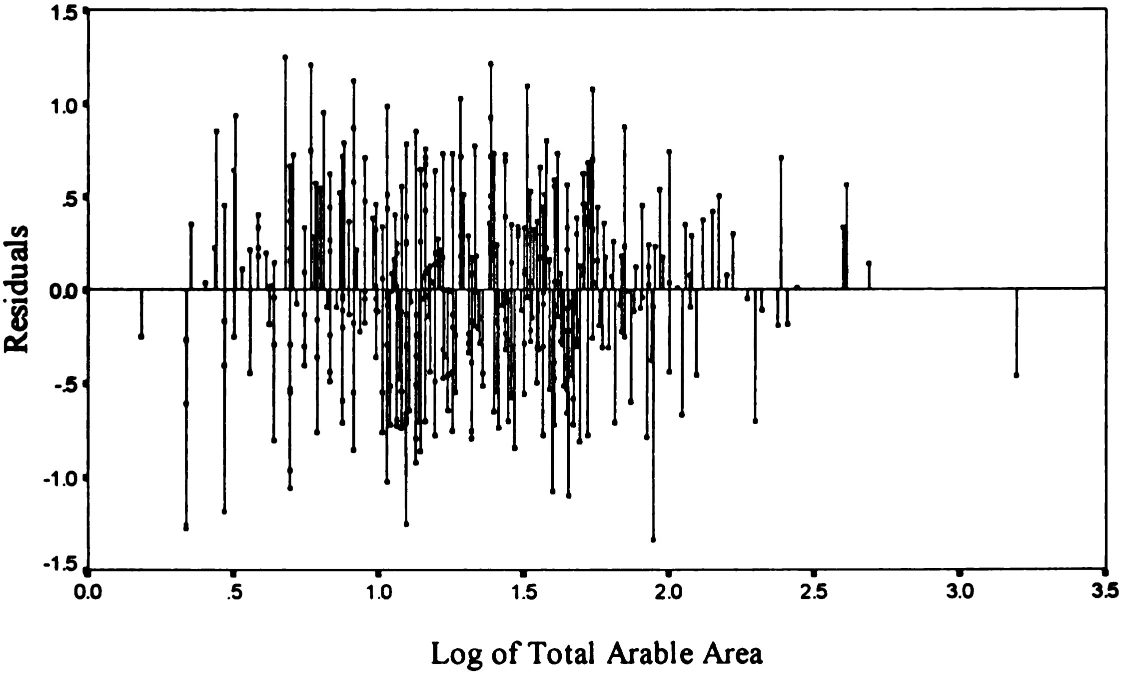

Figure A1: Plot of Residuals on Total Arable Area, 1988/89

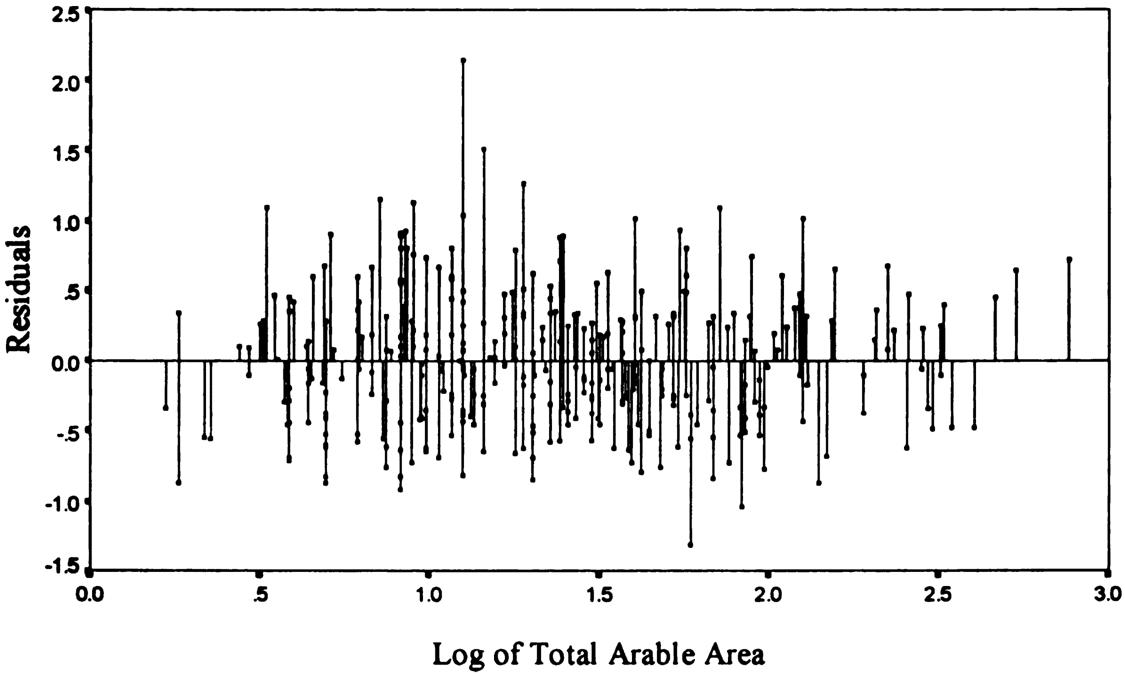

Figure A2: Plot of Residuals on Total Arable Area, 1989/90

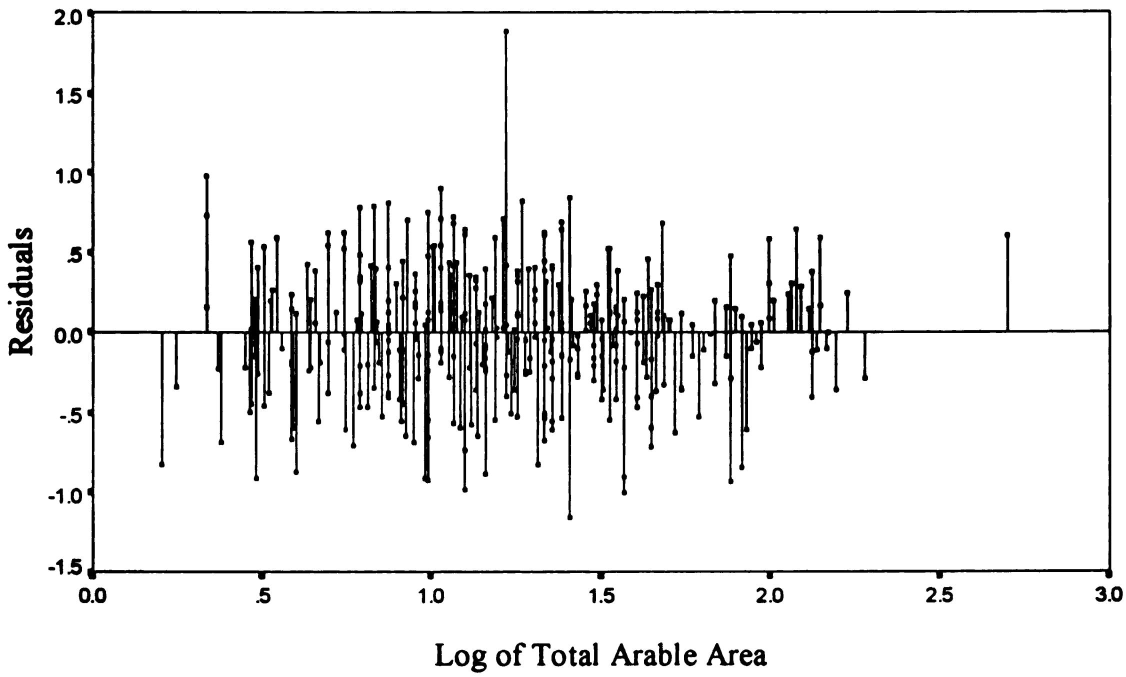

Figure A3: Plots of Residuals on Total Arable Area, 1992/93

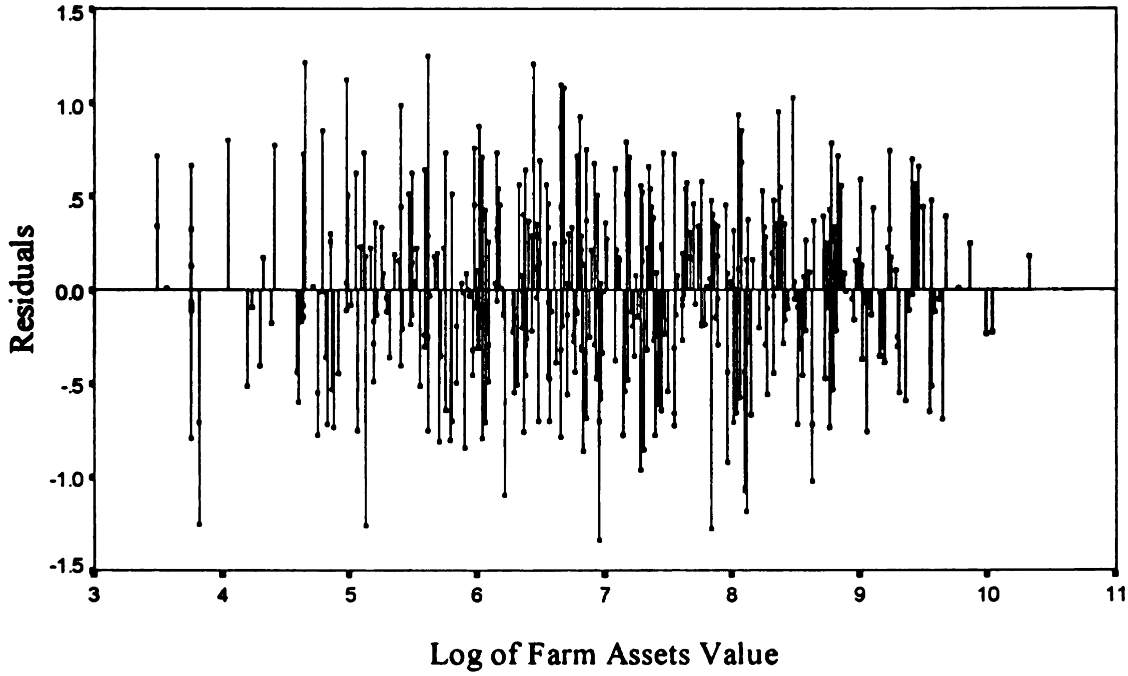

Figure A4: Plot of Residuals on Farm Assets Value, 1988/89

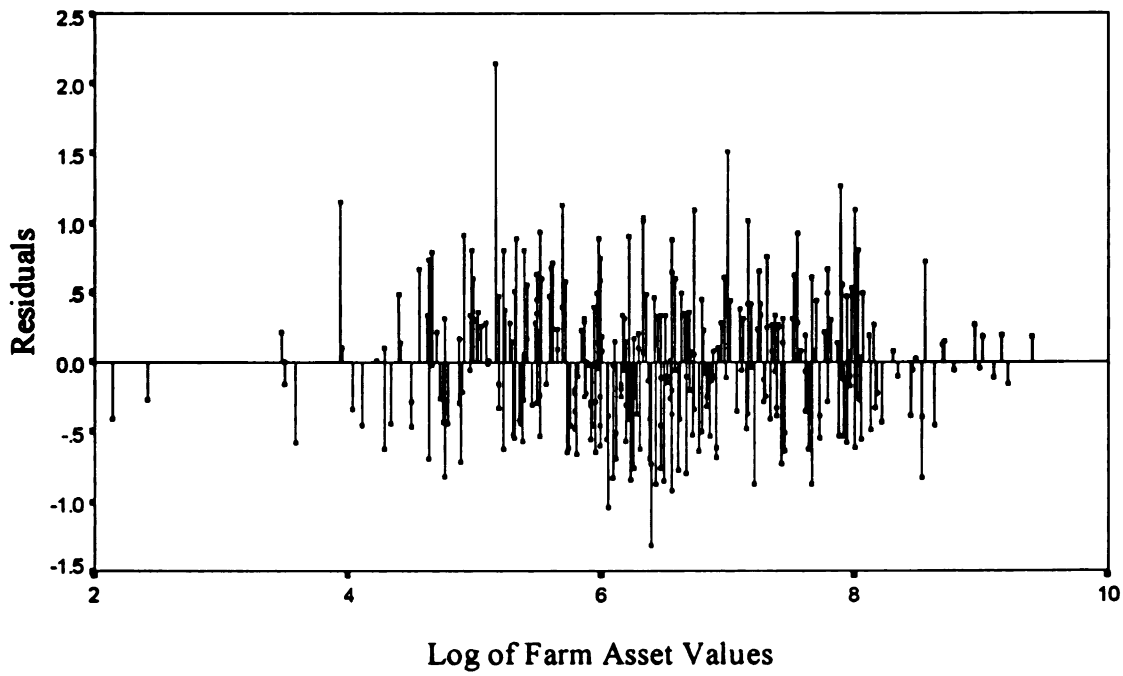

Figure A5: Plot of Residuals on Farm Assets Value, 1989/90

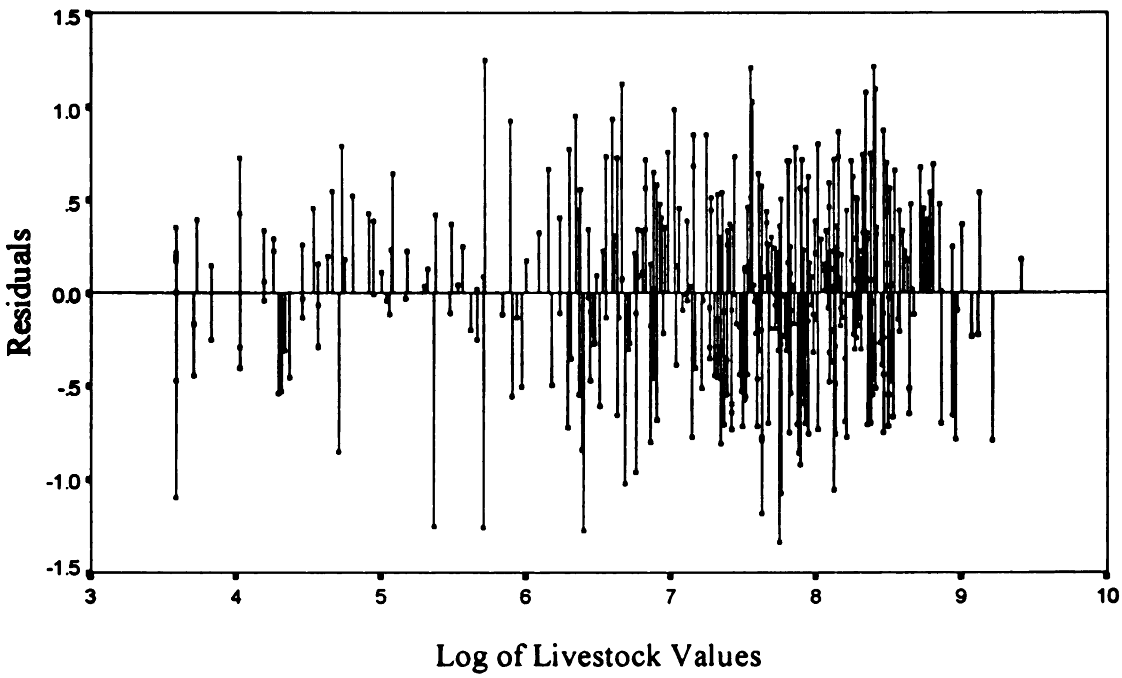

Figure A6: Plot of Residuals on Farm Livestock Value, 1988/89

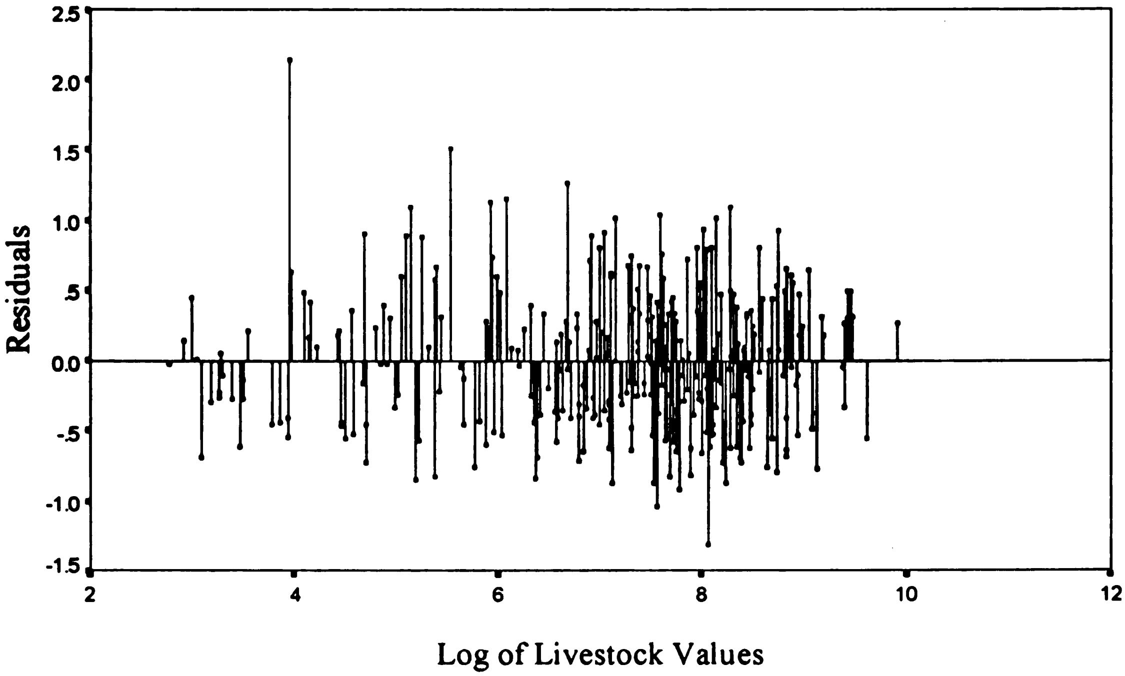

Figure A7: Plot of Residuals on Farm Livestock Value, 1989/90

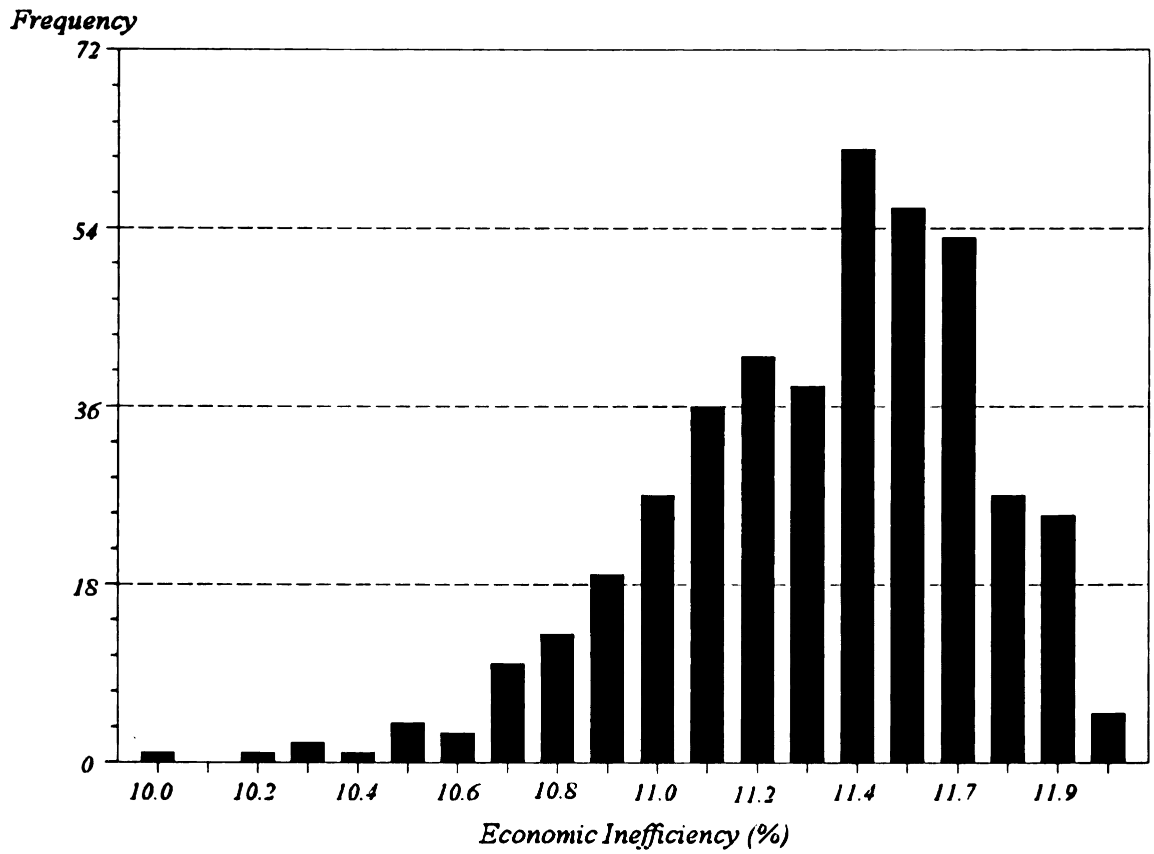

Figure A8: Distribution of Farm-level Economic Inefficiency; Half-Normal Case, 1988/89.

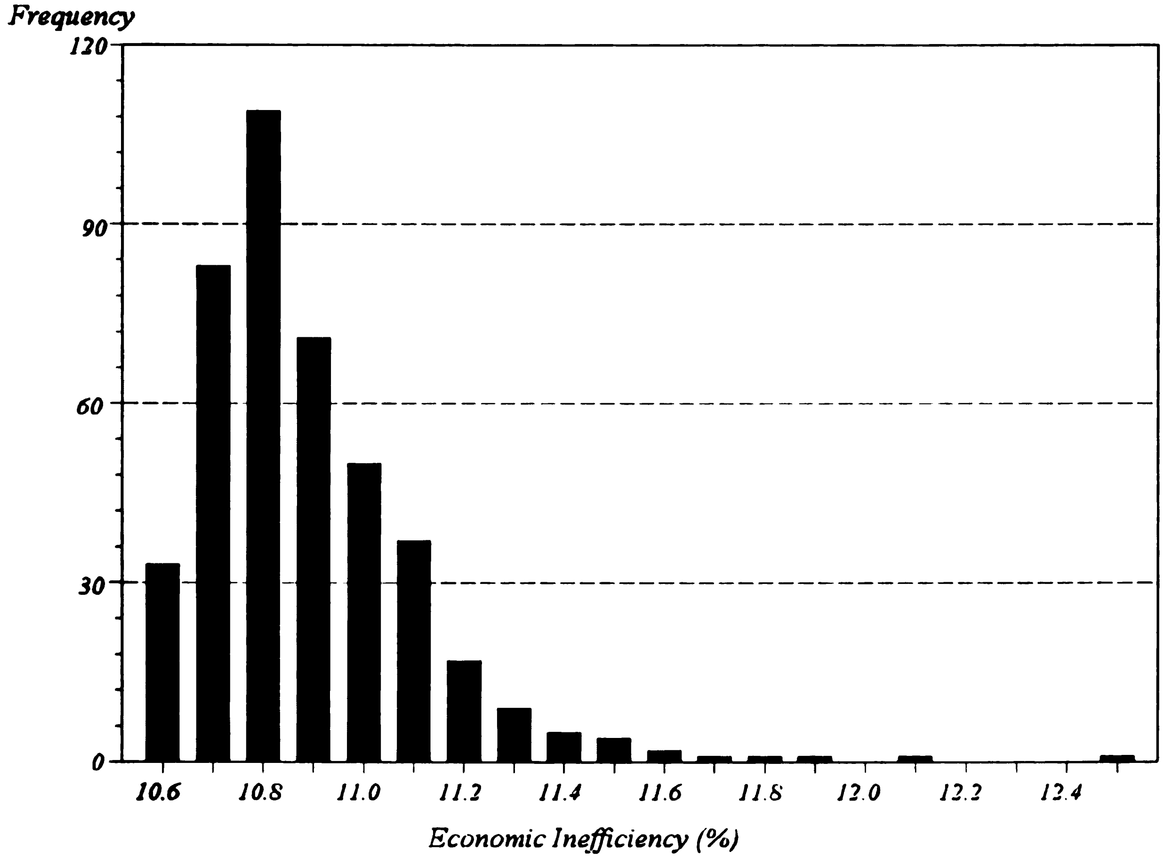

Figure A9: Distribution of Farm-level Economic Inefficiency; Exponential Case, 1988/89.

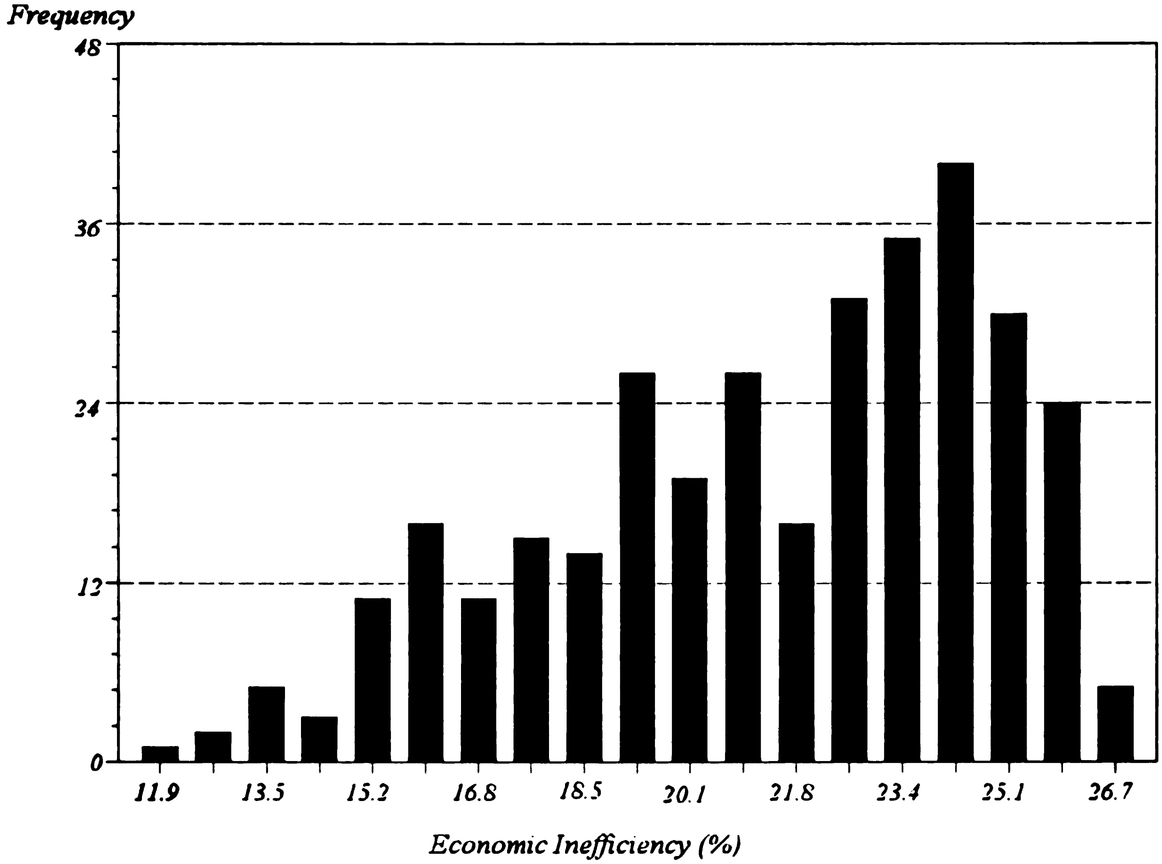

Figure A10: Distribution of Farm-level Economic Inefficiency; Half-Normal Case, 1989/90.

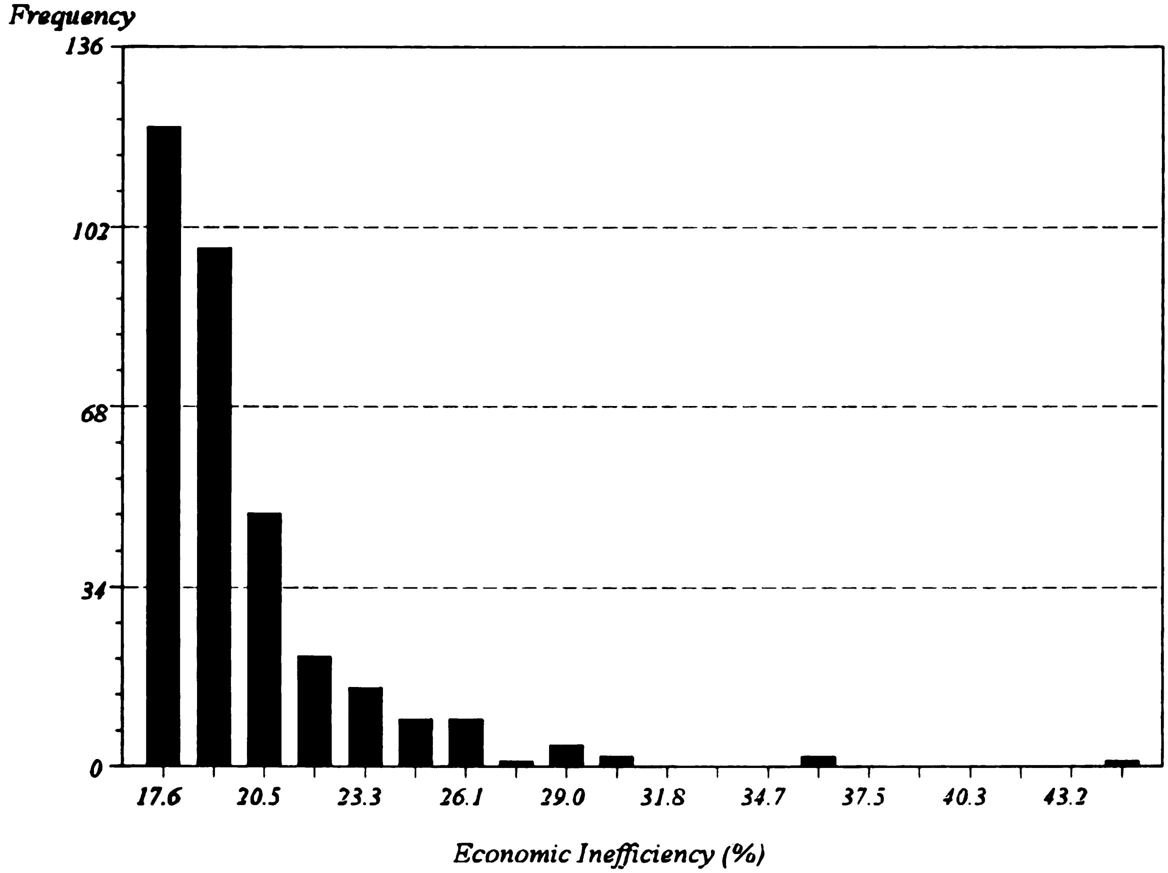

Figure A11: Distribution of Farm-level Economic Inefficiency; Exponential Case, 1989/90.

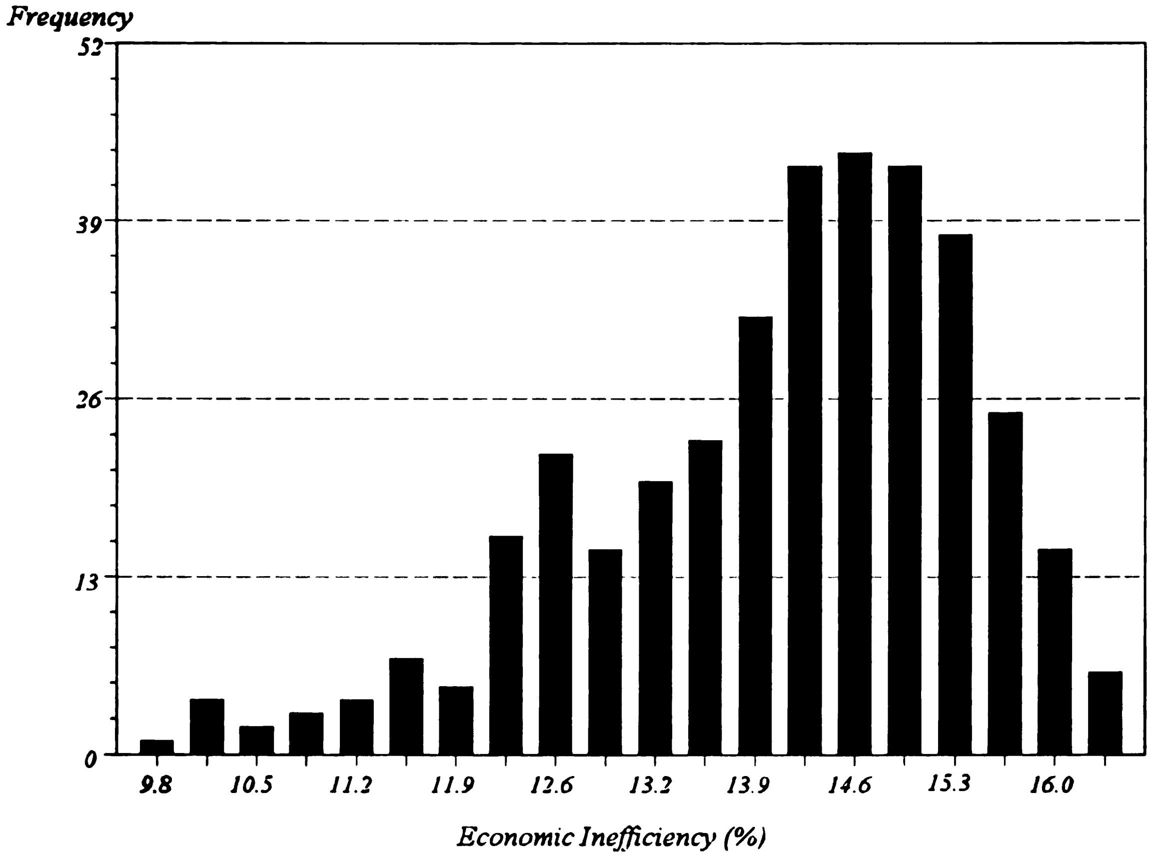

Figure A12: Distribution of Farm-level Economic Inefficiency; Half-Normal Case, 1992/93.

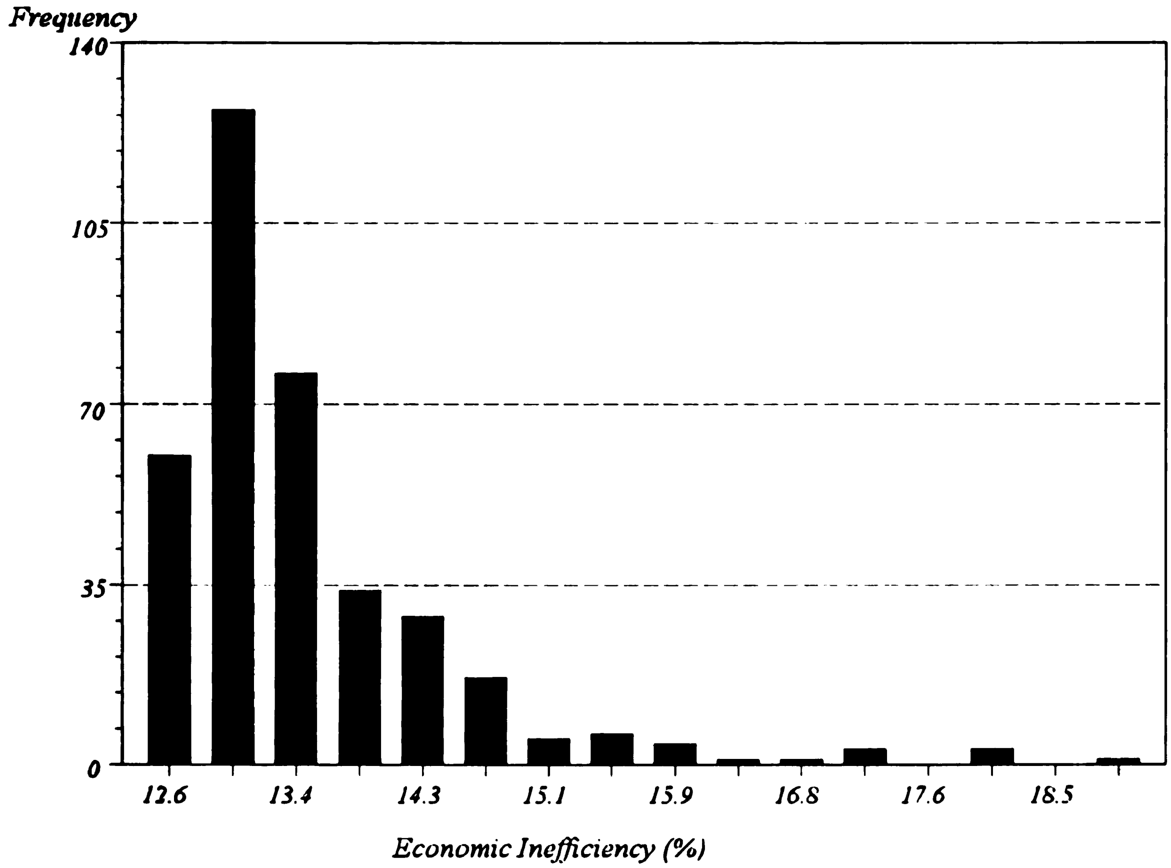

Figure A13: Distribution of Farm-level Economic Inefficiency; Exponential Case, 1992/93.

APPENDIX

A3: TABLES

Table A.1: Distribution of Small-Scale Farming Areas by Natural Regions

Natural Region	I	II	III	IV	V
National Extent (%)	1.8%	13.4%	18.5%	37.4%	26.9%
% Land Cultivated (National)	12.6%	32.7%	20.0%	16.8%	11.2%
SSFA Extent (%)	0.9%	7.8%	17.3%	44.7%	29.3%
% Land Cultivated (SSFA)	38.4%	42.2%	33.1%	23.1%	17.1%
Mean Annual Rainfall (mm)	>1,000	750-1000	650-800	450-650	<450
Reliability of Rainfall	Reliable	Fairly Reliable	Unreliable	Very Unreliable	Erratic and very low rainfall.
Altitude	High	High	Medium-High	Low-Medium	Low river valleys
Recommended Practices	Specialized and diversified farming. Main products: fruits, tea, coffee, and forestry	Intensive farming based on crop and livestock production.	Semi-intensive, crops only on soils of high available moisture, mainly livestock.	Semi-extensive farming systems, very limited drought-tolerant crops as a guideline. Based on livestock production.	Extensive farming systems on *veld* as practiced utilization alone by large-scale commercial farmers, even drought-tolerant crops are difficult to produce.
Actual Practices	Crop and Livestock. Specialized growers around major tea and coffee estates.	Crop and livestock production	Crop and livestock production	Crop and livestock production with high drought risk. Little irrigation practiced.	Crop and livestock production with high drought risk

Source: Chasi and Shamudzarira, 1992.

VARIABLE NAMES (Tables A2-A4 and A6-A11)

Lnntvc	Logarithm of Total Variable Costs
Lnnpl	Logarithm of Labor Price
Lnnms	Logarithm of Maize Seed Price
Lnnls	Logarithm of Legume Seed Price
Lnnss	Logarithm of Small Grains Seed Price
Lnncs	Logarithm of Cash Crop Seed Prices
Lnvm	Logarithm of Maize Output Value
Lnvl	Logarithm of Legume Output Value
Lnvs	Logarithm of Small Grains Output Value
Lnvc	Logarithm of Cash Crop Output Value
Lnta	Logarithm of Total Crop Area
Lnva	Logarithm of Value of Farm Assets
Lnlv	Logarithm of Value of Livestock
Lnplpl	Logarithm of Labor Price * Logarithm of Labor Price
Lnplms	Logarithm of Labor Price * Logarithm of Maize Seed Price
Lnplls	Logarithm of Labor Price * Logarithm of Legume Seed Price
Lnplss	Logarithm of Labor Price * Logarithm of Small Grain Seed Price
Lnplcs	Logarithm of Labor Price * Logarithm of Cash Crop Seed Price
Lnplvm	Logarithm of Labor Price * Logarithm of Maize Output Value
Lnplvl	Logarithm of Labor Price * Logarithm of Legume Output Value
Lnplvs	Logarithm of Labor Price * Logarithm of Small Grains Output Value
Lnplvc	Logarithm of Labor Price * Logarithm of Cash Crop Output Value
Lnplta	Logarithm of Labor Price * Logarithm of Total Crop Area
Lnplva	Logarithm of Labor Price * Logarithm of Farm Asset Value
Lnpllv	Logarithm of Labor Price * Logarithm of Livestock Value
Lnmsms	Logarithm of Maize Seed Price * Logarithm of Maize Seed Price
Lnmsls	Logarithm of Maize Seed Price * Logarithm of Legume Seed Price
Lnmsss	Logarithm of Maize Seed Price * Logarithm of Small Grain Seed Price
Lnmscs	Logarithm of Maize Seed Price * Logarithm of Cash Crop Seed Price
Lnmsvm	Logarithm of Maize Seed Price * Logarithm of Maize Output Value
Lnmsvl	Logarithm of Maize Seed Price * Logarithm of Legume Output Value

Lnmsvs	Logarithm of Maize Seed Price * Logarithm of Small Grains Output Value
Lnmsvc	Logarithm of Maize Seed Price * Logarithm of Cash Crop Output Value
Lnmsta	Logarithm of Maize Seed Price * Logarithm of Total Crop Area
Lnmsva	Logarithm of Maize Seed Price * Logarithm of Farm Asset Value
Lnmslv	Logarithm of Maize Seed Price * Logarithm of Livestock Value
Lnlsls	Logarithm of Legume Seed Price * Logarithm of Legume Seed Price
Lnlsss	Logarithm of Legume Seed Price * Logarithm of Small Grain Seed Price
Lnlscs	Logarithm of Legume Seed Price * Logarithm of Cash Crop Seed Price
Lnlsvm	Logarithm of Legume Seed Price * Logarithm of Maize Output Value
Lnlsvl	Logarithm of Legume Seed Price * Logarithm of Legume Output Value
Lnlsvs	Logarithm of Legume Seed Price * Logarithm of Small Grains Output Value
Lnlsvc	Logarithm of Legume Seed Price * Logarithm of Cash Crop Output Value
Lnlsta	Logarithm of Legume Seed Price * Logarithm of Total Crop Area
Lnlsva	Logarithm of Legume Seed Price * Logarithm of Farm Asset Value
Lnlslv	Logarithm of Legume Seed Price * Logarithm of Livestock Value
Lnssss	Logarithm of Small Grain Seed Price * Logarithm of Small Grain Seed Price
Lnsscs	Logarithm of Small Grain Seed Price * Logarithm of Cash Crop Seed Price
Lnssvm	Logarithm of Small Grain Seed Price * Logarithm of Maize Output Value
Lnssvl	Logarithm of Small Grain Seed Price * Logarithm of Legume Output Value
Lnssvs	Logarithm of Small Grain Seed Price * Logarithm of Small Grains Output Value
Lnssvc	Logarithm of Small Grain Seed Price * Logarithm of Cash Crop Output Value
Lnssta	Logarithm of Small Grain Seed Price * Logarithm of Total Crop Area
Lnssva	Logarithm of Small Grain Seed Price * Logarithm of Farm Asset Value
Lnsslv	Logarithm of Small Grain Seed Price * Logarithm of Livestock Value
Lncscs	Logarithm of Cash Crop Seed Price * Logarithm of Cash Crop Seed Price
Lncsvm	Logarithm of Cash Crop Seed Price * Logarithm of Maize Output Value
Lncsvl	Logarithm of Cash Crop Seed Price * Logarithm of Legume Output Value
Lncsvs	Logarithm of Cash Crop Seed Price * Logarithm of Small Grains Output Value
Lncsvc	Logarithm of Cash Crop Seed Price * Logarithm of Cash Crop Output Value
Lncsta	Logarithm of Cash Crop Seed Price * Logarithm of Total Crop Area
Lncsva	Logarithm of Cash Crop Seed Price * Logarithm of Farm Asset Value
Lncslv	Logarithm of Cash Crop Seed Price * Logarithm of Livestock Value
Lnvmvm	Logarithm of Maize Output Value * Logarithm of Maize Output Value

Lnvmvl	Logarithm of Maize Output Value * Logarithm of Legume Output Value
Lnvmvs	Logarithm of Maize Output Value * Logarithm of Small Grains Output Value
Lnvmvc	Logarithm of Maize Output Value * Logarithm of Cash Crop Output Value
Lnvmta	Logarithm of Maize Output Value * Logarithm of Total Crop Area
Lnvmva	Logarithm of Maize Output Value * Logarithm of Farm Asset Value
Lnvmlv	Logarithm of Maize Output Value * Logarithm of Livestock Value
Lnvlvl	Logarithm of Legume Output Value * Logarithm of Legume Output Value
Lnvlvs	Logarithm of Legume Output Value * Logarithm of Small Grains Output Value
Lnvlvc	Logarithm of Legume Output Value * Logarithm of Cash Crop Output Value
Lnvlta	Logarithm of Legume Output Value * Logarithm of Total Crop Area
Lnvlva	Logarithm of Legume Output Value * Logarithm of Farm Asset Value
Lnvllv	Logarithm of Legume Output Value * Logarithm of Livestock Value
Lnvsvs	Logarithm of Small Grains Output Value * Logarithm of Small Grains Output Value
Lnvsvc	Logarithm of Small Grains Output Value * Logarithm of Cash Crop Output Value
Lnvsta	Logarithm of Small Grains Output Value * Logarithm of Total Crop Area
Lnvsva	Logarithm of Small Grains Output Value * Logarithm of Farm Asset Value
Lnvslv	Logarithm of Small Grains Output Value * Logarithm of Livestock Value
Lnvcvc	Logarithm of Cash Crop Output Value * Logarithm of Cash Crop Output Value
Lnvcta	Logarithm of Cash Crop Output Value * Logarithm of Total Crop Area
Lnvcva	Logarithm of Cash Crop Output Value * Logarithm of Farm Asset Value
Lnvclv	Logarithm of Cash Crop Output Value * Logarithm of Livestock Value
Lntata	Logarithm of Total Crop Area * Logarithm of Total Crop Area
Lntava	Logarithm of Total Crop Area * Logarithm of Farm Asset Value
Lntalv	Logarithm of Total Crop Area * Logarithm of Livestock Value
Lnvava	Logarithm of Farm Asset Value * Logarithm of Farm Asset Value
Lnvalv	Logarithm of Farm Asset Value * Logarithm of Livestock Value
Lnlvlv	Logarithm of Livestock Value * Logarithm of Livestock Value
Lnmyld	Logarithm of Maize Yield (per hectare)
Soildv	Dummy Variable for Soil Type
Naredv	Dummy Variable for Natural Region

Table A2: Cost Function Parameter Estimates, 1988/89

Source	SS	df	MS		
Model	281.767943	92	3.06269503	Number of obs =	425
Residual	76.8721046	332	.231542484	F(92, 332) =	13.23
Total	358.640048	424	.845849169	Prob > F =	0.0000
				R-squared =	0.7857
				Adj R-squared =	0.7263
				Root MSE =	.48119

lnntvc	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnnpl	2.181935	1.876374	1.163	0.246	-1.509145	5.873016
lnnms	.32642	1.708949	0.191	0.849	-3.035313	3.688153
lnnls	1.841902	1.253991	1.469	0.143	-.6248666	4.308671
lnnss	-.1978079	1.825438	-0.108	0.914	-3.788691	3.393076
lnncs	-.3453092	1.247514	-0.277	0.782	-2.799337	2.108719
lnvm	.2375073	.3166138	0.750	0.454	-.3853147	.8603293
lnvl	.2753739	.1603579	1.717	0.087	-.0400717	.5908196
lnvs	.2348941	.1713046	1.371	0.171	-.1020851	.5718733
lnvc	-.1078715	.1594815	-0.676	0.499	-.4215932	.2058502
lnta	1.301403	1.519228	0.857	0.392	-1.687124	4.28993
lnva	-.2465336	.342116	-0.721	0.472	-.9195219	.4264548
lnlv	**-.9414897**	**.3662787**	**-2.570**	**0.011**	**-1.662009**	**-.22097**
lnplpl	.4928374	.7163851	0.688	0.492	-.9163888	1.902064
lnplms	.5713693	1.439168	0.397	0.692	-2.259668	3.402406
lnplls	-1.112583	1.29843	-0.857	0.392	-3.666771	1.441605
lnplss	-.280558	1.588426	-0.177	0.860	-3.405206	2.84409
lnplcs	-.0766641	.8536051	-0.090	0.928	-1.755821	1.602492
lnplvm	-.1356581	.1219556	-1.112	0.267	-.3755613	.1042451
lnplvl	-.064935	.0699666	-0.928	0.354	-.2025687	.0726988
lnplvs	.0879258	.0636784	1.381	0.168	-.0373383	.2131899
lnplvc	.0960029	.0770975	1.245	0.214	-.0556583	.2476641
lnplta	-.0062507	.5570305	-0.011	0.991	-1.102005	1.089504
lnplva	-.1705082	.1083388	-1.574	0.116	-.3836253	.0426088
lnpllv	.1556421	.1229563	1.266	0.206	-.0862295	.3975136
lnmsms	-.2810722	.7042502	-0.399	0.690	-1.666427	1.104283
lnmsls	-1.435706	1.409949	-1.018	0.309	-4.209267	1.337855
lnmsss	-1.325868	1.443191	-0.919	0.359	-4.164818	1.513083
lnmscs	.163998	1.046098	0.157	0.876	-1.893817	2.221813
lnmsvm	-.0247498	.167273	-0.148	0.882	-.3537983	.3042988
lnmsvl	-.0333283	.0805488	-0.414	0.679	-.1917787	.1251221
lnmsvs	-.0948619	.0775081	-1.224	0.222	-.2473308	.0576069
lnmsvc	.0260666	.0890902	0.293	0.770	-.1491858	.201319
lnmsta	.1846572	.7228257	0.255	0.799	-1.237239	1.606553
lnmsva	.1462234	.1323523	1.105	0.270	-.1141315	.4065784
lnmslv	.10494	.1568918	0.669	0.504	-.2036873	.4135673
lnlsls	-.6999541	.4353748	-1.608	0.109	-1.556395	.156487
lnlsss	-.4132391	1.218865	-0.339	0.735	-2.810911	1.984433
lnlscs	-.4675326	1.172373	-0.399	0.690	-2.773749	1.838684
lnlsvm	**.2330831**	**.0995754**	**2.341**	**0.020**	**.0372048**	**.4289614**
lnlsvl	.0461964	.0600599	0.769	0.442	-.0719496	.1643424
lnlsvs	.032191	.053128	0.606	0.545	-.072319	.136701

Table A2: Cost Function Parameter Estimates, 1988/89; Cont.

lnntvc	**Coef.**	**Std. Err.**	**t**	**P>|t|**	**[95% Conf.**	**Interval]**
lnlsvc	-.0353689	.0677167	-0.522	0.602	-.1685767	.0978389
lnlsta	.2274562	.3684577	0.617	0.537	-.4973498	.9522623
lnlsva	.0043063	.0839675	0.051	0.959	-.1608691	.1694817
lnlslv	-.1322264	.0982885	-1.345	0.179	-.3255731	.0611203
lnssss	-.8773263	1.004936	-0.873	0.383	-2.854171	1.099518
lnsscs	**2.781**	**1.238367**	**2.246**	**0.025**	**.3449651**	**5.217036**
lnssvm	-.0265365	.1338814	-0.198	0.843	-.2898993	.2368263
lnssvl	-.0609989	.0638254	-0.956	0.340	-.186552	.0645543
lnssvs	-.0298169	.0765842	-0.389	0.697	-.1804684	.1208346
lnssvc	-.0386804	.0772922	-0.500	0.617	-.1907245	.1133638
lnssta	-.4685351	.6172766	-0.759	0.448	-1.682802	.7457314
lnssva	.1270251	.1272372	0.998	0.319	-.1232678	.3773179
lnsslv	.1274581	.1404135	0.908	0.365	-.1487541	.4036703
lncscs	.0210311	.1201704	0.175	0.861	-.2153604	.2574226
lncsvm	-.0991596	.0889305	-1.115	0.266	-.2740979	.0757788
lncsvl	.0335114	.0454315	0.738	0.461	-.0558586	.1228813
lncsvs	-.0399392	.0388103	-1.029	0.304	-.1162844	.036406
lncsvc	.0124298	.0395662	0.314	0.754	-.0654022	.0902618
lncsta	-.4432274	.4405551	-1.006	0.315	-1.309859	.4234038
lncsva	-.1032881	.0786219	-1.314	0.190	-.257948	.0513719
lncslv	.122084	.0848856	1.438	0.151	-.0448975	.2890654
lnvmvm	.0036215	.0224437	0.161	0.872	-.0405284	.0477713
lnvmvl	**-.0255003**	**.0109565**	**-2.327**	**0.021**	**-.0470532**	**-.0039474**
lnvmvs	.0086399	.0105224	0.821	0.412	-.0120591	.029339
lnvmvc	-.0042758	.015292	-0.280	0.780	-.0343571	.0258056
lnvmta	-.1187173	.0966813	-1.228	0.220	-.3089025	.0714679
lnvmva	-.0085343	.0189474	-0.450	0.653	-.0458063	.0287377
lnvmlv	-.0059888	.0184947	-0.324	0.746	-.0423703	.0303927
lnvlvl	**.032456**	**.013815**	**2.349**	**0.019**	**.00528**	**.0596321**
lnvlvs	-.0078824	.005934	-1.328	0.185	-.0195554	.0037906
lnvlvc	.0025828	.0061715	0.419	0.676	-.0095573	.0147229
lnvlta	-.0043365	.0548101	-0.079	0.937	-.1121553	.1034823
lnvlva	-.0102527	.0090707	-1.130	0.259	-.0280959	.0075906
lnvllv	-.0001593	.010569	-0.015	0.988	-.02095	.0206315
lnvsvs	**.0620153**	**.018722**	**3.312**	**0.001**	**.0251866**	**.098844**
lnvsvc	**-.0182048**	**.0067742**	**-2.687**	**0.008**	**-.0315307**	**-.004879**
lnvsta	-.0719635	.0532357	-1.352	0.177	-.1766854	.0327584
lnvsva	-.0101671	.0109954	-0.925	0.356	-.0317967	.0114624
lnvslv	-.0106479	.0119428	-0.892	0.373	-.034141	.0128452
lnvcvc	**.0483224**	**.017032**	**2.837**	**0.005**	**.0148181**	**.0818267**
lnvcta	.0085238	.0564768	0.151	0.880	-.1025736	.1196212
lnvcva	-.0046636	.011541	-0.404	0.686	-.0273664	.0180392
lnvclv	.0101124	.0143769	0.703	0.482	-.018169	.0383938
lntata	-.2651539	.6034283	-0.439	0.661	-1.452179	.9218711
lntava	.0225956	.0821455	0.275	0.783	-.1389957	.1841869
lntalv	.1698425	.104068	1.632	0.104	-.0348733	.3745584
lnvava	-.0043682	.0283801	-0.154	0.878	-.0601957	.0514593
lnvalv	**.0440943**	**.01937**	**2.276**	**0.023**	**.0059909**	**.0821977**
lnlvlv	.0257843	.0335216	0.769	0.442	-.0401572	.0917259
lnmyld	**.2417465**	**.0916578**	**2.637**	**0.009**	**.0614432**	**.4220498**
naredv	-.1197627	.0943709	-1.269	0.205	-.305403	.0658775
_cons	4.700692	2.921266	1.609	0.109	-1.045832	10.44722

Table A3: Cost Function Parameter Estimates, 1989/90

Source	SS	df	MS
Model	163.350063	92	1.77554416
Residual	52.8250064	238	.221953808
Total	216.175069	330	.655075967

Number of obs =	331
F(92, 238) =	8.00
Prob > F =	0.0000
R-squared =	0.7556
Adj R-squared =	0.6612
Root MSE =	.47112

lnntvc	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnnpl	1.202693	2.538294	0.474	0.636	-3.797699	6.203086
lnnms	**-14.62855**	**5.37043**	**-2.724**	**0.007**	**-25.2082**	**-4.048905**
lnnls	5.39497	6.095133	0.885	0.377	-6.612329	17.40227
lnnss	9.089892	8.085755	1.124	0.262	-6.838895	25.01868
lnncs	2.946817	2.14524	1.374	0.171	-1.279265	7.1729
lnvm	-.3934095	.4357339	-0.903	0.368	-1.251797	.4649782
lnvl	.1855843	.2651913	0.700	0.485	-.3368377	.7080063
lnvs	**.9271844**	**.322376**	**2.876**	**0.004**	**.2921095**	**1.562259**
lnvc	.3618935	.3220547	1.124	0.262	-.2725483	.9963353
lnta	**-4.446299**	**1.410127**	**-3.153**	**0.002**	**-7.224224**	**-1.668374**
lnva	.057471	.6648002	0.086	0.931	-1.252173	1.367115
lnlv	-.5566243	.5338295	-1.043	0.298	-1.608258	.4950098
lnplpl	**-2.148327**	**.675764**	**-3.179**	**0.002**	**-3.479569**	**-.8170844**
lnplms	1.391912	1.414696	0.984	0.326	-1.395012	4.178836
lnplls	-.6479844	1.544934	-0.419	0.675	-3.691476	2.395507
lnplss	.9792789	1.804431	0.543	0.588	-2.575418	4.533975
lnplcs	.4177538	.4698497	0.889	0.375	-.5078414	1.343349
lnplvm	-.1564965	.0904241	-1.731	0.085	-.3346303	.0216372
lnplvl	.0529845	.0695169	0.762	0.447	-.0839625	.1899316
lnplvs	**-.1298038**	**.0665668**	**-1.950**	**0.052**	**-.2609391**	**.0013315**
lnplvc	-.1251304	.0670772	-1.865	0.063	-.2572713	.0070105
lnplta	**.7261927**	**.3321205**	**2.187**	**0.030**	**.0719215**	**1.380464**
lnplva	-.1322473	.1242058	-1.065	0.288	-.3769304	.1124358
lnpllv	.0520916	.1221693	0.426	0.670	-.1885796	.2927628
lnmsms	**4.543392**	**1.750686**	**2.595**	**0.010**	**1.094573**	**7.992211**
lnmsls	.161141	4.687577	0.034	0.973	-9.0733	9.395582
lnmsss	.5426468	3.675511	0.148	0.883	-6.698042	7.783336
lnmscs	.1781339	.9871572	0.180	0.857	-1.766547	2.122815
lnmsvm	**.4598778**	**.231185**	**1.989**	**0.048**	**.0044476**	**.915308**
lnmsvl	-.2078598	.146235	-1.421	0.157	-.4959401	.0802204
lnmsvs	.0124977	.1518466	0.082	0.934	-.2866372	.3116326
lnmsvc	.0950556	.1585101	0.600	0.549	-.2172064	.4073176
lnmsta	.7963968	.6330115	1.258	0.210	-.4506241	2.043418
lnmsva	.2945237	.2861697	1.029	0.304	-.2692253	.8582727
lnmslv	.2496788	.236321	1.057	0.292	-.2158693	.7152269
lnlsls	.4043474	2.862709	0.141	0.888	-5.235137	6.043831
lnlsss	-2.540515	5.58096	-0.455	0.649	-13.5349	8.453872
lnlscs	-1.379248	1.447098	-0.953	0.341	-4.230004	1.471508
lnlsvm	-.1126675	.2314556	-0.487	0.627	-.5686307	.3432957
lnlsvl	.0728604	.1424487	0.511	0.609	-.2077609	.3534818
lnlsvs	-.2297092	.2489734	-0.923	0.357	-.7201823	.2607638

Table A3: Cost Function Parameter Estimates, 1989/90; Cont.

lnntvc	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnlsvc	-.1253353	.1728307	-0.725	0.469	-.4658085	.2151379
lnlsta	.5812628	.9832944	0.591	0.555	-1.355809	2.518335
lnlsva	.129506	.3463019	0.374	0.709	-.5527023	.8117142
lnlslv	-.2746906	.2492875	-1.102	0.272	-.7657824	.2164012
lnssss	-6.799468	4.12991	-1.646	0.101	-14.93531	1.336379
lnsscs	-1.342388	1.787939	-0.751	0.454	-4.864595	2.179819
lnssvm	.1116485	.3421449	0.326	0.744	-.5623705	.7856676
lnssvl	.0029353	.1833645	0.016	0.987	-.3582894	.36416
lnssvs	**-.4828878**	**.2272007**	**-2.125**	**0.035**	**-.930469**	**-.0353066**
lnssvc	-.1016463	.1987065	-0.512	0.609	-.4930944	.2898018
lnssta	**2.675578**	**1.064143**	**2.514**	**0.013**	**.5792365**	**4.77192**
lnssva	-.4549504	.4136745	-1.100	0.273	-1.269881	.3599806
lnsslv	.2443025	.3691593	0.662	0.509	-.4829345	.9715395
lncscs	-.0836028	.5714187	-0.146	0.884	-1.209287	1.042081
lncsvm	-.1042513	.0706205	-1.476	0.141	-.2433723	.0348698
lncsvl	.0123016	.0570347	0.216	0.829	-.1000556	.1246589
lncsvs	.0735846	.0677236	1.087	0.278	-.0598296	.2069988
lncsvc	.070232	.0547382	1.283	0.201	-.0376013	.1780652
lncsta	-.2793334	.3554489	-0.786	0.433	-.9795611	.4208942
lncsva	.0134336	.1082024	0.124	0.901	-.1997232	.2265904
lncslv	-.0041358	.0788617	-0.052	0.958	-.1594919	.1512204
lnvmvm	**.1172194**	**.0271108**	**4.324**	**0.000**	**.0638115**	**.1706273**
lnvmvl	-.0261498	.0148381	-1.762	0.079	-.0553806	.0030811
lnvmvs	-.0153507	.0120771	-1.271	0.205	-.0391423	.008441
lnvmvc	**-.0533866**	**.0163154**	**-3.272**	**0.001**	**-.0855275**	**-.0212456**
lnvmta	-.0109863	.0500879	-0.219	0.827	-.1096584	.0876859
lnvmva	**-.0500821**	**.0211264**	**-2.371**	**0.019**	**-.0917007**	**-.0084636**
lnvmlv	.0171595	.0145297	1.181	0.239	-.0114637	.0457826
lnvlvl	**.059724**	**.0188591**	**3.167**	**0.002**	**.022572**	**.096876**
lnvlvs	-.0075347	.007738	-0.974	0.331	-.0227784	.0077089
lnvlvc	.0016778	.0084253	0.199	0.842	-.0149198	.0182754
lnvlta	.0228468	.0351981	0.649	0.517	-.0464928	.0921864
lnvlva	.0117911	.0153529	0.768	0.443	-.0184538	.0420361
lnvllv	-.012975	.0126127	-1.029	0.305	-.0378219	.0118718
lnvsvs	-.0378805	.0263479	-1.438	0.152	-.0897855	.0140244
lnvsvc	-.0037913	.0078067	-0.486	0.628	-.0191703	.0115877
lnvsta	.0687325	.0391645	1.755	0.081	-.0084208	.1458858
lnvsva	-.003433	.0160604	-0.214	0.831	-.0350718	.0282058
lnvslv	.0142546	.0152231	0.936	0.350	-.0157347	.0442439
lnvcvc	**.0599644**	**.027669**	**2.167**	**0.031**	**.0054569**	**.1144718**
lnvcta	-.0658737	.0442775	-1.488	0.138	-.1530995	.0213521
lnvcva	.0145258	.0171449	0.847	0.398	-.0192493	.0483009
lnvclv	-.0002904	.0136466	-0.021	0.983	-.0271738	.0265931
lntata	-.2057172	.2666095	-0.772	0.441	-.730933	.3194986
lntava	-.0171117	.0849263	-0.201	0.840	-.1844149	.1501916
lntalv	-.038378	.065963	-0.582	0.561	-.168324	.0915679
lnvava	.049942	.0438982	1.138	0.256	-.0365367	.1364206
lnvalv	-.0076695	.0324114	-0.237	0.813	-.0715194	.0561805
lnlvlv	.0463611	.0362729	1.278	0.202	-.0250957	.117818
soildv	.0258822	.026022	0.995	0.321	-.0253807	.0771451
naredv	**.4220394**	**.1947231**	**2.167**	**0.031**	**.0384385**	**.8056402**
_cons	8.917189	6.707242	1.329	0.185	-4.295954	22.13033

Table A4: Cost Function Parameter Estimates, 1992/93

Source	SS	df	MS
Model	334.96306	67	4.99944866
Residual	38.7163969	300	.129054656
Total	373.679457	367	1.01820016

Number of obs	= 368
F(67, 300)	= 38.74
Prob > F	= 0.0000
R-squared	= 0.8964
Adj R-squared	= 0.8733
Root MSE	= .35924

lnntvc	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnnpl	**1.827252**	**.560909**	**3.258**	**0.001**	**.7234372**	**2.931066**
lnnms	.3862968	.3885023	0.994	0.321	-.3782379	1.150832
lnnls	-.2555809	.4157097	-0.615	0.539	-1.073657	.5624955
lnnss	.0618437	.6819459	0.091	0.928	-1.28016	1.403847
lnncs	.6278361	.4469642	1.405	0.161	-.2517461	1.507418
lnvm	.1070234	.1028707	1.040	0.299	-.0954162	.309463
lnvl	.0113246	.0775311	0.146	0.884	-.1412491	.1638982
lnvs	**.1766903**	**.0712737**	**2.479**	**0.014**	**.0364305**	**.31695**
lnvc	-.0490335	.0941514	-0.521	0.603	-.2343143	.1362473
lnta	**2.741386**	**.4520063**	**6.065**	**0.000**	**1.851881**	**3.63089**
lnplpl	-.1027808	.1442423	-0.713	0.477	-.3866357	.1810741
lnplms	-.1283844	.1011693	-1.269	0.205	-.3274757	.0707069
lnplls	-.0170987	.111635	-0.153	0.878	-.2367856	.2025882
lnplss	.1738935	.2044089	0.851	0.396	-.2283634	.5761504
lnplcs	-.1456388	.162008	-0.899	0.369	-.4644549	.1731772
lnplvm	-.0220948	.0677983	-0.326	0.745	-.1555153	.1113258
lnplvl	**.0563623**	**.0215182**	**2.619**	**0.009**	**.0140165**	**.0987082**
lnplvs	-.0171901	.0295818	-0.581	0.562	-.0754042	.041024
lnplvc	.0195656	.0252926	0.774	0.440	-.0302078	.0693389
lnplta	-.1217912	.199872	-0.609	0.543	-.5151198	.2715375
lnmsms	.2738252	.1573819	1.740	0.083	-.0358871	.5835375
lnmsls	-.049289	.091957	-0.536	0.592	-.2302515	.1316736
lnmsss	.0533736	.1247252	0.428	0.669	-.1920735	.2988206
lnmscs	-.089509	.118636	-0.754	0.451	-.322973	.1439551
lnmsvm	-.0423044	.0474763	-0.891	0.374	-.1357333	.0511244
lnmsvl	-.0166178	.0162461	-1.023	0.307	-.0485886	.0153529
lnmsvs	**.0409057**	**.0180293**	**2.269**	**0.024**	**.0054258**	**.0763856**
lnmsvc	-.0081391	.0185343	-0.439	0.661	-.0446127	.0283345
lnmsta	-.1899358	.1355995	-1.401	0.162	-.4567824	.0769108
lnlsls	-.0415439	.1168973	-0.355	0.723	-.2715864	.1884987
lnlsss	-.0356604	.1747543	-0.204	0.838	-.3795599	.3082391
lnlscs	.0455543	.1231488	0.370	0.712	-.1967906	.2878991
lnlsvm	.0327537	.0490417	0.668	0.505	-.0637556	.129263
lnlsvl	.0038648	.0152738	0.253	0.800	-.0261925	.0339221
lnlsvs	-.0119814	.0185338	-0.646	0.518	-.0484541	.0244913
lnlsvc	-.0182276	.0256717	-0.710	0.478	-.068747	.0322919

Table A4: Cost Function Parameter Estimates, 1992/93; Cont.

lnntvc	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnlsta	**.2882071**	**.1489551**	**1.935**	**0.054**	**-.0049221**	**.5813364**
lnssss	-.0004937	.2081956	-0.002	0.998	-.4102024	.4092149
lnsscs	-.0187019	.1579172	-0.118	0.906	-.3294677	.2920638
lnssvm	.0229546	.0780258	0.294	0.769	-.1305926	.1765018
lnssvl	-.0505484	.027704	-1.825	0.069	-.1050672	.0039704
lnssvs	-.046639	.0329268	-1.416	0.158	-.1114358	.0181579
lnssvc	-.0185912	.0281233	-0.661	0.509	-.0739352	.0367527
lnssta	-.1404483	.1868296	-0.752	0.453	-.5081107	.2272142
lncscs	.1012175	.0707728	1.430	0.154	-.0380565	.2404915
lncsvm	**-.1031952**	**.0497309**	**-2.075**	**0.039**	**-.2010607**	**-.0053297**
lncsvl	-.0121678	.019923	-0.611	0.542	-.0513744	.0270388
lncsvs	.0380602	.0262543	1.450	0.148	-.0136056	.089726
lncsvc	**.0270311**	**.0112711**	**2.398**	**0.017**	**.0048506**	**.0492116**
lncsta	.0804236	.1753737	0.459	0.647	-.2646948	.4255419
lnvmvm	**.045051**	**.0187918**	**2.397**	**0.017**	**.0080707**	**.0820314**
lnvmvl	.0005212	.0103431	0.050	0.960	-.019833	.0208754
lnvmvs	**-.0186616**	**.0083746**	**-2.228**	**0.027**	**-.0351419**	**-.0021812**
lnvmvc	.0008506	.0105827	0.080	0.936	-.0199751	.0216763
lnvmta	**-.1392231**	**.060189**	**-2.313**	**0.021**	**-.2576692**	**-.020777**
lnvlvl	**.0406757**	**.0123428**	**3.295**	**0.001**	**.0163862**	**.0649652**
lnvlvs	-.0047385	.0037059	-1.279	0.202	-.0120314	.0025544
lnvlvc	-.0010041	.0033728	-0.298	0.766	-.0076414	.0056333
lnvlta	-.0367877	.0288515	-1.275	0.203	-.0935646	.0199892
lnvsvs	.007991	.010888	0.734	0.464	-.0134354	.0294175
lnvsvc	**.0125826**	**.0042362**	**2.970**	**0.003**	**.0042461**	**.0209191**
lnvsta	-.0625456	.0325369	-1.922	0.056	-.1265752	.0014839
lnvcvc	.0217	.0120156	1.806	0.072	-.0019455	.0453454
lnvcta	-.0299407	.033284	-0.900	0.369	-.0954404	.035559
lntata	-.2934997	.3249412	-0.903	0.367	-.9329525	.345953
lnmzyld	**.2652344**	**.0599377**	**4.425**	**0.000**	**.1472828**	**.383186**
naredv	-.1018572	.0679297	-1.499	0.135	-.2355362	.0318218
_cons	**1.381531**	**.6713047**	**2.058**	**0.040**	**.0604689**	**2.702594**

Table A5: Correlation Coefficients for Selected Variables

Variable Pairs		1988/89	1989/90	1992/93
Area vs Output:	Maize Area*Value of maize	0.47	0.16	0.43
	Legume Area*Value of Legumes	0.65	0.53	0.69
	Small Grain Area*Small Grains Value	0.70	0.70	0.72
	Cash Crop Area*Cash Crop Value	**0.80**	0.64	**0.82**
Area vs Area:	Legume Area*Maize Area	0.13	0.49	0.25
	Legume Area*Small Grain Area	0.52	0.38	0.14
	Maize Area*Cash Crop Area	0.36	0.22	0.40
Prices:	Small Grains Seed Price*Labor Price	0.38	0.32	0.74
	Small Grains Seed Price*Maize Seed Price	0.53	0.26	0.43
	Small Grains Seed Price*Legume Seed Price	0.47	0.33	0.63
	Small Grains Seed Price*Cash Crop Seed	0.24	0.32	0.52
	Legume Seed Price*Labor Price	0.20	0.23	0.66
	Legume Seed Price*Maize Seed Price	0.43	0.30	0.28
	Legume Seed Price*Cash Crop Seed Price	0.21	0.18	0.44
	Maize Seed Price*Cash Crop Seed Price	0.40	0.20	0.18
	Cash Crop Seed Price*Labor Price	0.26	0.63	0.49
Area vs Prices:	Small Grains Area*Labor Price	0.05	-0.43	0.01
	Small Grain Area*Cash Crop Seed Price	0.17	-0.42	-0.13
Others:	Maize Value*Cash Crop Value	0.41	0.25	0.25
	Small Grain Value*Labor Price	0.04	-0.43	0.03
	Small Grain Value*Cash Crop Seed	0.25	-0.43	-0.18
	Livestock Value*Farm Assets Value	0.23	0.51	na

Note: The two ρ-values ≥ 0.8 are bolded. na = not available.

Table A6: Cost Frontier Parameter Estimates (Normal), 1988/89

```
| Limited Dependent Variable Model - FRONTIER |
| Maximum Likelihood Estimates                |
| Dependent variable              LNNTVC      |
| Weighting variable                 ONE      |
| Number of observations             425      |
| Iterations completed                 1      |
| LM Stat. at start values      .1958422      |
| LM statistic kept as scalar    LMSTAT       |
| Log likelihood function      -239.6463      |
| Variances: Sigma-squared(v)=     .15929     |
|            Sigma-squared(u)=     .05938     |
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
Constant	4.893544276	3.4337953	1.425	.1541	
LNNPL	2.181983173	2.4065727	.907	.3646	.80323966
LNNMS	.3264582826	2.5551009	.128	.8983	1.1506815
LNNLS	1.842231828	1.7399391	1.059	.2897	1.2757095
LNNSS	-.1980276613	2.2348253	-.089	.9294	1.1731809
LNNCS	-.3444927219	1.5411917	-.224	.8231	1.0593265
LNVM	.2373514274	.34837318	.681	.4957	5.6776400
LNVL	.2752270691	.17616423	1.562	.1182	3.8561645
LNVS	.2348215065	.18665202	1.258	.2084	2.6761662
LNVC	-.1078956901	.17207737	-.627	.5306	1.5420195
LNTA	1.304619173	1.8180294	.718	.4730	1.3768872
LNVA	-.2464832254	.37679493	-.654	.5130	6.9843414
LNLV	**-.9416201250**	**.42490622**	**-2.216**	**.0267****	**7.2387206**
LNPLPL	.4928432807	.81598021	.604	.5459	.35264508
LNPLMS	.5716469600	1.8308136	.312	.7549	.47413023
LNPLLS	-1.112870780	1.5030105	-.740	.4590	.52011633
LNPLSS	-.2803768953	2.0986495	-.134	.8937	.48300873
LNPLCS	-.7687189600E-01	.82368682	-.093	.9256	.44125415
LNPLVM	-.1355962113	.13982783	-.970	.3322	4.5397799
LNPLVL	-.6492315483E-01	.70224913E-01	-.925	.3552	3.1599528
LNPLVS	.8793910786E-01	.76223743E-01	1.154	.2486	2.1743363
LNPLVC	.9599041531E-01	.82156302E-01	1.168	.2427	1.1233033
LNPLTA	-.6627057221E-02	.61698791	-.011	.9914	1.1045645
LNPLVA	-.1705106307	.12000435	-1.421	.1554	5.4945124
LNPLLV	.1556508409	.15519951	1.003	.3159	5.7795826
LNMSMS	-.2811024468	1.1026848	-.255	.7988	.69533029
LNMSLS	-1.435700146	1.7832386	-.805	.4208	.75118869
LNMSSS	-1.325669578	2.0255354	-.654	.5128	.69234133
LNMSCS	.1638671609	1.4529255	.113	.9102	.63482545
LNMSVM	-.2469981833E-01	.21640788	-.114	.9091	6.4134497
LNMSVL	-.3330112145E-01	.93746336E-01	-.355	.7224	4.5211933
LNMSVS	-.9484060605E-01	.99271237E-01	-.955	.3394	3.2383088
LNMSVC	.2607265647E-01	.97765582E-01	.267	.7897	1.5378683
LNMSTA	.1839824705	.91554811	.201	.8407	1.5711864
LNMSVA	.1462058492	.15921985	.918	.3585	7.9290467
LNMSLV	.1049926927	.21734019	.483	.6290	8.2586770
LNLSLS	-.7000308309	.54952665	-1.274	.2027	.86196438
LNLSSS	-.4133817472	1.8276461	-.226	.8211	.76679446
LNLSCS	-.4676086955	1.3761356	-.340	.7340	.69123221
LNLSVM	**.2330942678**	**.11414206**	**2.042**	**.0411****	**7.1940733**
LNLSVL	.4621109868E-01	.65161705E-01	.709	.4782	5.0395316
LNLSVS	.3219041278E-01	.70187979E-01	.459	.6465	3.4851812
LNLSVC	-.3538235185E-01	.70375828E-01	-.503	.6151	1.7808488

Table A6: Cost Frontier Parameter Estimates (Normal), 1988/89; Cont.

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
LNLSTA	.2273775403	.45224341	.503	.6151	1.7521162
LNLSVA	.4311442504E-02	.10630259	.041	.9676	8.8511575
LNLSLV	-.1322267101	.12304719	-1.075	.2826	9.1747954
LNSSSS	-.8773549385	1.4579156	-.602	.5473	.72085685
LNSSCS	2.780844230	1.4588899	1.906	.0566*	.63646762
LNSSVM	-.2651320733E-01	.19454247	-.136	.8916	6.6022275
LNSSVL	-.6099576707E-01	.84591178E-01	-.721	.4709	4.5318528
LNSSVS	-.2982070098E-01	.95114637E-01	-.314	.7539	3.1687438
LNSSVC	-.3867654472E-01	.81601355E-01	-.474	.6355	1.6734754
LNSSTA	-.4686571716	.75083500	-.624	.5325	1.6067637
LNSSVA	.1270511741	.15456794	.822	.4111	8.1772232
LNSSLV	.1274686306	.15790916	.807	.4195	8.4663002
LNCSCS	.2099270466E-01	.14047115	.149	.8812	.68022330
LNCSVM	-.9918842473E-01	.10868331	-.913	.3614	5.8871905
LNCSVL	.3351949588E-01	.44108165E-01	.760	.4473	4.3953617
LNCSVS	-.3993180999E-01	.43286984E-01	-.922	.3563	3.1205264
LNCSVC	.1244267938E-01	.42323188E-01	.294	.7688	1.3180145
LNCSTA	-.4434617813	.44677157	-.993	.3209	1.4398880
LNCSVA	-.1033097455	.88659123E-01	-1.165	.2439	7.1770890
LNCSLV	.1220961543	.10538005	1.159	.2466	7.6063538
LNVMVM	.3618022632E-02	.23765312E-01	.152	.8790	17.168468
LNVMVL	**-.2549823674E-01**	**.12658998E-01**	**-2.014**	**.0440****	**21.954498**
LNVMVS	.8641760970E-02	.10953782E-01	.789	.4302	14.482953
LNVMVC	-.4272400601E-02	.16372993E-01	-.261	.7941	10.230055
LNVMTA	-.1187615901	.11025806	-1.077	.2814	7.9468257
LNVMVA	-.8530289904E-02	.21035287E-01	-.406	.6851	39.979292
LNVMLV	-.5982512326E-02	.20300386E-01	-.295	.7682	41.701333
LNVLVL	**.3245371190E-01**	**.14740860E-01**	**2.202**	**.0277****	**10.772224**
LNVLVS	-.7884090660E-02	.57632540E-02	-1.368	.1713	12.442016
LNVLVC	.2582391425E-02	.59542981E-02	.434	.6645	5.5281200
LNVLTA	-.4311669969E-02	.57406599E-01	-.075	.9401	5.6226780
LNVLVA	-.1024877944E-01	.88413892E-02	-1.159	.2464	26.213959
LNVLLV	-.1575229266E-03	.10759790E-01	-.015	.9883	28.396614
LNVSVS	**.6201242574E-01**	**.21837442E-01**	**2.840**	**.0045****	**6.3346163**
LNVSVC	**-.1820376086E-01**	**.72554972E-02**	**-2.509**	**.0121****	**2.6501878**
LNVSTA	-.7193950867E-01	.62550511E-01	-1.150	.2501	3.8566413
LNVSVA	-.1016568374E-01	.11162082E-01	-.911	.3624	18.189565
LNVSLV	-.1064889125E-01	.13316396E-01	-.800	.4239	19.744443
LNVCVC	**.4831972327E-01**	**.15871828E-01**	**3.044**	**.0023****	**4.2986908**
LNVCTA	.8521775292E-02	.62481919E-01	.136	.8915	2.3162624
LNVCVA	-.4661715577E-02	.13219119E-01	-.353	.7244	11.846978
LNVCLV	.1011247294E-01	.16003489E-01	.632	.5275	12.017633
LNTATA	-.2655047518	.68106890	-.390	.6967	.99972989
LNTAVA	.2251275496E-01	.88404666E-01	.255	.7990	9.6564848
LNTAVL	.1697879963	.11428770	1.486	.1374	10.124702
LNVAVA	-.4373806024E-02	.30619464E-01	-.143	.8864	25.464669
LNVALV	.4410238486E-01	.22934632E-01	1.923	.0545*	51.002857
LNLVLV	.2578586366E-01	.33205468E-01	.777	.4374	27.078326
LNMYLD	**.2417886430**	**.99201799E-01**	**2.437**	**.0148****	**2.5989920**
NAREDV	-.1197881190	.10363613	-1.156	.2477	.48235294
	Variance parameters for compound error				
Lambda	.6105714285	1.3013953	.469	.6390	
Sigma	**.4676312961**	**.15708671**	**2.977**	**.0029****	

Table A7: Cost Frontier Parameter Estimates (Normal), 1989/90.

```
| Limited Dependent Variable Model - FRONTIER |
| Maximum Likelihood Estimates                |
| Dependent variable              LNNTVC      |
| Weighting variable                 ONE      |
| Number of observations             331      |
| Iterations completed                 1      |
| LM Stat. at start values     4.674091      |
| LM statistic kept as scalar  LMSTAT        |
| Log likelihood function     -214.0113      |
| Variances: Sigma-squared(v)=     .12644    |
|            Sigma-squared(u)=     .24783    |
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
Constant	.7772335521	6.3785334	.122	.9030	
LNNPL	.5210438104	2.6534721	.196	.8443	.88227558
LNNMS	-6.690481867	5.4033328	-1.238	.2156	1.3461501
LNNLS	-2.966153603	6.7364816	-.440	.6597	1.0946537
LNNSS	**19.18680248**	**9.4817718**	**2.024**	**.0430****	**1.1917822**
LNNCS	1.012341742	2.2277577	.454	.6495	.87544951
LNVM	-.3094579460E-01	.58076913E-01	-.533	.5941	5.1916238
LNVL	**-.1028003032**	**.52401302E-01**	**-1.962**	**.0498****	**3.3436941**
LNVS	.3972262313E-01	.66367035E-01	.599	.5495	2.4289928
LNVC	-.1227581354E-01	.66580990E-01	-.184	.8537	1.2108494
LNTA	-1.969701153	1.2839181	-1.534	.1250	1.3503719
LNVA	-.4310299014	.64216650	-.671	.5021	6.4394190
LNLV	.2408067145	.61138016	.394	.6937	7.1224702
LNPLPL	**-1.467898809**	**.65152898**	**-2.253**	**.0243****	**.44421681**
LNPLMS	.9933825368	1.6117261	.616	.5377	1.1952261
LNPLLS	.3599382788E-01	1.6172621	.022	.9822	.97472234
LNPLSS	.6112676341	1.9704567	.310	.7564	1.0611853
LNPLCS	.1444241103	.48743527	.296	.7670	.85741185
LNPLTA	**.5682847196**	**.29018407**	**1.958**	**.0502****	**1.1531831**
LNPLVA	-.9609940601E-01	.13510063	-.711	.4769	5.7166342
LNPLLV	-.3805862534E-01	.12920669	-.295	.7683	6.2404563
LNMSMS	1.792155066	2.1743747	.824	.4098	.91544618
LNMSLS	4.382639890	5.1525647	.851	.3950	1.4783277
LNMSSS	-5.334549118	4.2774921	-1.247	.2124	1.6075868
LNMSCS	.4608088842	1.1987046	.384	.7007	1.1898211
LNMSTA	.3151551741	.60467220	.521	.6022	1.8096588
LNMSVA	.4671132134	.32227365	1.449	.1472	8.6643952
LNMSLV	.2217408306	.24882709	.891	.3729	9.5547595
LNLSLS	.3112810544	3.1965202	.097	.9224	.60582448
LNLSSS	-1.418344412	6.4771925	-.219	.8267	1.3081353
LNLSCS	-1.274695525	1.6894039	-.755	.4505	.96675937
LNLSTA	.3908017850	1.1458301	.341	.7331	1.4742554
LNLSVA	.7644700964E-01	.44037046	.174	.8622	7.0536661

Table A7: Cost Frontier Parameter Estimates (Normal), 1989/90; Cont.

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
LNLSTA	.5828917791	1.2502375	.466	.6411	1.4742554
LNLSVA	.1313592922	.41945716	.313	.7542	7.0536661
LNLSLV	-.2744981641	.31214573	-.879	.3792	7.7836915
LNSSSS	-6.790416780	4.7474827	-1.430	.1526	.71444207
LNSSCS	-1.343078918	2.2486285	-.597	.5503	1.0553449
LNSSVM	.1108473992	.37142407	.298	.7654	6.1849992
LNSSVL	.3464399774E-02	.20123759	.017	.9863	3.9735414
LNSSVS	**-.4827733890**	**.23115928**	**-2.088**	**.0368****	**2.8560128**
LNSSVC	-.1015097675	.20302900	-.500	.6171	1.4613889
LNSSTA	**2.673631853**	**1.2455863**	**2.146**	**.0318****	**1.6050268**
LNSSVA	-.4537575738	.45778804	-.991	.3216	7.6773717
LNSSLV	.2436891462	.48116575	.506	.6125	8.4697311
LNCSCS	-.8398519409E-01	.77095273	-.109	.9133	.46587571
LNCSVM	-.1043201132	.85380186E-01	-1.222	.2218	4.5742041
LNCSVL	.1213096090E-01	.80583728E-01	.151	.8803	2.8111466
LNCSVS	.7384121734E-01	.10159421	.727	.4673	1.7128804
LNCSVC	.7021557131E-01	.75509990E-01	.930	.3524	1.1680506
LNCSTA	-.2794617518	.43004486	-.650	.5158	1.1189231
LNCSVA	.1347734249E-01	.15083783	.089	.9288	5.6747968
LNCSLV	-.4162864608E-02	.11856165	-.035	.9720	6.1372630
LNVMVM	**.1171707572**	**.31890769E-01**	**3.674**	**.0002****	**15.034542**
LNVMVL	-.2612736678E-01	.15988950E-01	-1.634	.1022*	18.658161
LNVMVS	-.1535455265E-01	.12714494E-01	-1.208	.2272	13.156604
LNVMVC	**-.5339736403E-01**	**.17838732E-01**	**-2.993**	**.0028****	**7.2448809**
LNVMTA	-.1098301642E-01	.52853673E-01	-.208	.8354	7.0971665
LNVMVA	**-.5011451932E-01**	**.22992053E-01**	**-2.180**	**.0293****	**34.048816**
LNVMLV	.1718559580E-01	.14501450E-01	1.185	.2360	37.755287
LNVLVL	**.5962107979E-01**	**.21043313E-01**	**2.833**	**.0046****	**8.3137646**
LNVLVS	-.7526445470E-02	.80267059E-02	-.938	.3484	9.2734422
LNVLVC	.1678094331E-02	.88701116E-02	.189	.8499	5.1565872
LNVLTA	.2289630373E-01	.38803408E-01	.590	.5552	4.9709757
LNVLVA	.1178580592E-01	.15192934E-01	.776	.4379	21.970795
LNVLLV	-.1298801152E-01	.13457597E-01	-.965	.3345	24.610321
LNVSVS	-.3788410000E-01	.27166357E-01	-1.395	.1632	5.7703077
LNVSVC	-.3780957023E-02	.97998630E-02	-.386	.6996	3.5028585
LNVSTA	.6884375275E-01	.38667027E-01	1.780	.0750*	3.8055501
LNVSVA	-.3464481027E-02	.17292436E-01	-.200	.8412	15.558662
LNVSLV	.1424871785E-01	.16862878E-01	.845	.3981	18.204183
LNVCVC	**.6002903737E-01**	**.28057839E-01**	**2.139**	**.0324****	**3.0405703**
LNVCTA	-.6584018253E-01	.52185943E-01	-1.262	.2071	1.9298398
LNVCVA	.1455979709E-01	.20267770E-01	.718	.4725	7.8488264
LNVCLV	-.3000040342E-03	.16152645E-01	-.019	.9852	8.7199356
LNTATA	-.2062284820	.26995003	-.764	.4449	1.0491833
LNTAVA	-.1704889315E-01	.96171312E-01	-.177	.8593	8.8268865
LNTALV	-.3839771417E-01	.75927476E-01	-.506	.6131	9.8744344
LNVAVA	.4989516221E-01	.48209386E-01	1.035	.3007	21.489860
LNVALV	-.7613587438E-02	.30282753E-01	-.251	.8015	46.825796
LNLVLV	.4633078330E-01	.40056964E-01	1.157	.2474	26.539769
NAREDV	**.4219532343**	**.19466332**	**2.168**	**.0302****	**.30815710**
SOILDV	.2586533276E-01	.23680105E-01	1.092	.2747	.44410876
	Variance parameters for compound error				
Lambda	**1.377449627**	**.37731683**	**3.651**	**.0003****	
Sigma	**.5231786230**	**.79397240E-01**	**6.589**	**.0000****	

Table A8: Cost Frontier Parameter Estimates (Normal), 1992/93.

```
| Limited Dependent Variable Model - FRONTIER |
| Maximum Likelihood Estimates                |
| Dependent variable                LNNTVC    |
| Weighting variable                   ONE    |
| Number of observations               368    |
| Iterations completed                   1    |
| LM Stat. at start values        4.012769    |
| LM statistic kept as scalar     LMSTAT      |
| Log likelihood function        -106.6425    |
| Variances: Sigma-squared(v)=      .07063    |
|            Sigma-squared(u)=      .09515    |
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
Constant	1.627588802	1.0290454	1.582	.1137	
LNNPL	**1.826944604**	**.61554564**	**2.968**	**.0030****	**1.7388216**
LNNMS	.3858863009	.44938862	.859	.3905	1.7544106
LNNLS	-.2555987795	.51206082	-.499	.6177	2.4087634
LNNSS	.6238316734E-01	.95436376	.065	.9479	1.9325746
LNNCS	.6278538246	.73049927	.859	.3901	2.2196989
LNVM	.1069955173	.18403930	.581	.5610	7.1497868
LNVL	.1134199332E-01	.80990643E-01	.140	.8886	2.5772566
LNVS	**.1767130073**	**.76529567E-01**	**2.309**	**.0209****	**3.5580386**
LNVC	-.4902568099E-01	.11708982	-.419	.6754	1.8032684
LNTA	**2.741694143**	**.61785318**	**4.437**	**.0000****	**1.2177632**
LNPLPL	-.1027754640	.19958054	-.515	.6066	1.7349561
LNPLMS	-.1283803882	.13317240	-.964	.3350	3.2156495
LNPLLS	-.1708235439E-01	.11963948	-.143	.8865	4.5787074
LNPLSS	.1739499845	.27395870	.635	.5255	3.6779324
LNPLCS	-.1456767491	.20381653	-.715	.4748	4.1173248
LNPLVM	-.2206361393E-01	.76401174E-01	-.289	.7727	12.276423
LNPLVL	**.5636429163E-01**	**.25351088E-01**	**2.223**	**.0262****	**4.1970061**
LNPLVS	-.1718485404E-01	.32826838E-01	-.524	.6006	6.2314152
LNPLVC	.1955703071E-01	.27341206E-01	.715	.4744	2.9012274
LNPLTA	-.1218152085	.23590245	-.516	.6056	2.0627293
LNMSMS	.2739238099	.18403744	1.488	.1366	1.7652662
LNMSLS	-.4922317208E-01	.11280427	-.436	.6626	4.3899015
LNMSSS	.5327312242E-01	.18631819	.286	.7749	3.5756691
LNMSCS	-.8951055778E-01	.15051083	-.595	.5520	3.9873081
LNMSVM	-.4226055304E-01	.52519259E-01	-.805	.4210	12.525402
LNMSVL	-.1662030866E-01	.20101089E-01	-.827	.4083	4.8336116
LNMSVS	**.4090297380E-01**	**.18975457E-01**	**2.156**	**.0311****	**6.4994562**
LNMSVC	-.8135033920E-02	.21109158E-01	-.385	.7000	3.3089376
LNMSTA	-.1899932224	.15913041	-1.194	.2325	2.2211818
LNLSLS	-.4144775329E-01	.14345356	-.289	.7726	3.2874154
LNLSSS	-.3578668376E-01	.23425728	-.153	.8786	5.0346705
LNLSCS	.4555439635E-01	.17466476	.261	.7942	5.6522160
LNLSVM	.3275066490E-01	.63106255E-01	.519	.6038	17.130738

Table A8: Cost Frontier Parameter Estimates (Normal), 1992/93; Cont.

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
LNLSVL	.3858075601E-02	.17920754E-01	.215	.8295	5.7799213
LNLSVS	-.1198368423E-01	.23078430E-01	-.519	.6036	8.7345313
LNLSVC	-.1823903559E-01	.33025323E-01	-.552	.5808	4.6003379
LNLSTA	.2881939328	.18826551	1.531	.1258	2.9281693
LNSSSS	-.4627973547E-03	.41907754	-.001	.9991	2.0720305
LNSSCS	-.1863367650E-01	.23212085	-.080	.9360	4.5477349
LNSSVM	.2288422372E-01	.10033773	.228	.8196	13.768926
LNSSVL	-.5054026240E-01	.36935255E-01	-1.368	.1712	4.7765119
LNSSVS	-.4663176071E-01	.45651631E-01	-1.021	.3070	6.9350380
LNSSVC	-.1857588631E-01	.39256932E-01	-.473	.6361	3.2810114
LNSSTA	-.1403606280	.29947805	-.469	.6393	2.3254654
LNCSCS	.1011902080	.10240267	.988	.3231	2.7695815
LNCSVM	-.1031923864	.80967293E-01	-1.274	.2025	15.864477
LNCSVL	-.1216330283E-01	.27416737E-01	-.444	.6573	5.8213300
LNCSVS	.3804696985E-01	.35003574E-01	1.087	.2771	7.5331993
LNCSVC	.2703426776E-01	.14896241E-01	1.815	.0695*	4.1236235
LNCSTA	.8039532208E-01	.23174766	.347	.7287	2.6731814
LNVMVM	**.4506088241E-01**	**.21522671E-01**	**2.094**	**.0363****	**26.352182**
LNVMVL	.5173073996E-03	.11101620E-01	.047	.9628	19.539507
LNVMVS	-.1866329603E-01	.10120471E-01	-1.844	.0652*	25.387309
LNVMVC	.8495437654E-03	.12390089E-01	.069	.9453	13.795925
LNVMTA	-.1392406094	.91887603E-01	-1.515	.1297	8.9188446
LNVLVL	**.4067500287E-01**	**.12408608E-01**	**3.278**	**.0010****	**7.2792272**
LNVLVS	-.4739722696E-02	.39265194E-02	-1.207	.2274	9.3476876
LNVLVC	-.1003527223E-02	.37632005E-02	-.267	.7897	5.5334338
LNVLTA	-.3678220352E-01	.30551572E-01	-1.204	.2286	3.4941215
LNVSVS	.7985421508E-02	.11228736E-01	.711	.4770	9.6837998
LNVSVC	**.1258006710E-01**	**.42519136E-02**	**2.959**	**.0031****	**5.6222526**
LNVSTA	-.6252298038E-01	.33864508E-01	-1.846	.0649*	4.6983002
LNVCVC	.2170191625E-01	.12344899E-01	1.758	.0788*	5.8700932
LNVCTA	-.2993842678E-01	.33525111E-01	-.893	.3718	2.7917639
LNTATA	-.2936388608	.37218142	-.789	.4301	.83817794
LNMZYLD	**.2652325563**	**.62205832E-01**	**4.264**	**.0000****	**2.8355027**
NAREDV	-.1018358194	.76422914E-01	-1.333	.1827	.43478261
	Variance parameters for compound error				
Lambda	1.160691602	.61187706	1.897	.0578*	
Sigma	**.4071648028**	**.59393046E-01**	**6.855**	**.0000****	

Table A9: Cost Frontier Parameter Estimates (Exponential), 1988/89

```
| Limited Dependent Variable Model - FRONTIER |
| Maximum Likelihood Estimates                |
| Dependent variable              LNNTVC      |
| Weighting variable                 ONE      |
| Number of observations             425      |
| Iterations completed                 1      |
| LM Stat. at start values      .1389457      |
| LM statistic kept as scalar   LMSTAT        |
| Log likelihood function      -239.6800      |
| Exponential frontier model                  |
| Variances: Sigma-squared(v)=      .16732    |
|            Sigma-squared(u)=      .01355    |
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
Constant	4.815517570	3.4111612	1.412	.1580	
LNNPL	2.181983173	2.3954090	.911	.3623	.80323966
LNNMS	.3264582826	2.5472688	.128	.8980	1.1506815
LNNLS	1.842231828	1.7374942	1.060	.2890	1.2757095
LNNSS	-.1980276613	2.2233682	-.089	.9290	1.1731809
LNNCS	-.3444927219	1.5357355	-.224	.8225	1.0593265
LNVM	.2373514274	.34676732	.684	.4937	5.6776400
LNVL	.2752270691	.17584309	1.565	.1175	3.8561645
LNVS	.2348215065	.18537877	1.267	.2053	2.6761662
LNVC	-.1078956901	.17159372	-.629	.5295	1.5420195
LNTA	1.304619173	1.8111123	.720	.4713	1.3768872
LNVA	-.2464832254	.37553758	-.656	.5116	6.9843414
LNLV	**-.9416201250**	**.42227158**	**-2.230**	**.0258****	**7.2387206**
LNPLPL	.4928432807	.81272897	.606	.5442	.35264508
LNPLMS	.5716469600	1.8288617	.313	.7546	.47413023
LNPLLS	-1.112870780	1.4998752	-.742	.4581	.52011633
LNPLSS	-.2803768953	2.0890015	-.134	.8932	.48300873
LNPLCS	-.7687189600E-01	.82380024	-.093	.9257	.44125415
LNPLVM	-.1355962113	.13868126	-.978	.3282	4.5397799
LNPLVL	-.6492315483E-01	.70142058E-01	-.926	.3547	3.1599528
LNPLVS	.8793910786E-01	.75861929E-01	1.159	.2464	2.1743363
LNPLVC	.9599041531E-01	.81994305E-01	1.171	.2417	1.1233033
LNPLTA	-.6627057221E-02	.61402897	-.011	.9914	1.1045645
LNPLVA	-.1705106307	.11973370	-1.424	.1544	5.4945124
LNPLLV	.1556508409	.15415090	1.010	.3126	5.7795826
LNMSMS	-.2811024468	1.0912982	-.258	.7967	.69533029
LNMSLS	-1.435700146	1.7757728	-.808	.4188	.75118869
LNMSSS	-1.325669578	2.0230134	-.655	.5123	.69234133
LNMSCS	.1638671609	1.4476762	.113	.9099	.63482545
LNMSVM	-.2469981833E-01	.21603266	-.114	.9090	6.4134497
LNMSVL	-.3330112145E-01	.94282443E-01	-.353	.7239	4.5211933
LNMSVS	-.9484060605E-01	.99596014E-01	-.952	.3410	3.2383088
LNMSVC	.2607265647E-01	.97336013E-01	.268	.7888	1.5378683
LNMSTA	.1839824705	.91168935	.202	.8401	1.5711864
LNMSVA	.1462058492	.15854853	.922	.3564	7.9290467
LNMSLV	.1049926927	.21585487	.486	.6267	8.2586770
LNLSLS	-.7000308309	.54690707	-1.280	.2006	.86196438
LNLSSS	-.4133817472	1.8219619	-.227	.8205	.76679446
LNLSCS	-.4676086955	1.3711002	-.341	.7331	.69123221
LNLSVM	**.2330942678**	**.11467624**	**2.033**	**.0421****	**7.1940733**
LNLSVL	.4621109868E-01	.64972573E-01	.711	.4769	5.0395316
LNLSVS	.3219041278E-01	.70148287E-01	.459	.6463	3.4851812

Table A9: Cost Frontier Parameter Estimates (Exponential), 1988/89; Cont.

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
LNLSVC	-.3538235185E-01	.70101441E-01	-.505	.6137	1.7808488
LNLSTA	.2273775403	.45015007	.505	.6135	1.7521162
LNLSVA	.4311442504E-02	.10598710	.041	.9676	8.8511575
LNLSLV	-.1322267101	.12256044	-1.079	.2806	9.1747954
LNSSSS	-.8773549385	1.4505772	-.605	.5453	.72085685
LNSSCS	2.780844230	1.4540841	1.912	.0558*	.63646762
LNSSVM	-.2651320733E-01	.19356805	-.137	.8911	6.6022275
LNSSVL	-.6099576707E-01	.84270502E-01	-.724	.4692	4.5318528
LNSSVS	-.2982070098E-01	.94730785E-01	-.315	.7529	3.1687438
LNSSVC	-.3867654472E-01	.81338187E-01	-.476	.6344	1.6734754
LNSSTA	-.4686571716	.74803367	-.627	.5310	1.6067637
LNSSVA	.1270511741	.15397522	.825	.4093	8.1772232
LNSSLV	.1274686306	.15718866	.811	.4174	8.4663002
LNCSCS	.2099270466E-01	.14000058	.150	.8808	.68022330
LNCSVM	-.9918842473E-01	.10855207	-.914	.3609	5.8871905
LNCSVL	.3351949588E-01	.43939319E-01	.763	.4455	4.3953617
LNCSVS	-.3993180999E-01	.43293197E-01	-.922	.3563	3.1205264
LNCSVC	.1244267938E-01	.42163792E-01	.295	.7679	1.3180145
LNCSTA	-.4434617813	.44505783	-.996	.3190	1.4398880
LNCSVA	-.1033097455	.88123135E-01	-1.172	.2411	7.1770890
LNCSLV	.1220961543	.10495784	1.163	.2447	7.6063538
LNVMVM	.3618022632E-02	.23681327E-01	.153	.8786	17.168468
LNVMVL	**-.2549823674E-01**	**.12606113E-01**	**-2.023**	**.0431****	**21.954498**
LNVMVS	.8641760970E-02	.10939562E-01	.790	.4296	14.482953
LNVMVC	-.4272400601E-02	.16230414E-01	-.263	.7924	10.230055
LNVMTA	-.1187615901	.10983482	-1.081	.2796	7.9468257
LNVMVA	-.8530289904E-02	.20965336E-01	-.407	.6841	39.979292
LNVMLV	-.5982512326E-02	.20213776E-01	-.296	.7673	41.701333
LNVLVL	**.3245371190E-01**	**.14702261E-01**	**2.207**	**.0273****	**10.772224**
LNVLVS	-.7884090660E-02	.57778321E-02	-1.365	.1724	12.442016
LNVLVC	.2582391425E-02	.59348816E-02	.435	.6635	5.5281200
LNVLTA	-.4311669969E-02	.57148866E-01	-.075	.9399	5.6226780
LNVLVA	-.1024877944E-01	.88139707E-02	-1.163	.2449	26.213959
LNVLLV	-.1575229266E-03	.10735097E-01	-.015	.9883	28.396614
LNVSVS	**.6201242574E-01**	**.21754202E-01**	**2.851**	**.0044****	**6.3346163**
LNVSVC	**-.1820376086E-01**	**.72299261E-02**	**-2.518**	**.0118****	**2.6501878**
LNVSTA	-.7193950867E-01	.62348068E-01	-1.154	.2486	3.8566413
LNVSVA	-.1016568374E-01	.11125237E-01	-.914	.3608	18.189565
LNVSLV	-.1064889125E-01	.13233235E-01	-.805	.4210	19.744443
LNVCVC	**.4831972327E-01**	**.15796826E-01**	**3.059**	**.0022****	**4.2986908**
LNVCTA	.8521775292E-02	.62272348E-01	.137	.8912	2.3162624
LNVCVA	-.4661715577E-02	.13158960E-01	-.354	.7231	11.846978
LNVCLV	.1011247294E-01	.15907020E-01	.636	.5250	12.017633
LNTATA	-.2655047518	.67866134	-.391	.6956	.99972989
LNTAVA	.2251275496E-01	.87898840E-01	.256	.7979	9.6564848
LNTAVL	.1697879963	.11396079	1.490	.1363	10.124702
LNVAVA	-.4373806024E-02	.30476408E-01	-.144	.8859	25.464669
LNVALV	**.4410238486E-01**	**.22682248E-01**	**1.944**	**.0519****	**51.002857**
LNLVLV	.2578586366E-01	.33028987E-01	.781	.4350	27.078326
LNMYLD	**.2417886430**	**.99130070E-01**	**2.439**	**.0147****	**2.5989920**
NAREDV	-.1197881190	.10339076	-1.159	.2466	.48235294
	Variance parameters for compound error				
Theta	8.590372227	18.315128	.469	.6390	
Sigmav	**.4090507191**	**.65196741E-01**	**6.274**	**.0000****	

Table A10: Cost Frontier Parameter Estimates (Exponential), 1989/90

Limited Dependent Variable Model - FRONTIER	
Maximum Likelihood Estimates	
Dependent variable	LNNTVC
Weighting variable	ONE
Number of observations	331
Iterations completed	1
LM Stat. at start values	6.501468
LM statistic kept as scalar	LMSTAT
Log likelihood function	-164.5451
Exponential frontier model	
Variances: Sigma-squared(v)=	.11870
Sigma-squared(u)=	.04090

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
Constant	8.728353212	8.2870870	1.053	.2922	
LNNPL	1.195173504	2.8345563	.422	.6733	.88227558
LNNMS	**-14.64737130**	**6.1796176**	**-2.370**	**.0178****	**1.3461501**
LNNLS	5.348154992	8.2475338	.648	.5167	1.0946537
LNNSS	9.145605495	9.4684551	.966	.3341	1.1917822
LNNCS	2.949294706	2.7485416	1.073	.2833	.87544951
LNVM	-.3915471509	.43552847	-.899	.3686	5.1916238
LNVL	.1844759243	.27023104	.683	.4948	3.3436941
LNVS	**.9275496661**	**.31266273**	**2.967**	**.0030****	**2.4289928**
LNVC	.3613435623	.36165097	.999	.3177	1.2108494
LNTA	**-4.444700967**	**1.4892708**	**-2.984**	**.0028****	**1.3503719**
LNVA	.5517143286E-01	.70008155	.079	.9372	6.4394190
LNLV	-.5572006410	.62133406	-.897	.3698	7.1224702
LNPLPL	**-2.148329038**	**.76940117**	**-2.792**	**.0052****	**.44421681**
LNPLMS	1.395392148	1.8420922	.758	.4487	1.1952261
LNPLLS	-.6558077930	1.7739150	-.370	.7116	.97472234
LNPLSS	.9890554844	2.1935657	.451	.6521	1.0611853
LNPLCS	.4176391935	.57490701	.726	.4676	.85741185
LNPLVM	-.1564474102	.82076860E-01	-1.906	.0566*	4.5698587
LNPLVL	.5300758934E-01	.78873006E-01	.672	.5015	2.8809659
LNPLVS	-.1298936598	.76168718E-01	-1.705	.0881*	1.8034776
LNPLVC	-.1250359879	.82203910E-01	-1.521	.1282	1.0992641
LNPLTA	**.7267371372**	**.32288909**	**2.251**	**.0244****	**1.1531831**
LNPLVA	-.1324007118	.14177467	-.934	.3504	5.7166342
LNPLLV	.5205533096E-01	.14324477	.363	.7163	6.2404563
LNMSMS	**4.535577918**	**2.0932064**	**2.167**	**.0302****	**.91544618**
LNMSLS	.2063299026	5.6972364	.036	.9711	1.4783277
LNMSSS	.5282460132	4.4428317	.119	.9054	1.6075868
LNMSCS	.1733663403	1.6255476	.107	.9151	1.1898211
LNMSVM	.4597363171	.24435079	1.881	.0599*	6.9811986
LNMSVL	-.2073052726	.18287678	-1.134	.2570	4.4672883
LNMSVS	.1225181177E-01	.20712408	.059	.9528	3.2334759
LNMSVC	.9466529399E-01	.19940217	.475	.6350	1.6376282
LNMSTA	.7953529663	.79501241	1.000	.3171	1.8096588
LNMSVA	.2937634298	.36992505	.794	.4271	8.6643952
LNMSLV	.2503738356	.30812137	.813	.4165	9.5547595
LNLSLS	.4320744816	3.4457634	.125	.9002	.60582448
LNLSSS	-2.589362893	6.1145441	-.423	.6719	1.3081353
LNLSCS	-1.373664130	1.8483524	-.743	.4574	.96675937
LNLSVM	-.1130971792	.23542576	-.480	.6309	5.6946340
LNLSVL	.7292086828E-01	.19360356	.377	.7064	3.6291793
LNLSVS	-.2299063679	.27369986	-.840	.4009	2.6301577

Table A10: Cost Frontier Parameter Estimates (Exponential), 1989/90; Cont.

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
LNLSVC	-.1248766448	.28742869	-.434	.6640	1.3314201
LNLSTA	.5828917791	1.2276473	.475	.6349	1.4742554
LNLSVA	.1313592922	.40542361	.324	.7459	7.0536661
LNLSLV	-.2744981641	.29951531	-.916	.3594	7.7836915
LNSSSS	-6.790416780	4.6722604	-1.453	.1461	.71444207
LNSSCS	-1.343078918	2.1937264	-.612	.5404	1.0553449
LNSSVM	.1108473992	.36408508	.304	.7608	6.1849992
LNSSVL	.3464399774E-02	.19628103	.018	.9859	3.9735414
LNSSVS	**-.4827733890**	**.22496563**	**-2.146**	**.0319****	**2.8560128**
LNSSVC	-.1015097675	.19706800	-.515	.6065	1.4613889
LNSSTA	**2.673631853**	**1.2167171**	**2.197**	**.0280****	**1.6050268**
LNSSVA	-.4537575738	.45703790	-.993	.3208	7.6773717
LNSSLV	.2436891462	.46815271	.521	.6027	8.4697311
LNCSCS	-.8398519409E-01	.74802506	-.112	.9106	.46587571
LNCSVM	-.1043201132	.83767788E-01	-1.245	.2130	4.5742041
LNCSVL	.1213096090E-01	.77413479E-01	.157	.8755	2.8111466
LNCSVS	.7384121734E-01	.97556745E-01	.757	.4491	1.7128804
LNCSVC	.7021557131E-01	.72514648E-01	.968	.3329	1.1680506
LNCSTA	-.2794617518	.41888265	-.667	.5047	1.1189231
LNCSVA	.1347734249E-01	.14543915	.093	.9262	5.6747968
LNCSLV	-.4162864608E-02	.11295242	-.037	.9706	6.1372630
LNVMVM	**.1171707572**	**.30954828E-01**	**3.785**	**.0002****	**15.034542**
LNVMVL	-.2612736678E-01	.15540308E-01	-1.681	.0927*	18.658161
LNVMVS	-.1535455265E-01	.12602284E-01	-1.218	.2231	13.156604
LNVMVC	**-.5339736403E-01**	**.17378214E-01**	**-3.073**	**.0021****	**7.2448809**
LNVMTA	-.1098301642E-01	.51227923E-01	-.214	.8302	7.0971665
LNVMVA	**-.5011451932E-01**	**.22791218E-01**	**-2.199**	**.0279****	**34.048816**
LNVMLV	.1718559580E-01	.14419664E-01	1.192	.2333	37.755287
LNVLVL	**.5962107979E-01**	**.20292999E-01**	**2.938**	**.0033****	**8.3137646**
LNVLVS	-.7526445470E-02	.77459270E-02	-.972	.3312	9.2734422
LNVLVC	.1678094331E-02	.85313713E-02	.197	.8441	5.1565872
LNVLTA	.2289630373E-01	.37318747E-01	.614	.5395	4.9709757
LNVLVA	.1178580592E-01	.14910252E-01	.790	.4293	21.970795
LNVLLV	-.1298801152E-01	.13291297E-01	-.977	.3285	24.610321
LNVSVS	-.3788410000E-01	.26433034E-01	-1.433	.1518	5.7703077
LNVSVC	-.3780957023E-02	.94258034E-02	-.401	.6883	3.5028585
LNVSTA	.6884375275E-01	.37729793E-01	1.825	.0681*	3.8055501
LNVSVA	-.3464481027E-02	.16652952E-01	-.208	.8352	15.558662
LNVSLV	.1424871785E-01	.16388681E-01	.869	.3846	18.204183
LNVCVC	**.6002903737E-01**	**.27434197E-01**	**2.188**	**.0287****	**3.0405703**
LNVCTA	-.6584018253E-01	.50131544E-01	-1.313	.1891	1.9298398
LNVCVA	.1455979709E-01	.19631003E-01	.742	.4583	7.8488264
LNVCLV	-.3000040342E-03	.15636141E-01	-.019	.9847	8.7199356
LNTATA	-.2062284820	.26426703	-.780	.4352	1.0491833
LNTAVA	-.1704889315E-01	.95030148E-01	-.179	.8576	8.8268865
LNTALV	-.3839771417E-01	.74856142E-01	-.513	.6080	9.8744344
LNVAVA	.4989516221E-01	.47074227E-01	1.060	.2892	21.489860
LNVALV	-.7613587438E-02	.29968423E-01	-.254	.7995	46.825796
LNLVLV	.4633078330E-01	.38889218E-01	1.191	.2335	26.539769
NAREDV	**.4219532343**	**.19435845**	**2.171**	**.0299****	**.30815710**
SOILDV	.2586533276E-01	.23284518E-01	1.111	.2666	.44410876
	Variance parameters for compound error				
Theta	**4.944528311**	**2.3607572**	**2.094**	**.0362****	
Sigmav	**.3445318724**	**.48332369E-01**	**7.128**	**.0000****	

Table A11: Cost Frontier Parameter Estimates (Exponential), 1992/93

Limited Dependent Variable Model - FRONTIER	
Maximum Likelihood Estimates	
Dependent variable	LNNTVC
Weighting variable	ONE
Number of observations	368
Iterations completed	1
LM Stat. at start values	2.124636
LM statistic kept as scalar	LMSTAT
Log likelihood function	-107.1903
Exponential frontier model	
Variances: Sigma-squared(v)=	.08349
Sigma-squared(u)=	.02171

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
Constant	1.528820402	1.0107048	1.513	.1304	
LNNPL	**1.826944604**	**.60796336**	**3.005**	**.0027****	**1.7388216**
LNNMS	.3858863009	.44172618	.874	.3823	1.7544106
LNNLS	-.2555987795	.50186893	-.509	.6105	2.4087634
LNNSS	.6238316734E-01	.93314582	.067	.9467	1.9325746
LNNCS	.6278538246	.70215579	.894	.3712	2.2196989
LNVM	.1069955173	.17980905	.595	.5518	7.1497868
LNVL	.1134199332E-01	.79463301E-01	.143	.8865	2.5772566
LNVS	**.1767130073**	**.75582819E-01**	**2.338**	**.0194****	**3.5580386**
LNVC	-.4902568099E-01	.11460677	-.428	.6688	1.8032684
LNTA	**2.741694143**	**.60902887**	**4.502**	**.0000****	**1.2177632**
LNPLPL	-.1027754640	.19357022	-.531	.5955	1.7349561
LNPLMS	-.1283803882	.12992241	-.988	.3231	3.2156495
LNPLLS	-.1708235439E-01	.11730852	-.146	.8842	4.5787074
LNPLSS	.1739499845	.26630597	.653	.5136	3.6779324
LNPLCS	-.1456767491	.19823708	-.735	.4624	4.1173248
LNPLVM	-.2206361393E-01	.74645303E-01	-.296	.7676	12.276423
LNPLVL	**.5636429163E-01**	**.24678598E-01**	**2.284**	**.0224****	**4.1970061**
LNPLVS	-.1718485404E-01	.32074637E-01	-.536	.5921	6.2314152
LNPLVC	.1955703071E-01	.26770717E-01	.731	.4651	2.9012274
LNPLTA	-.1218152085	.23064624	-.528	.5974	2.0627293
LNMSMS	.2739238099	.18082231	1.515	.1298	1.7652662
LNMSLS	-.4922317208E-01	.10994377	-.448	.6544	4.3899015
LNMSSS	.5327312242E-01	.18104428	.294	.7686	3.5756691
LNMSCS	-.8951055778E-01	.14703149	-.609	.5427	3.9873081
LNMSVM	-.4226055304E-01	.51693643E-01	-.818	.4136	12.525402
LNMSVL	-.1662030866E-01	.19753625E-01	-.841	.4001	4.8336116
LNMSVS	**.4090297380E-01**	**.18664718E-01**	**2.191**	**.0284****	**6.4994562**
LNMSVC	-.8135033920E-02	.20475571E-01	-.397	.6911	3.3089376
LNMSTA	-.1899932224	.15552644	-1.222	.2219	2.2211818
LNLSLS	-.4144775329E-01	.14032223	-.295	.7677	3.2874154
LNLSSS	-.3578668376E-01	.23038107	-.155	.8766	5.0346705
LNLSCS	.4555439635E-01	.17157991	.265	.7906	5.6522160

Table A11: Cost Frontier Parameter Estimates (Exponential), 1992/93, Cont.

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
LNLSVM	.3275066490E-01	.61406950E-01	.533	.5938	17.130738
LNLSVL	.3858075601E-02	.17482452E-01	.221	.8253	5.7799213
LNLSVS	-.1198368423E-01	.22511185E-01	-.532	.5945	8.7345313
LNLSVC	-.1823903559E-01	.32048903E-01	-.569	.5693	4.6003379
LNLSTA	.2881939328	.18245556	1.580	.1142	2.9281693
LNSSSS	-.4627973547E-03	.41763218	-.001	.9991	2.0720305
LNSSCS	-.1863367650E-01	.22768809	-.082	.9348	4.5477349
LNSSVM	.2288422372E-01	.98798291E-01	.232	.8168	13.768926
LNSSVL	-.5054026240E-01	.35901030E-01	-1.408	.1592	4.7765119
LNSSVS	-.4663176071E-01	.44456366E-01	-1.049	.2942	6.9350380
LNSSVC	-.1857588631E-01	.38421196E-01	-.483	.6288	3.2810114
LNSSTA	-.1403606280	.29128616	-.482	.6299	2.3254654
LNCSCS	.1011902080	.98862412E-01	1.024	.3060	2.7695815
LNCSVM	-.1031923864	.77586744E-01	-1.330	.1835	15.864477
LNCSVL	-.1216330283E-01	.26557839E-01	-.458	.6470	5.8213300
LNCSVS	.3804696985E-01	.34105160E-01	1.116	.2646	7.5331993
LNCSVC	.2703426776E-01	.14624235E-01	1.849	.0645*	4.1236235
LNCSTA	.8039532208E-01	.22509628	.357	.7210	2.6731814
LNVMVM	**.4506088241E-01**	**.21100655E-01**	**2.136**	**.0327****	**26.352182**
LNVMVL	.5173073996E-03	.10829083E-01	.048	.9619	19.539507
LNVMVS	-.1866329603E-01	.99497834E-02	-1.876	.0607	25.387309
LNVMVC	.8495437654E-03	.12147886E-01	.070	.9442	13.795925
LNVMTA	-.1392406094	.90509404E-01	-1.538	.1239	8.9188446
LNVLVL	**.4067500287E-01**	**.12159024E-01**	**3.345**	**.0008****	**7.2792272**
LNVLVS	-.4739722696E-02	.38623162E-02	-1.227	.2198	9.3476876
LNVLVC	-.1003527223E-02	.36954016E-02	-.272	.7860	5.5334338
LNVLTA	-.3678220352E-01	.30044830E-01	-1.224	.2209	3.4941215
LNVSVS	.7985421508E-02	.11038799E-01	.723	.4694	9.6837998
LNVSVC	**.1258006710E-01**	**.42191948E-02**	**2.982**	**.0029****	**5.6222526**
LNVSTA	-.6252298038E-01	.33276391E-01	-1.879	.0603*	4.6983002
LNVCVC	.2170191625E-01	.12192080E-01	1.780	.0751*	5.8700932
LNVCTA	-.2993842678E-01	.32758646E-01	-.914	.3608	2.7917639
LNTATA	-.2936388608	.36232763	-.810	.4177	.83817794
LNMZYLD	**.2652325563**	**.61163489E-01**	**4.336**	**.0000****	**2.8355027**
NAREDV	-.1018358194	.75054036E-01	-1.357	.1748	.43478261
	Variance parameters for compound error				
Theta	6.786365303	3.5898432	1.890	.0587*	
Sigmav	**.2889524560**	**.34005725E-01**	**8.497**	**.0000****	