Economics of Smallholder Farming in Rhodesia

A Cross-Section Analysis of Two Areas

Benton F. Massell
and
R. W. M. Johnson

Food Research Institute
Stanford University

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DIRECTOR'S PREFACE

Concern with economic growth and development and with the economic problems of low-income countries since the close of World War II has led to more general recognition of the critical importance of the agricultural sector, both in providing for rapidly increasing human populations and in generating productivity in other sectors. In the second largest continent, Africa, colonial administrators and development planners in the new states have launched a multitude of programs intended to improve the condition of that major part of the population that obtains its livelihood from farming and to accelerate the flow of foodstuffs, industrial materials, and investable funds from agriculture. That these efforts have so often been barren may be attributed in large part to general ignorance about the economic nature of the existing agricultural systems, and, in particular, about the ways in which small farmers organize their very limited resources for production. The present study by Messrs. Massell and Johnson is an effort to extend our understanding, not by speculation, but by careful analysis of observed behavior of African farmers in two situations differing primarily in the amount of resources available to them and in the form of land tenure.

The results of this analysis, presented with due caution by the authors, speak to a wide range of critical and disputed questions about the productive efficiency of smallholder agriculture. These questions relate to various aspects of the employment of labor: the relative magnitude of its marginal product; the competing demands of nonagricultural activity for labor time; the impact of seasonal migration for wage employment; the response of labor inputs to increased economic return; and the opportunities for increased use of hired labor in traditional agriculture. The authors explore allocative efficiency in the two samples of farms; the potential to be expected from greater total inputs of machinery, soil-building practices, fertilizers, managerial skills, and agricultural education; and the relative advantages of the two alternative farming systems. Their data provide information about economies of scale, including the matter of minimum size of farm that is consistent with active participation in the market economy and willingness to invest and innovate. And their study contributes to the debates about the relative advantages of various forms of land tenure, and about whether or not significant productivity increases can be achieved without a major transformation of the entire agricultural system.

The Food Research Institute is very pleased to be able to make available to a wider audience this complete report of the Massell-Johnson study. It is an important contribution to the small, but growing, body of knowledge about the productive activities of a critically important part of the world's population.

William O. Jones
Director

Stanford, California
August 1968

PREFACE

This study contains an analytical and empirical examination of the factors responsible for low productivity, and the problems of raising productivity, in African smallholder agriculture. The analysis is based on an examination of survey data obtained from two agricultural areas in Rhodesia: Chiweshe Reserve and the Mt. Darwin Native Purchase Areas (see map on page 3).

The Chiweshe data were collected by one of the authors (Johnson), with the assistance of six research assistants who remained in the area throughout the crop year. The Darwin data were obtained from D. T. Johnson, Agricultural Officer, Mt. Darwin District, Rhodesia. We are greatly indebted to him for making this information available to us. Except as otherwise indicated, all of the figures in this study are derived from the two sets of unpublished data.

Some of the results of this study were reported by Massell in two earlier papers, one in *Econometrica* and the other in *Food Research Institute Studies*. An earlier version of the entire study was published by The RAND Corporation as a RAND Report. We gratefully acknowledge the support given to the research by The RAND Corporation. We are also grateful to the Rockefeller Foundation for a generous grant in support of this research.

We are indebted to many individuals for helpful comments on earlier drafts of this study, notably Richard R. Nelson, William O. Jones, Montague Yudelman, Albert Madansky, and Charles Wolf, Jr.

B. F. M. AND R. W. M. J.

Stanford, California
and
Canterbury, New Zealand
August 1968

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Chapter 1

INTRODUCTION

At the core of the world's problems of underdevelopment lies the modernization of agriculture. Whether it is a question of feudal farming in parts of Latin America or the usurious landlord-peasant relationship of monsoon Asia or tribal communal agriculture in tropical Africa, the outcome—low productivity, low output, disgust with rural life and exodus to the cities—now presents the greatest single obstacle to achievement of dynamic economic growth.

Yet the literature available for serious study of this central problem is still very inadequate and in some measure reflects the relative lack of priority farming has suffered in the elaboration of development strategy.

—*Economist,* August 22, 1964, p. 273

This monograph contains an analysis of agricultural underdevelopment in Rhodesia. Our primary concern is to present an analytical and empirical examination of the factors responsible for low productivity, and of the problems of raising productivity, in African agriculture. Although parts of the study relate to factors specific to Rhodesian smallholder agriculture, much of the analysis is relevant to agricultural problems throughout Africa, and possibly to other parts of the underdeveloped world.

The study focuses on analytical issues, but parts of the analysis have important policy implications. Much of the discussion sheds light on the prospects for raising agricultural productivity and on the policy measures that might have a high payoff.

To some extent, also, the study deals with methodological issues. It examines the role of the production function as an empirical tool, and discusses some of the conceptual and statistical difficulties of using the production function to analyze survey data on smallholder farms.

Rhodesia contains two predominant racial groups: Africans and Europeans. Corresponding to the two groups are two distinct patterns of agriculture. The European agricultural sector consists of large estates that use relatively capital-intensive methods and employ Africans as wage laborers. By contrast, the African agricultural sector is characterized by small holdings that are worked mainly by family labor using relatively little capital. This study is concerned with African agriculture only.

Within the African agricultural sector, two types of areas can be distinguished: reserves and purchase areas. Both can be termed "smallholder" agriculture, as techniques of production are labor-intensive and nonmechanized, and the scale of production is small. But there are important differences between reserves and purchase areas. Purchase area farms are larger, are based on freehold tenure (instead of tribal tenure), make greater use of capital, and obtain much larger outputs.

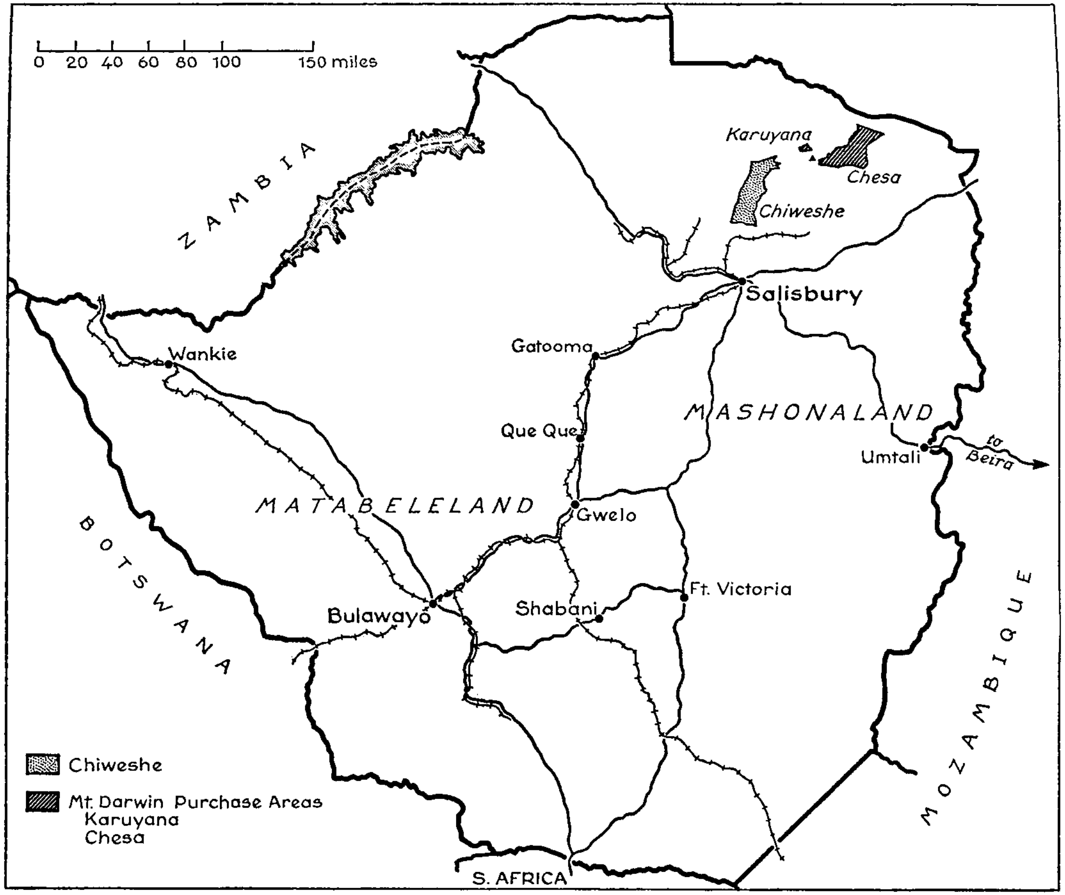
In a sense, the reserves and purchase areas can be viewed as alternative models of agricultural development, and both can be regarded as alternatives to agricultural "transformation"—that is, the formation of much-larger-scale, highly mechanized farms. Should the government's program for raising agricultural output focus on improvement of the reserves, on the development of purchase areas, or on transformation? What are the opportunities for increasing output in reserve and purchase area agriculture? And what gains can be achieved by committing resources to either type of area?

This study makes no claim to provide definitive answers to these questions. But the questions are dealt with, and an attempt is made to shed some light on some of the underlying issues. The study contains a detailed analysis of two sets of survey data—one drawn from a reserve and the other from a purchase area. This permits us to investigate the factors underlying differences in the level of economic performance among farms in each area, and also to compare the performance of farms in one area with that of farms in the other area. Both within and between areas the results provide insight about the relative importance of several factors in explaining interfarm differences in output. Particular emphasis is given to the role of management, as contrasted with the more conventional inputs of economic theory: labor, capital, and land.

To improve the performance of African farmers will require extensive experimentation on new seeds, new crops, and new methods of cultivation. Much of this work will have to be done in the agricultural experimental stations. To a large extent, too, raising agricultural output will require intensive study by anthropologists of socio-cultural influences on production practices. But, in addition, it will be necessary to know more about the economics of smallholder agriculture, derived from analyses of factors responsible for existing low levels of production and of factors accounting for differences among farms in economic performance. A considerable amount of information has already been provided by surveys of African agriculture. But although something is known about acreages planted, outputs, yields, and amounts of fertilizer used throughout large parts of Africa, there has been little systematic research on the interrelationships among these factors.

Empirical economic research can provide a useful complement to experimental work in providing more information about the determinants of agricultural productivity. The cost of experimentation is frequently much greater than the cost of direct observation by empirical economists. Although the results obtained in the experimental station are more precise and more reliable than those the economist can provide, it makes sense for the economist to take a rough cut at the problem to provide a set of promising hypotheses for the experimentalist to test using the more refined methods of the laboratory.

Empirical analysis of survey data also enables one to observe production as it is actually conducted in African villages; on experimental farms procedures are


0 20 40 60 80 100 150 miles
ZAMBIA
Karuyana
Chesa
Chiweshe
Salisbury
Gatooma
Wankie
MASHONALAND
Que Que
Umtali
to Beira
MATABELELAND
Gwelo
BOTSWANA
Ft. Victoria
Shabani
Bulawayo
MOZAMBIQUE
Chiweshe
Mt. Darwin Purchase Areas
Karuyana
Chesa
S. AFRICA

RHODESIA

likely to be quite different. Some attempt has been made to simulate actual farm techniques and behavior by letting African peasant farmers do some of the work in the experimental fields. But a farmer working for the Ministry of Agriculture, and directed by an agricultural extension agent, is unlikely to use the same techniques he would employ on his own plot in the reserve. For this reason, some inputs may contribute more to output on an experimental farm than in an African village.

Chapter 2

A SUMMARY VIEW OF RHODESIAN AFRICAN AGRICULTURE

The Physical Environment

Rhodesia contains 150,000 square miles and lies in the south-central part of Africa. A large part of the country is more than 3,000 feet above sea level, it is relatively far from the ocean, and the climate is predominantly subtropical rather than tropical. The soils are typically granite sands, interspersed with small occurrences of red loams and clay loams. Drainage is a common problem, and impenetrable horizons frequently develop in the subsoil. For crops grown by African farmers, the red and clay loams are generally regarded as inherently more fertile than the sandy soils.

A period of fairly heavy and frequent rain lasts from November until March, with the heaviest fall occurring from December through February. Rain is infrequent during the remainder of the year. Some 38 per cent of the land area receives an annual rainfall in excess of 28 inches, and an additional 49 per cent receives between 20 and 28 inches. A minimum of 28 inches is considered desirable for intensive crop farming, although semi-intensive farming can be practiced on land receiving as little as 20 inches. But while total rainfall is adequate throughout much of the country, there is a great deal of interseasonal and intraseasonal variation in some areas.

The variability of rainfall poses a challenge to farmers in Rhodesia. The intraseasonal variation makes it important to perform the different phases of cultivation at appropriate times. Because yield is closely related to rainfall, the interseasonal variation in rainfall is accompanied by a correspondingly high degree of variability in crop yields from one year to another. This poses a threat to farmers, especially African farmers, many of whom have small holdings of arable land and are not much above the margin of subsistence. Farmers are forced to allocate their resources and plan their farming operations under conditions of gross uncertainty. In such circumstances, the principal objective of many African farmers is to produce with high probability enough grain to feed themselves and their families. Because of the structure of prices, the uncertainty of yields tends to inhibit production for market sale.[1]

Throughout most parts of Rhodesia, weeds grow rapidly and are, in many cases, troublesome and difficult to eliminate. In African agriculture, weeding is typically a time-consuming and painstaking chore. If weeding is not begun early and carried out properly, yields are adversely affected.

Agricultural scientists have classified Rhodesia into natural regions on the basis of climatological, soil, and land-utilization information. There are six main regions, ranging from highly productive land to land that is unsuitable for farming. Natural Region I, which has the greatest inherent agricultural potential, con-

[1] This is discussed in Chapter 5.

tains 1.6 per cent of the land. In this region, rainfall is heavy and subject to little variation. An additional 18.7 per cent of the land is in Natural Region II, suitable for intensive farming; and a further 17.4 per cent is in Natural Region III, suitable for semi-intensive farming. The remainder of the land can be used only for extensive farming or cannot be used for farming at all.

In Rhodesia, land is apportioned between Europeans and Africans by legislation. In 1961 the European areas constituted 36.8 million acres and the African areas 44.3 million acres. The remainder consists of unassigned land, game preserves, and forests. Within the African areas, 40.1 million acres consist of reserves:[2] areas where land is held largely according to traditional law, as modified by the Native Land Husbandry Act of 1951 (*15*). The remaining 4.2 million acres consist of purchase area land: land that is held under freehold tenure through leases with the option to purchase. The European areas contain 81, 77, and 64 per cent of the land in Natural Regions I, II, and III, respectively. By contrast, most of the African areas are suitable for extensive farming only (*13*). Thus the pattern of European settlement, reinforced by restrictive legislation, has relegated to the African farmer areas with the lowest inherent agricultural fertility.

Technology of African Farming

Rhodesia contains two predominant tribes: the Shona and the Matabele. Both of the samples examined in detail in this study were drawn from the Shona areas.

Traditionally, the Shona village units consisted of scattered homesteads, with plots of cultivated land surrounding each homestead. A form of shifting cultivation was practiced. Each household cultivated its plot of land until the fertility of the soil was exhausted. Then the family would move on to new land, clearing the bush by burning. Old land was then permitted to revert to bush; in time it regained its fertility and was ready for further cultivation.

Traditional agriculture was based solely on labor and land. As land was regarded as a "free good," a family's agricultural output was limited by the number of acres the family could cultivate; this, in turn, was determined by the availability of labor for preparing the seedbed and planting, the most time-consuming farm operation.

The first important change in technology was the introduction of the ox-drawn plow. The people already had cattle. Consequently, when the plow was introduced, the backbreaking work of hoeing new land was transferred from human motive power to animal power. Use of the ox-drawn plow substituted capital for labor and enabled a family to cultivate a larger number of acres.

The number of plows used by Africans increased from 3.4 thousand in 1911 to 108 thousand in 1941, and reached 174 thousand by 1950.[3] The introduction of the plow was of a greater economic significance in the early years, when land was still plentiful. By the 1940's, land became a limiting factor of production. The size of a family's agricultural holding was then limited more by the availability of land than by the labor requirements for plowing.

Population pressure on the land resulted from European settlement, restrictive legislation pertaining to land apportionment, and the phenomenal rate of increase

[2] Including so-called "Special Native Areas."

[3] These figures were obtained from records kept by the Native Commissioners.

in the African population. The amount of land available for cultivation per family was reduced, forcing the people to abandon their traditional system of shifting cultivation and to adopt a settled form of agriculture. The need to use the same land more and more frequently resulted in soil depletion and decreasing crop yields. Also, because of the spectacular increase in the number of cattle in the African areas, the use of land for grazing competed with the use of land for crops.

At the same time, African exposure to European culture and to the European pattern of consumption increased demand for some of the material goods that form part of the European way of life. The Rhodesian economy was called upon to support not only a growing (human and livestock) population, but to provide the people with a growing per capita income. In part, the answer lay in improving agricultural technology; in part, also, it lay in providing alternative forms of employment.

Two important improvements in technology have been the application of manure to the soil and the implementation of a crop rotation pattern. Another technological improvement related to the physical layout of farms. Shifting cultivation had left a very disorganized mixture of odd-shaped ploughed fields and patches of grazing. This was changed as cultivated fields were brought together in large blocks and protected from soil erosion by the construction of contour ridges along the slopes. Homesteads were shifted to the edge of the blocks.

Introduction of the plow, use of manure compost, crop rotation, and centralization of the arable land all increased agricultural productivity; the last three had a long-term effect by limiting the depletion of soil fertility. But the improvements in technology provided only a modest increase in crop yields. Moreover, the farmers were slow in adopting the new methods. As a result, the level of technology did not improve rapidly enough to provide rising incomes for the expanding African population.

In the first half of the century, the land under cultivation by Africans increased by a factor of four. But soil fertility continued to decline, and farmers were forced to turn to marginal land. As a result, despite the improvements in technology during this period, and despite a 50 per cent increase in the per capita acreage cultivated, real income per capita in the African agricultural sector was very likely no higher in 1950 than in 1900.

More recently, the government has begun to take a more active role in raising the productivity of African agriculture. In the reserves, the policy of centralization continued until 1951, when a new soil conservation legislation measure was introduced: the Native Land Husbandry Act (*15*). This act provided for the registration of individual titles to arable plots of land in the reserves and for the compulsory introduction of soil conservation measures throughout the reserves. The legislation was intended to raise yields and to prevent the further reduction of soil fertility. However, owing largely to sociological and political factors, African farmers vigorously protested the Act, which was consequently abandoned in 1961.

Labor Migration

From 1900 to 1960, the total African population of Rhodesia increased from an estimated .5 million to 3.2 million. During this same period, the population on the land approximately doubled. As a result of growing population pressure on the land, an increasing percentage of the population has migrated into the employment centers to work for wages. The principal source of wage income has been the European estate farms; but mining, manufacturing, and other sectors have also provided employment opportunities for Africans.

In 1921 the labor force contained approximately 177,000 African adult males. Only 30 per cent of the total African labor force, or 53,000 workers, were employed in the wage economy; the remaining 124,000 were engaged in the African agricultural economy as self-employed workers. During the past four decades the growth of the money economy has drawn an increasing number of Africans into wage employment. By 1961, the total labor force had expanded to 572,000; and 40 per cent of this larger labor force, or 229,000 workers, were in wage employment.

The increased migration out of the African agricultural sector and into wage employment can easily be explained by three factors. First, the desire for cash income has grown considerably during the past few decades. Second, at the same time, the rapid growth of the cash economy has provided an increasing demand for African labor. Third, the opportunity cost of labor in the reserves has dropped during this period because of the growing prevalence of the labor-saving plow, the rapid increase in the African population, and the failure of improvements in technology to offset soil deterioration and raise yields. Thus strong incentives have developed for Africans to migrate into the centers where there are employment opportunities.

The flexible pattern of labor migration that has developed in Rhodesia has to a large extent preserved the structure of tribal society. Some workers have become fully committed to wage employment, especially in the cities. But most workers regard the rural area as their home, and plan to return in time to their village to settle down. A large proportion of the migrants leave their families behind to maintain the rural home and work in the fields; they pay frequent visits to their families and typically remit a portion of their cash income.

Labor migration has been criticized because it creates a group of individuals who are fully committed neither to good farming nor to wage employment. A migrant laborer may remain away from the reserve for only short periods, so he changes jobs frequently. This rapid turnover inhibits the training of a skilled labor force. At the same time, if the head of the household is absent, the standards of agriculture are believed to decline. Typically the women are more conservative and more resistant to new techniques of agricultural production. Thus, labor migration is said to result in reduced agricultural productivity.

Current Problems and Alternatives

In Rhodesia, as in other parts of Africa, a large part of the economically active African population is still engaged in agriculture. As noted in Chapter 1, there is an important distinction between reserves and purchase areas. By far the majority of those resident in the African rural areas live in the reserves. Agriculture in the reserves is undertaken by family units, with little or no hired labor and with relatively little use of capital, and is characterized by low productivity of both labor and land. It is common for some surplus above family subsistence needs to be produced for sale, but such surpluses are seldom large. Cash incomes from farming are low and subject to large annual fluctuations. Despite increasing population pressure on the land, crop output in the reserves has risen only slowly.

But despite the pessimistic overall picture, a growing number of reserve farmers have begun to respond to the advice of the agricultural extension service and have attained substantially improved standards of farm management. These farmers have been classified by the government into one of three categories: Cooperator, Plotholder, or Master Farmer.

A Cooperator is any farmer who uses manure or fertilizer, carries out some rotation, and plants his crops in rows (except for millet which is normally broadcast); a Plotholder is a farmer who is under tuition by an extension worker in order to become a Master Farmer; a Master Farmer is a farmer who has gone through the Plotholder stage and has reached specified, higher standards of crop and animal husbandry as laid down by the Ministry of Agriculture. Recent figures for the number in each of these categories are shown in Table 2:1. It is encouraging that in the fifteen-year period covered by the table, the numbers of farmers in all three categories have risen relatively much more rapidly than the total number of farmers. About one-third of the farmers were in the three categories combined in 1963.

Table 2:2 shows the average yields obtained by farmers in each of the three categories discussed above, as well as the yields of "ordinary" farmers—that is, those who have not been placed into one of the three groups. The difference in yields between Master Farmers and Plotholders was not great; the latter obtained higher yields during some years shown in the table. Both Master Farmers and Plotholders obtained higher yields than Cooperators, and Cooperators obtained higher yields than ordinary farmers during each of the years for which data were available.

As noted in Chapter 1, purchase areas are characterized by much larger plots of land, held under freehold tenure. Labor is provided both by members of the family and by hired workers. There is considerably more investment in capital of all kinds—implements, cattle, land improvement, and fertilizer—although no real mechanization (such as tractors). Purchase area farmers have a greater opportunity to invest in the land by undertaking extensive soil conservation measures that raise and maintain soil fertility. Output of the average purchase area farm far surpasses that of the average reserve farm.

At one time any farmer with enough capital could buy a purchase area farm. Nevertheless, the allocation of farm units had proceeded slowly before 1945, at which time only 1,872 farms had been settled in the purchase areas. From 1945 to 1953, applications by farmers for settlement on purchase area farms increased sharply. In 1953, as part of an attempt to be selective in allocating purchase area

TABLE 2:1.—THE NUMBER OF COOPERATORS, PLOTHOLDERS, AND MASTER FARMERS IN RHODESIA, 1948, 1955, AND 1963*

Year	Cooperators	Plotholders	Master Farmers	All farmers
1948	14,293	2,017	764	213,760
1955	76,644	5,482	5,322	342,275
1963	108,433	11,150	14,362	415,081

* Data from R. W. M. Johnson, "African Agriculture in Southern Rhodesia, 1945–1960," *Food Research Institute Studies,* Vol. IV, No. 2, 1964, p. 181; and Southern Rhodesia, Ministry of Agriculture, *Annual Report, 1963* (Salisbury, 1964).

TABLE 2:2.—AVERAGE YIELDS PER ACRE BY AFRICAN FARMERS IN RHODESIA BY GOVERNMENT RATING GROUPS, 1946–58*

(Bags of grain)

Year	Master Farmers	Plotholders	Cooperators	Ordinary farmers
1946	...	10.0	...	1.1
1947	...	6.2	...	1.0
1948	8.1	10.1	6.5	2.5
1949	7.5	8.6	6.0	2.0
1950	6.6	7.9	4.4	1.5
1951	5.5	4.8	3.0	1.2
1952	7.0	6.6	3.5	2.0
1953	7.5	7.5	4.8	2.5
1954	7.1	6.0	4.5	1.9
1955	6.4	5.5	4.0	2.2
1956	9.0	7.0	4.8	2.5
1957	6.3	5.3	3.8	1.8
1958	6.5	5.8	3.9	2.2

* Data from Southern Rhodesia, Director of Native Agriculture, *Annual Reports,* 1946–1958. The series was discontinued in 1959.

land, Master Farmer certificates were made a prerequisite for settlement. Since 1953, settlement in these areas has steadily increased. By 1963, seven thousand farmers had been settled on an area of 1.6 million acres.

The general agricultural extension program of the Rhodesian government initially tended to neglect the purchase areas because of a shortage of qualified staff. But since 1957 a greater effort has been made to provide adequate staffing for the purchase areas.

In the following chapter the differences between purchase area and reserve farming are illustrated with reference to the areas from which our two samples have been drawn: Chiweshe Reserve and the Mt. Darwin Purchase Area.

Chapter 3

TWO AGRICULTURAL ECONOMIES: CHIWESHE AND DARWIN

Chiweshe Reserve has an area of 211,000 acres, lies at an altitude of 4,000 feet, and is in Natural Region II. Although arable land is worked individually by family groups, the land is held in tribal trust, according to customary law. Because the farmer does not have freehold tenure, there is little incentive for him to improve his holding through soil conservation and other measures. Also, as land is tribal property, it cannot be mortgaged by the farmer to obtain credit.

The Mt. Darwin district of Rhodesia contains two purchase areas—Chesa and Karuyana—from which our sample has been drawn. Chesa contains 246,000 acres, and Karuyana contains 16,000. We shall refer to these areas simply as Darwin.

Darwin is situated at an altitude of 4,000 feet, in heavily wooded country that has been sparsely occupied until the present time. Karuyana falls within Natural Region II, and Chesa in Natural Region III. Therefore, although Chiweshe Reserve and Karuyana Purchase Area have roughly the same annual rainfall expectancy, Chesa's rainfall expectancy is somewhat lower.

Farmers in Darwin have freehold tenure. Most farmers in the area have undertaken considerable land improvement, possibly because of the greater security of tenure.

In Chiweshe, the agricultural holding of a family averages nine acres of arable land and the right to graze cattle on communal grazing land. The average family size is 7.2 persons. All arable plots are close together in blocks, whereas grazing land tends to be on uncultivated ridges, wet lands, and stream margins. Holdings in Darwin average approximately 219 acres in one consolidated block, with an average of 23 acres cultivated. This is large for African agriculture.

The population of Chiweshe is estimated at 29 thousand at the height of the growing season, but only 22.5 thousand in August, when agricultural activity is at its lowest ebb. The 1962 census revealed that Chesa and Karuyana have populations of 6,540 and 440, respectively. Most of the farms have been settled since the end of World War II, mainly during the 1950's. Farmers in Darwin do not exhibit the migration patterns observed in Chiweshe. The average family of 5.3 persons in Darwin remains approximately constant throughout the year.

The Chiweshe sample survey was conducted in an area of ten square miles, during the 1960–61 crop year. Five villages were chosen, mainly for their convenient location; all farms in these villages—118 farms in all—were surveyed. Each farm was visited at least once a week during the entire crop year. In terms of crop production, the 1960–61 season was approximately average for Chiweshe. The area sampled appears to be reasonably representative of the reserve as a whole.[4]

[4] The area sampled contains 3.1 per cent of the total land area of the reserve as a whole; 2.7 per cent of the total farmers; 3.4 per cent of the cattle; 2.7 per cent of the arable land; and 2.8 per cent of the families owning cattle.

Five farms were surveyed in Karuyana Purchase Area and 25 farms in Chesa during the 1961–62 crop year. In terms of the total amount and the distribution of rainfall, the season was termed "average" by the District Agricultural Officer, and is believed to have been roughly comparable with the 1960–61 crop year in Chiweshe.

The Darwin survey was conducted by the District Agricultural Officer. Weekly records were kept for each of the 30 farms. The farms were not randomly selected, but "were chosen for convenience and overall coverage of the area" (7). In other words, the sample was regarded by the District Agricultural Officer as representative, in regard to arable acreage and yields.

In both Chiweshe and Darwin, income earned on the farm is principally derived from the production of corn, millet, and peanuts. Rice, sorghum, sunhemp, cowpeas, potatoes, and cotton account for a small proportion of the value of crop output in the two samples. Most farmers in Chiweshe and all farmers in Darwin have livestock, which are sold for cash income, slaughtered for home consumption, or given as payment of the bride-price; and each farmer has a small vegetable garden and many have fruit trees.

As already noted, many Chiweshe farmers take advantage of the opportunities to earn income away from the farm. The pattern of migration varies with respect to total time spent away from the farm, and frequency of such trips. In 1960–61, out of 147 families with rights to cultivate in the area, 29 were absent during the entire year, compared with 118 families resident in the area for at least part of the year. Our study is focused on the 118 families who spent at least part of the year in the area. Even in December—when agricultural activity is at its height—the heads of 25 of these families were away from the reserve for most or all of the month, leaving their families behind to work in the fields. The number of absentees reached a peak of 55 in August. All told, of the 118 families, 73 family heads left the area at least once for a period in excess of two weeks, and only 45 family heads remained in the area throughout the year.

Although opportunities for employment were just as great in Darwin, outside employment was infrequent. This presumably reflects the greater opportunities available to the Darwin farm family to earn a cash income on their farm and the time required to clear and improve their land.

In this study, we are concerned only with on-farm income. Moreover, the analysis is confined to income derived from crop production. Livestock, therefore, is regarded here not as an independent source of income, but merely as an input used in the production of the three major crops.

In Chiweshe, the major part of crop output is consumed directly on the farm. Millet is used almost exclusively for making a "home brew" beer (a product with an exceptionally high nutritional value). Corn and peanuts are staples. Only the surplus corn and peanuts above subsistence needs are offered for sale. In Darwin, by contrast, a substantially larger proportion of output is sold.[5] For estimating production function coefficients, we do not distinguish between cash and subsistence income. Our interest is with the factors influencing the value of crop output, whether consumed on the farm or sold in the market.

[5] See Chapter 5.

In the subsequent analysis, we turn to the estimation of crop production coefficients, focusing on the three principal crops. To use the statistical methods presented in Chapter 7, the investigation was limited to farms in each sample with complete production records, and which grew all three crops. Accordingly, from the original samples, we deleted farms that had incomplete crop production data or that did not grow all three crops. This left final samples of 56 Chiweshe farms and 20 Darwin farms, with which the remainder of the study is concerned.[6]

[6] In the original Darwin sample, eight farms were deleted because of incomplete production records, and two farms were deleted that grew no millet. In the original Chiweshe sample, though, a number of farms did not grow millet. These farms tended to be smaller than the farms growing all three crops, and to obtain lower yields. It appears that limiting the Chiweshe sample to farms growing all three crops introduces an upward bias in terms of size and economic performance.

Chapter 4

A STATISTICAL PROFILE OF CHIWESHE AND DARWIN

Output

In the Chiweshe sample, output is measured in pounds harvested. There is frequently some difference in crop quality from one farm to another, but such differences tend to be of little importance in this area. Therefore we feel justified in treating output of each crop as a homogeneous variable. For comparability among crops, output of each crop is weighted by the crop price. The Grain Marketing Board paid $2.72 per 200 lb. bag for millet.[7] In our sample, 25 farmers sold corn to the GMB but only two sold peanuts and one sold millet. In addition, some sales took place among farmers in the area; we have no information about the volume of such sales, but know the approximate prices at which the sales took place. Corn and peanuts sold locally at about the same as the GMB price. Millet sold locally for nearly triple the GMB price: $8.56 per bag. We suspect that more millet was sold locally than was sold to the GMB. Therefore, in weighting the crops, we have used the local prices.[8]

For the Darwin sample, we have followed the same procedure, weighting the physical output of each crop by the average price at which the crop was sold in the area. These prices are nearly identical to those in Chiweshe, so that output in the two areas can be compared. The figures for output and sales are shown in Table 4:1. The table brings out the difference in economic performance between

TABLE 4:1.—AVERAGE VALUE PER FARM OF OUTPUT AND SALES OF THE THREE PRINCIPAL CROPS: CHIWESHE AND DARWIN

(U.S. dollars)

Item	Corn	Peanuts	Millet	Total
Average output				
Chiweshe	51.56	19.61	12.15	83.32
Darwin	445.21	211.94	100.28	757.43
Average sales				
Chiweshe	2.60	.07	.03	2.70
Darwin	326.76	88.53	6.86	422.15
Percentage of output sold				
Chiweshe	5.0	0.4	0.2	3.2
Darwin	73.4	41.8	6.8	55.7
Percentage of farms selling				
Chiweshe	45	4	2	45
Darwin	95	80	15	95

[7] Prices are converted to U.S. dollars from Rhodesian shillings which equal 14 U.S. cents.
[8] See the discussion of prices in Chapter 5.

TABLE 4:2.—CHIWESHE AND DARWIN FARMS BY PERCENTAGE OF OUTPUT MARKETED

Percentage marketed	Number of farms Chiweshe	Darwin
Over 60	0	6
50–60	0	7
40–50	0	1
30–40	0	3
20–30	1	1
10–20	5	1
0.1–10	19	0
0	31	1

the two areas. The average value of crop output per farm in Darwin is 9 times as great as in Chiweshe, and the value of sales per farm is 156 times as great. A large percentage of the Darwin farms sell at least some part of their output, and the percentage of output that is marketed is much larger in Darwin (56 per cent as compared with just over 3 per cent in Chiweshe).

Table 4:2 shows the number of farms in each sample that marketed various shares of their output. The vast majority of the Chiweshe farms sold less than 10 per cent, whereas 13 of the 20 Darwin farms sold more than 50 per cent of their total output. It is clear from the table that Darwin is much more market oriented than Chiweshe.

Land

Land is measured in acres planted to each crop during the survey year. Each Chiweshe farmer has "rights," determined by historical and cultural factors, to cultivate a certain number of acres. Good land is scarce in the reserve; land rights are highly valued, and are not marketable. As a result, it is generally impossible for a more industrious farmer to acquire additional land. Although a few farmers in the sample left some land fallow, most farmers cultivated their entire arable acreage. On a per family basis, 10.6 acres were cultivated during the 1960–61 season.

In Darwin, holdings are much larger than in Chiweshe, and the average arable acreage is more than six times as great. When the survey was conducted, no farmer in the sample was cultivating his entire arable potential; arable acreage is therefore not an effective constraint on crop production as it is in Chiweshe. The average acreage cultivated by the Darwin farmers was 23.7 acres, more than twice as much as in Chiweshe.[9]

When a farmer is first admitted to a purchase area, the government sometimes helps him clear the land. After that, further clearing is left to the farmer. As land clearing is especially time-consuming, it is not likely to be undertaken unless the farmer has enough complementary inputs to justify the effort and expense. Presumably, the farmer has in each case developed a notion of how many

[9] This is particularly noteworthy when one bears in mind that the Chiweshe sample contains an upward bias in acreage planted and is therefore not representative in this respect of the reserve as a whole.

TABLE 4:3.—COMPARISON OF LAND UTILIZATION IN CHIWESHE AND DARWIN

Crop	Acres per farm		Per cent of total	
	Chiweshe	Darwin	Chiweshe	Darwin
Corn	7.96	15.28	74.9	64.5
Peanuts	1.54	6.49	14.5	23.2
Millet	1.13	2.92	10.6	12.3
Total	10.62	23.69	100.0	100.0

acres can be cultivated effectively by the available labor supply, while still maintaining soil fertility.

The allocation of land among crops is shown in Table 4:3. Darwin farms planted a larger proportion of their holdings to peanuts and a smaller percentage to corn. The greater emphasis on corn in Chiweshe probably reflects the larger proportion of output that was produced for home consumption, together with the emphasis Chiweshe farmers place on security.[10]

Soil Type

Some Chiweshe farms are on sandy soil and others on red loam. For all three crops, higher yields were experienced on red loam, although the differential fertility was least with peanuts, as can be seen in Table 4:4, Part A.

Four types of soil can be distinguished in the Darwin sample: brown sand, black cotton, clay loam, and red loam. Table 4:4, Part B shows the median yields on each type of soil. The yield is lowest on black cotton for all three crops, and is highest on red loam for corn and millet, and on clay loam for peanuts. If we aggregate brown sand and red loam into one category, and black cotton and clay loam into a second category, median yields are higher in the first category for all three crops, as the table shows.

Unfortunately the classification of soils in Chiweshe does not correspond with that in Darwin so that the soils are not directly comparable between areas. We do not believe that there is a great deal of difference between the two areas in the intrinsic fertility of the soils. However, the Chiweshe area has been cultivated much longer and soil fertility has declined. By contrast, the Darwin farms were settled more recently on "virgin soil" that had not previously been worked. The Darwin farmers have followed practices intended to maintain soil fertility, and it is reasonably certain that, at the time the surveys were taken, the average fertility of the soil was greater in Darwin than in Chiweshe.

Manure and Fertilizer

Organic manure (manure compost) and chemical fertilizer are used only in the production of corn. Not all cultivators used manure. It is assumed that each cultivator using manure behaved as though he had some fixed notion of how much to apply per acre, although the amount applied per acre varied from one farm to another. On farms that were manured, some fraction (typically well under half) of the corn acreage received a manure compost dressing, while the remainder received none.

[10] We shall return to this point in Chapter 5.

TABLE 4:4.—MEDIAN YIELD BY SOIL TYPE: CHIWESHE AND DARWIN

Soil type	Number of farms	Median yield (*pounds per acre*) Corn	Peanuts	Millet
	A: CHIWESHE			
Red loam	36	645	238	264
Sand soil	20	295	205	126
	B: DARWIN			
Brown sand	10	1,789	846	1,001
Black cotton	5	1,500	260	500
Clay loam	3	1,785	963	743
Red loam	2	3,931	629	1,284
Brown sand and red loam	12	2,071	824	1,034
Black cotton and clay loam	8	1,527	493	420

The average amount of organic manure, measured in tons of compost applied, was 30 tons per farm in the Darwin sample, compared with less than 4 tons per farm in the Chiweshe sample. But, of some interest, the proportion of farmers using manure was nearly the same in the two samples: 85 per cent for Darwin and 80 per cent for Chiweshe. Thus the difference between the areas is not that manure is used in one area and not in the other, but that Darwin farmers used substantially more than Chiweshe farmers. On those farms using manure, the mean application per acre of corn land was two tons in Darwin, but only one-half ton in Chiweshe. Per acre of *manured* corn land, the mean application was 3.3 tons in Chiweshe and 7.3 tons in Darwin. Thus Darwin farmers both applied manure to more acres and applied it more intensively than Chiweshe farmers. This is partly explained by the larger number of livestock in Darwin.

It is reasonable to assume that all fertilizer purchased was used during the same crop year. Moreover, fertilizer, like manure, was used only in producing corn. Because we know the price of fertilizer paid by farmers in the area, we can calculate the number of pounds used—almost exclusively calcium ammonium nitrate. Although fertilizer is frequently applied only to land that receives an earlier manure dressing, there were exceptions to this in the samples. We are thus able to study variations in the two variables independently.

Surprisingly, only 30 per cent of the Darwin farmers used chemical fertilizer as compared with 46 per cent of the Chiweshe farmers.[11] But, those farmers who used fertilizer used more in Darwin than in Chiweshe. The mean expenditure per farm on fertilizer in the Darwin sample was $7.71, compared with $5.26 in the Chiweshe sample. Thus, again, the difference between the two areas is *not* that one area has adopted a technique not used by the other; the difference relates to the amount of fertilizer used.

Fixed Capital

In indigenous Rhodesian agriculture, and especially in reserves, only relatively simple implements are used in cultivation: most commonly a plow, sometimes a

[11] This may to an extent reflect the greater availability of manure in Darwin.

TABLE 4:5.—FARM IMPLEMENTS IN THE TWO SAMPLES

Implement	Average number per farm		Percentage of farms with at least one	
	Chiweshe	Darwin	Chiweshe	Darwin
Single furrow plow	1.04	1.70	100	100
Disc plow	0	.05	0	5
Ridge plow	0	.05	0	5
Double furrow plow	0	.05	0	5
Planter	.02	.70	2	70
Cultivator	.77	1.60	83	100
Simple harrow	.29	.90	27	85
Disc harrow	0	.05	0	5
Sheller	.02	.25	2	25
Scotch cart	.21	.85	25	85
Water cart	0	.15	0	15
Mower	0	.05	0	5
Tractor	0	.10	0	5

cultivator or scotch cart,[12] occasionally other items. In the purchase areas, more sophisticated and more varied capital equipment is used. Table 4:5 presents a breakdown of the capital implements in the two samples. On a per-farm basis, all types of equipment are more prevalent in the Darwin sample. In Darwin, 70 per cent of the farmers have planters, as compared with only 2 per cent in Chiweshe; 85 per cent of the Darwin farmers have scotch carts, compared with 25 per cent in Chiweshe; and 25 per cent of the Darwin farmers have peanut shellers, compared with only 2 per cent of the Chiweshe farmers.

Table 4:6 presents the distribution of farms in the samples according to total value (at undepreciated replacement cost) of farm implements. The mean value of equipment was $268 in the Darwin sample and $57 in the Chiweshe sample. If the 56 Chiweshe farms are aggregated into 48 groups of farms that work together with the same set of implements, the average value per group is $66.

In Chiweshe, the implements found on a farm are largely the result of past income and accidental factors. More successful farmers are better able to add to their stock of implements, but capital accumulation has occurred in the area only slowly.

To qualify for a right to own land in a purchase area, a farmer must have some specified level of capital. Farmers in the purchase areas therefore begin with a larger capital endowment than reserve farmers.

Labor Utilization

In Chiweshe, labor is performed by members of the farm family, with only occasional use of hired workers; no hired workers were employed by any of the farms in the sample. In Darwin, family labor constitutes the principal component of the farm labor force; but, in addition, laborers from a nearby reserve are frequently employed. There is also what we have termed "social" labor, performed

[12] An ox-drawn cart used primarily to carry compost to the fields.

TABLE 4:6.—FARMS IN CHIWESHE AND DARWIN ACCORDING TO VALUE OF FIXED CAPITAL

Value (*U.S. dollars*)	Number of farms	
	Chiweshe	Darwin
Over 320	0	2
280–320	0	3
240–280	0	2
200–240	2	7
160–200	1	2
120–160	6	1
80–120	3	0
40– 80	9	3
0– 40	35	0
Total	56	20

jointly by the farm family and their friends, typically combining work in the fields with the consumption of beer.

For both samples, the survey data show: (1) hours worked by each member of the family; (2) which crop the work was related to; (3) which farm operation was performed; and (4) on what day the work was performed. Obviously, to be manageable, the data must be aggregated.

First, labor was classified into five categories: male adults, female adults, children (under 15 years),[13] social labor, and hired workers. (For the Chiweshe sample, only the first three categories were represented.) For each farm, total hours worked were calculated for each of the five groups.

Second, labor was classified according to the month in which it was performed, summing the hours worked per day within each month. This left hours worked cross-classified by group, month, crop, and operation.

A few words should be said about the farm operations. In the Chiweshe survey, the following operations were distinguished: (1) applying organic manure (in the case of corn); (2) plowing the fields and planting the crops; (3) weeding, cultivating, and transplanting; (4) harvesting. We were not able to obtain separate information on the time spent applying chemical fertilizer, but believe this to be relatively small—perhaps a few hours per farm during the year. Fertilizing time was included in the data for plowing and planting.

For Darwin, we have separate information on each of the following operations: (1) applying organic manure; (2) planting; (3) weeding, cultivating, and transplanting; (4) harvesting; (5) land improvement, including plowing. Application of fertilizer was not recorded separately and is believed to be included in the figures for either manure application or land improvement. The data pertaining to land improvement are not classified by crop.

The data are roughly comparable between samples with one exception: the Chiweshe planting figures have been combined with figures for plowing, whereas the Darwin planting figures are presented alone.

Table 4:7 shows the mean input per farm of labor, classified by farm operation

[13] The first three goups together constitute family labor.

TABLE 4:7.—HOURS WORKED PER FARM, BY OPERATION AND MONTH: CHIWESHE AND DARWIN*

	Manure application		Plowing, planting		Weeding, cultivating, transplanting		Harvesting		Land improvement		Total	
Month	Chiweshe	Darwin	Chiweshe	Darwin[a]	Chiweshe	Darwin	Chiweshe	Darwin	Chiweshe	Darwin[b]	Chiweshe	Darwin
September	2.31	...	—	...	—	...	—	...	—	...	2.31	...
October	39.70	43.15	3.88	1.15	—	—	—	0.60	—	550.40	43.58	595.30
November	11.04	74.35	160.56	91.50	5.19	4.05	—	—	—	589.20	176.79	759.10
December	0.36	15.15	48.06	339.30	119.23	128.30	—	—	—	354.05	167.65	836.80
January	—	1.80	—	143.25	210.90	643.50	—	—	—	83.65	210.90	872.20
February	—	20.65	—	8.55	116.17	617.70	—	5.35	—	68.65	116.17	720.90
March	—	11.75	—	2.45	11.19	257.50	33.76	188.40	—	269.90	44.95	730.00
April	—	13.30	—	—	0.54	6.35	178.09	648.75	—	86.60	178.63	755.00
May	—	2.40	—	—	—	—	164.66	659.15	—	216.55	164.66	878.10
June	—	—	—	—	—	—	1.56	597.70	—	222.05	1.56	819.75
July	—	17.95	—	—	—	—	—	429.55	—	229.85	—	677.35
August	—	49.70	—	—	—	3.20	—	24.60	—	209.25	—	286.75
September	...	35.15	...	—	...	—	...	—	—	371.05	—	406.20
Total	53.41	285.35	212.50	586.20	463.22	1,660.60	378.07	2,554.10	—	3,251.20	1,107.20	8,337.45

* Hours spent on corn, peanuts, and millet only except for the land improvement category which was not classified by crops. In Tables 4:8 through 4:10, the land improvement category is omitted, making the total for Darwin 5,086.25. Dots (...) indicate that data are not available; blanks (—) indicate 0.

[a] Planting only.

[b] Including plowing.

and month, for each sample. In aggregating over groups, man-hours, woman-hours, and laborer-hours are treated as equal in value, and child-hours and social-hours are weighted by one-half. Several points emerge from the table. First, the average labor input is much greater in Darwin than in Chiweshe, despite the larger family size in Chiweshe. The difference is especially pronounced during slack seasons, when Chiweshe labor input declines sharply.

In Chiweshe, labor input reaches a peak from November through February, and again in April-May at harvesting time. The input of labor in January was nearly twice the mean monthly labor input for the ten-month crop year. The table shows quite clearly the seasonal character of labor input on farms in Chiweshe Reserve.

Some work performed during the year, especially during slack seasons, is not recorded in the survey. Examples are shelling, pounding, and grading the crops —performed during the summer months (June-August); herding cattle; and building and repairing farm structures (the family's house and grain storage bins). Nevertheless, even taking account of these additional chores, there is a marked seasonal character to the expenditure of labor.

There is much less seasonal variation in the Darwin figures. The principal explanation is that land improvement tends to be performed when other tasks are less pressing. In addition to plowing, land improvement includes contouring, ridging, building dams, and other jobs that relate directly or indirectly to crop production, but excludes shelling, pounding, and grading, as well as any tasks not connected with crop output (such as herding cattle). It thus corresponds to a type of work that is not performed in Chiweshe, rather than to work that was performed but not recorded. In fact, one of the principal differences between the two areas is the large expenditure of time on land improvement—more than one-third of the total Darwin labor input.

The timing of the farm operations is similar in the two samples. Planting is continued until later in the season in Darwin. Harvesting is also carried on until later in Darwin, perhaps because planting is spread out over a longer period. Manure application and plowing (not shown separately here) are performed only during the beginning of the crop year in Chiweshe, but continue throughout the year in Darwin.

The fact that some farm operations are carried on over such a lengthy period in the samples as a whole does not necessarily mean that individual farms spread their labor to this extent. The length of (say) the harvesting period is due in part to the different times at which the crop ripens on different farms, which is due in turn to differences among farms in planting dates.

Table 4:8, Part A shows hours worked per farm in the two samples by group and by crop. In Chiweshe, there is a tendency for men to spend relatively more time on corn, leaving more of the work on peanuts and millet to the women. All told, women work roughly 50 per cent more than men in the Chiweshe sample. In Darwin, by comparison, women work only 20 per cent more than men. Children do relatively less work in Darwin than in Chiweshe, in part because there are fewer children in the area sampled. Men and women in Darwin appear to work on each of the three crops in roughly the same proportion.

Table 4:8, Part B presents hours worked per farm by operation and group.

TABLE 4:8.—HOURS WORKED PER FARM BY LABOR GROUP AND CROP (A), OR OPERATION (B): CHIWESHE AND DARWIN*

Crop or operation	Men		Women		Children		Hired laborers		Social[a]		Total[b]	
	Chiweshe	Darwin	Chiweshe	Darwin	Chiweshe	Darwin	Chiweshe	Darwin	Chiweshe	Darwin	Chiweshe	Darwin
A: HOURS PER CROP												
Corn	226	1,103	287	1,252	191	265	0	156	0	44	610	2,666
Peanuts	93	748	177	945	79	207	0	30	0	10	310	1,833
Millet	61	231	99	306	54	45	0	12	0	31	187	587
Total	380	2,082	563	2,503	324	517	0	198	0	85	1,107	5,086
B: HOURS PER OPERATION												
Manure application	31	119	15	123	14	6	0	39	0	1.4	53	285
Plowing and planting[c]	89	217	91	300	64	90	0	24	0	.4	212	586
Weeding, transplanting, and cultivation	148	675	250	799	127	203	0	76	0	16.9	463	1,661
Harvesting	12	1,071	206	1,281	118	218	0	59	0	66.6	378	2,554
Total	380	2,082	563	2,503	324	517	0	198	0	85.3	1,107	5,086

* All figures for Darwin exclude plowing; see notes on Table 4:7.

[a] Farm family and friends; see text.

[b] Weighted total with children and social at .5.

[c] For Darwin planting only.

TABLE 4:9.—HOURS WORKED PER FARM (A), OR PER ACRE (B), BY CROP AND OPERATION: CHIWESHE AND DARWIN

Operation	Corn		Peanuts		Millet		Total	
	Chiweshe	Darwin	Chiweshe	Darwin	Chiweshe	Darwin	Chiweshe	Darwin
				A: HOURS WORKED PER FARM				
Manure application	53.41	285.35	0	0	0	0	53.41	285.35
Plowing and planting	125.34	313.10[a]	58.38	231.45[a]	28.78	41.65[a]	212.50	586.20[a]
Weeding, transplanting, and cultivating	273.71	1,019.25	99.83	415.80	89.68	225.55	463.22	1,660.60
Harvesting	157.73	1,048.80	151.34	1,185.50	69.00	319.80	378.07	2,554.10
Total	610.19	2,666.50[a]	309.55	1,832.75[a]	187.46	587.00[a]	1,107.20	5,086.25[a]
				B: HOURS WORKED PER ACRE				
Manure application	6.73	18.55	0	0	0	0	6.73	18.55
Plowing and planting	15.79	20.35[a]	37.89	42.12[a]	25.47	14.24[a]	20.01	24.74[a]
Weeding, transplanting, and cultivating	34.49	66.25	64.79	75.66	79.37	77.14	43.62	70.07
Harvesting	19.87	68.17	98.22	215.76	61.06	109.37	36.45	107.81
Total	76.88	173.32[a]	200.90	333.54[a]	165.90	200.75[a]	106.81	221.17[a]

[a] Excluding plowing; see notes on Table 4:7.

Again, specialization by sex appears to be more prominent in Chiweshe than Darwin. Manure application, for example, is largely a man's job in Chiweshe; by contrast, weeding and harvesting are performed largely by the women. In Darwin, men and women roughly contribute in the same proportion to all operations.

Table 4:9, Part A classifies hours worked per farm by crop and operation. In Chiweshe, corn and millet each require more labor for weeding than for any other operation, while peanuts is a harvesting-intensive crop. In Darwin, harvesting is the principal use of labor for all three crops.[14]

Table 4:9, Part B presents hours per acre by crop and operation. This table demonstrates the greater labor commitment of the Darwin farmer. Despite his larger holding and smaller family, he works more hours per acre of cultivated land for all three crops. This reflects in part the higher yields in Darwin and the correspondingly higher requirements for harvesting. But the Darwin farmer also spends more time per acre applying manure (he uses much more, as we have already noted) and weeding. (The planting figures are, as already noted, not comparable.) This is particularly important when one bears in mind that an important class of labor—land improvement—has been omitted from the table. And, although the Darwin farmers use some hired labor, we have already seen that the bulk of the work is done by the farm family. Basically the difference is that (1) a larger proportion of the Darwin farm family remains in the area throughout the year to work in the fields, and (2) those on the farm work longer hours.[15]

Another point worth noting is the difference in labor-land ratios among crops.

[14] This reflects the higher yields obtained in Darwin.
[15] Also, males play a larger role in agriculture in Darwin than in Chiweshe.

In both areas, peanuts have the highest labor-land ratio, and corn the lowest; more labor per acre is expended on production of peanuts than on either of the other crops at both planting and harvesting time, but the labor-land ratio for weeding is highest for millet.

Government Rating

In Chapter 2 we referred to the government rating of African farmers according to certain objective criteria—in particular, according to their willingness to adopt soil conservation measures. An individual is classified as a Master Farmer, Plotholder, or Cooperator, according to the extent of his cooperation with the agricultural extension workers (Master Farmer being the highest rating). We noted that, in a sample of farms throughout Rhodesia, the average yields tended to reflect the farmers' ratings.

We have no information concerning the rating of farmers in the Darwin sample. We believe that most farmers in the sample—and especially those settled in the area since 1953—are Master Farmers. In the Chiweshe sample, we do have information regarding each farmer's rating. Of the 56 farmers in the sample, 3 are Master Farmers, 4 Plotholders, and 14 Cooperators. Owing to the small numbers, we have lumped together the Master Farmers and Plotholders, referring to this combined group as "skilled" farmers. Following the same terminological scheme, the 14 Cooperators were termed "semiskilled" farmers; and the remaining 35 farmers were referred to as "unskilled."

The value of crop output is substantially different among the three groups (Table 4:10), the output of semiskilled and skilled farmers, respectively, was 40 and 105 per cent greater than the output of unskilled farmers. Associated with the differences in output are differences in total cultivated acreage, so that yield varies much less than output among groups. Both skilled and semiskilled farmers obtained higher yields than unskilled farmers but, of some interest, semiskilled farmers received a higher yield than skilled farmers. There is a reason to believe that the government figures contain an unward bias, so that the actual differences among groups may be less than the table shows.[16]

TABLE 4:10.—COMPARATIVE ECONOMIC PERFORMANCE OF SKILLED, SEMISKILLED, AND UNSKILLED FARMERS IN CHIWESHE*

Measure	Classification		
	Skilled	Semiskilled	Unskilled
Total crop output (*U.S. dollars*)	138.96	94.80	67.64
Total cultivated area (*acres*)	16.20	10.61	9.53
Yield (*U.S. dollars per acre*)	8.58	8.93	7.10

* See text for description of classifications.

[16] In Chapter 11, we discuss the intergroup differences in more detail and attempt to explain why the differences in yield are not more pronounced.

Chapter 5

ATTITUDES, OBJECTIVES, AND PRICES

A farmer's crop output is determined by the resources at his disposal, by the technological relationship between output and inputs, and by natural forces such as the amount and distribution of rainfall. With respect to natural forces, Chiweshe and Darwin are roughly comparable. Although the surveys were taken in different years, the 1960–61 crop year in Chiweshe and the 1961–62 crop year in Darwin were both regarded as average. Most farms in the Darwin sample are in Natural Region II, as are the Chiweshe farms; a few of the Darwin farms are in Natural Region III, and consequently receive less rainfall. However, the difference in climate among farms in Darwin is not great.

There is little reason to suppose that the level of crop technology is significantly greater in Darwin than in Chiweshe. Although Darwin farmers use some farm implements not found in the Chiweshe sample, the techniques of production are not basically different in the two areas. Farmers in the two areas are likely to operate on the same production function; but the Darwin farmers operate further out on this function than do the Chiweshe farmers. Our hypothesis is that differences in output are attributable not to different techniques of production but to differences in inputs.[17]

It is useful to distinguish between two sets of inputs: (a) those that the farmer regards as data, that is *exogenous* variables; and (b) variables whose magnitude the farmer can influence, that is, *decision* variables. The hypothesis set forth here can be simply stated: (1) there is a difference in economic opportunity between Darwin and Chiweshe attributable to differences in the levels of the exogenous variables; (2) this difference in economic opportunity is responsible for the different approaches to farming taken by the two groups of farmers; (3) these differences together with the difference in economic opportunity lead to further differences in the levels of use of the decision variables.

The exogenous variables include the arable acreage at the farmer's disposal, the quality of the soil, and the type of tenure. As Chapter 4 revealed, the acreage cultivated by the Darwin farmer was more than double that cultivated by the Chiweshe farmer. Moreover, the Darwin farmer cultivates only a part of the arable acreage at his disposal. His cultivated acreage is limited by the availability of cooperating inputs—especially labor—whereas the Chiweshe farmer is constrained by the size of his arable plot.

Another difference between Darwin and Chiweshe relates to the form of land tenure. Although there is no direct evidence on the importance of freehold tenure versus tribal tenure, one can conjecture that freehold has played a large role in providing the purchase area farmer with greater economic opportunity

[17] Although not necessarily only those inputs that have been recorded in the surveys.

than the reserve farmer. The greater security of tenure in a purchase area is conducive to investment in the land and may go a long way toward accounting for the purchase area farmer's greater commitment to farming. Freehold tenure encourages the farmer to invest in his land—to maintain soil fertility. Although the Darwin soils were considered to be not significantly greater in inherent fertility than the Chiweshe soils, the Darwin farmers have been noted for maintaining the fertility of the soil through investment in the land, while such investment has not occurred in Chiweshe.

Freehold tenure also enables the purchase area farmer to pledge land to secure credit. The reserve farmer, with land ownership vested in the tribe, cannot use his land as security for a loan. Purchase area farmers do in fact have greater access to credit than do reserve farmers, and are consequently better able to invest in fixed capital and to purchase fertilizer, seeds, pesticides, and other inputs. To a large extent, the larger capital stock of the Darwin farmer is a result of his greater ability to borrow.[18]

Because the Darwin farmer has more land, has freehold title to his land, and is accordingly able to pledge his land as security, he is more likely to improve his holding. In a real sense, this institutional difference between Darwin and Chiweshe provides the Darwin farmer with greater economic opportunity. This greater economic opportunity of the Darwin farmer affects his attitude toward farming; his willingness to improve his holding; his allocation of land among crops; his use of fertilizer, manure, and labor; and his interest in developing new skills.

The difference in economic opportunity is notably manifested with respect to the returns to labor. The Chiweshe farmer has a larger family available to work on the farm, but he has a smaller holding, and the fertility of the soil is lower. He also has limited credit facilities with which to purchase fertilizer and other inputs. Because of the relatively high ratio of labor to other inputs, the marginal productivity of labor tends to be low in Chiweshe agriculture, and the Chiweshe farmer finds that it does not pay him to remain full time on the farm. He can obtain a greater income—or a given income more easily—by spending part or all of his time in wage employment. This explains the absence of farmers for extended periods of time.

At the same time, the farmer is usually reluctant to sever all ties with the reserve. For one thing, many Rhodesian Africans have a strong emotional attachment to land. To retain their rights to cultivate, the farmers are required to keep one foot in the reserve. There may also be sound economic reasons for not giving up the reserve holding. Jobs are relatively scarce in Rhodesia, so that it may be impossible for a farmer to find work for his wife and older children; the opportunity cost of their labor can be regarded as low or zero. Also, wages in town may be little more than enough to support the man himself! The farmer may leave his family in the reserve to cultivate the plot of land. He then returns for visits, and may return also at peak periods to help with the crop. The wife and children then assume primary responsibility for maintaining the farm, while the head of the household devotes himself to earning a supplemental wage income. A division of

[18] A requirement of buying a purchase area plot is the possession of a certain amount of capital. Thus the Darwin farmers began with a greater stock of wealth.

labor develops: the wife and children are charged with producing the family's food needs, and the head of the household earns a cash income to satisfy the non-food consumption demand.

The pattern of farming practiced in the reserves has shown itself to be compatible with extensive temporary labor migration into the cash sector in search of paid employment. The head of the household can be spared from agriculture for long periods of time without seriously impairing crop output. In fact, the absence of adult males ties in nicely with long-established social patterns, according to which the routine agricultural operations are performed largely by women and children. Migration relieves pressure on the land by reducing the number of mouths to be fed from subsistence production; at the same time, the wage earners are able to provide the family with a small supplemental cash income (*1*).

Because the Chiweshe farmer splits his time between the farm and wage employment, he develops a real commitment to neither. His visits to the city are regarded as only temporary, even though some visits may last for a year or longer. He regards as his home the farm where his family is resident. At the same time, however, he does not find it worthwhile spending time and effort to acquire new farming skills, learning new techniques of production, and working long hours; and without the full-time residence in the area of the head of the household, the remainder of the family is less responsive to new ideas and to change.

This model of subsistence agriculture does not assume that the marginal productivity of labor is zero in the reserves. On the contrary, the marginal productivity of labor is highly unlikely to decline to zero. Before this point is reached, the farmer finds it profitable to migrate and to work for wages in the city or on a European estate. It is likely that total output would be raised if more work were performed on a reserve farm. But the work is not forthcoming because the marginal return to this additional labor is too low relative to alternative employment opportunities and relative to the disutility of labor.

The Darwin farmer, on the other hand, has an opportunity to earn a large enough income from farming to make it worth his while to work full time on the farm. To him, the wage rate paid for work in the European sector of the economy is not high enough to attract him to these areas. He devotes his time to sound farming, works long hours on the farm, and makes a much greater attempt to improve his technique of production. In other words, he develops a "commitment" to good farming.[19] This greater commitment contributes to the Darwin farmer's higher labor-land ratio (despite his larger acreage and smaller family). Together with the differences in systems of tenure, it also contributes to the greater willingness of the Darwin farmer to invest in the land, to improve his holding, and to use more fertilizer.

The difference in orientation is reflected also in differences in the allocation of land among crops. Because the Chiweshe farmer is able to produce only enough to feed the family, with possibly a small surplus, the pattern of farming is dictated primarily by subsistence needs. Production for sale is regarded as only

[19] By commitment to farming, we intend to convey the notion of a farmer who takes seriously the management of his farm and who makes a genuine attempt to increase farm output. Commitment is obviously one of the components of management ability (others being inherent ability and education or training).

a subsidiary activity; cash income is derived primarily from wage earnings, not from crop production.

The emphasis on subsistence is strengthened by the variability in crop yields from year to year, and in the spread between wholesale and retail prices. If there were no variation in crop yields from year to year, the Chiweshe farmer could allocate his resources to produce just enough for subsistence requirements, and then maximize the market value of the surplus. But yields are highly variable. Variability of yields would not in itself be a problem if there were a perfect market in which the farmer could exchange his more plentiful crops for the scarcer crops. But the market is highly imperfect. A farmer may be able to exchange crops locally with his neighbors. But in the event of a widespread shortage of a staple crop, the farmers are forced to buy from the Grain Marketing Board. And, as we have noted, the GMB selling price for (say) corn is two and one-half times the buying price. The price spread inhibits specialization and puts a premium on achieving self-sufficiency in food production.

A Chiweshe farmer places great value on self-sufficiency. His primary objective is to provide each year, with high probability, sufficient quantities of each crop to satisfy the family's demand for food. Because of the annual variations in yields, farmers plan to grow more of each crop than their anticipated needs. Because of the spread between the GMB buying and selling prices, the cost of a shortfall is greater than the gain from a surplus. It consequently makes sense for the farmer to focus on reducing the probability of a shortfall.[20]

In Chiweshe, each farm family has some preferred pattern of consumption of the principal food crops. In any year, somewhat more of the relatively plentiful crops and less of the relatively scarce crops are consumed. In a good year, when crop output is above average, more of all crops are consumed. But the marginal propensity to consume food is less than unity. In a good year, part of the increased crop output is sold for cash to buy other goods, or to buy cattle.

In Darwin, the farmer's objective function is more likely to be formulated in terms of total output than in terms of subsistence needs. A substantially larger share of output is marketed; indeed, the chief source of cash income is crop production. The allocation of land among crops is consequently more oriented toward market sales and less toward subsistence than is the case in Chiweshe.

The local price of a crop tends to be close to the Grain Marketing Board purchase price, except in years of a widespread shortage, at which time the local price may be substantially above the GMB price. In the present case, the local prices for corn and peanuts were approximately equal to the respective GMB prices, but the local price for millet was nearly triple the GMB price. The divergence between the local and GMB millet price raises the question of which price is the more appropriate in valuing output. In the descriptive material presented in Chapter 4, millet was valued at the local price. Farmers producing a surplus for sale may be influenced in their resource allocation by either the GMB or the local price. However, as only one farm sold millet to the GMB, and as we suspect several farms exchanged millet locally, the local price appears more relevant. Moreover, the

[20] In other words, the farmer considers not only the expected return from each crop, but also the variance. Because of the disastrous effects of a food shortage, he is highly risk averse, and this tends to increase his reliance on subsistence production.

subsistence farmer probably regards the local price as the price he is likely to have to pay for the crop in the event his own production falls short of consumption needs.[21] In other words, the local price is regarded both as the opportunity cost of the crop in the event of a surplus and as the replacement cost of the crop in the event of a shortfall.

The subsistence orientation of the Chiweshe farmer and the importance he attaches to security and self-sufficiency raise some conceptual problems with regard to the valuation of output. In the 1960–61 crop year only 6 farms in the Chiweshe sample sold in excess of 10 per cent of their total crop output to the GMB, and most farmers sold none. If farmers focus on producing their subsistence requirements and produce little or no grain for sale, then they are little influenced by market prices. In this case, the valuation of output at market prices may have little meaning.

Similarly, it is misleading to use market prices in appraising a farmer's economic performance. To allocate resources efficiently, a farmer should equate the marginal productivity of each resource in every use and should use each marketed resource up to the point where its marginal productivity equals its marginal cost. But if the farmer emphasizes security rather than profit maximization, then the standards of efficiency are different. One cannot gauge efficiency by examining economic performance in a single year only; rather it is necessary to have time series data, to permit analysis of the farmer's success over time in achieving self-sufficiency.[22] Unfortunately, this information is not available to us in the present study.

In Darwin, prices present less of a problem. Because output is market oriented, one would expect the farmer's allocation of resources among crops to be influenced strongly by market prices. Despite the spread between the GMB wholesale and retail price of grain, and despite the uncertainty of crop yields, the Darwin farmer is sufficiently beyond the margin of subsistence not to be overly concerned with the likelihood of a shortfall. Self-sufficiency is of less concern to him than the expected value of total crop output.

[21] Unless there is an areawide shortfall.
[22] Or else to have information on variability of crop yields and prices.

Chapter 6

A MODEL OF PRODUCTION

The production function is a technological relationship between output and a set of factor inputs. In the present study the production of each crop is treated as a separate activity; and output of each crop is expressed as a function of a set of factor inputs. Some factors that are believed to influence the levels of crop output were not recorded in the surveys and are accordingly not included in the production functions. The factors that have been observed and that are hypothesized to be arguments in the production functions are: land, labor, chemical fertilizer, organic manure, fixed capital, soil type, and management.

Chapter 4 describes each of these variables and how they enter the production process. However, in specifying the production function, several problems of definition and measurement arise. These are dealt with in the present chapter.

Land and Soil Type

Land presents no problems. Land input is measured simply in acres planted to each crop.

Soils in each sample are classified according to certain physical properties. The discussion in Chapter 4 revealed that yields differ from one type of soil to another. It is therefore important to introduce soil type into the production function, so as to eliminate its effects from those of other variables.

In Chiweshe, two types of soil were distinguished. To distinguish between farms on red loam and farms on sandy soil, a soil dummy variable was used; this variable takes on the values unity and zero for farms with red loam and sandy soil, respectively. The coefficient associated with the soil dummy variable in the production relationship is then a measure of the net contribution to output of red loam as compared with sandy soil.

In Darwin, with a sufficiently large sample, we could define a dummy variable for each of the four soil types; we could then include three of these dummy variables (deleting the fourth to avoid a singular matrix) in the production function. This would yield a coefficient for each soil type. But the sample was too small to proceed in this way. Instead, soil types were combined into two groups: "good" soil, consisting of brown sand and red loam; and "bad" soil, consisting of clay loam and black cotton. The dummy variable is then assigned a value of unity if the farm has either brown sand or red loam; and a value of zero otherwise.

Fixed Capital

As an index of a farm's fixed capital inputs, the value of farm implements (at undepreciated initial cost) was used. This index is subject to criticism on several counts.

First, it omits two important components of the capital stock: accumulated investment in the land, and the services of draft animals. Neither of these was recorded in the surveys.

Second, there is a very imperfect relationship between the book value of capital on the farm and the flow of capital services in the production function sense. Visits to Chiweshe Reserve, for example, revealed in many instances that items of equipment were lying idle in the field. Rather than attempting to determine which implements were serviceable and which not—probably an impossible task, at any rate—we merely enumerated all items present on each farm. Darwin farmers kept their implements in a better state of repair, so that the book value of implements may be a better approximation to capital input in Darwin than in Chiweshe.

Third, even if the book value of implements can be regarded as a good measure of the flow of capital services, we have no information on the extent to which implements were used for one crop rather than another.[23] Therefore, we considered capital as a "joint" input equally available for use in all crops. To the extent that work on different crops proceeds sequentially, this assumption appears reasonable. In both samples there is evidence that the farm focuses on one crop at a time; it typically does not work on two or more crops simultaneously, so that the demand for capital in different uses is not usually competitive.

In Chiweshe, a further difficulty arises from the fact that many farms share implements with adjoining farms (usually this occurs among members of the same family group). In such a case, it is difficult to determine how much use each farm obtains from the implements. We have employed the arbitrary procedure of dividing the joint value by the number of farms sharing.

A related difficulty arises when one farm owns a piece of farm equipment but rents or lends it to a neighbor. Although the neighbor has the use of the item, he uses it at the convenience of the owner. For example, a farmer owning a plow may use the plow first, lending it to a neighbor or a relative later in the season. Although each may use the plow, the owner can choose when to use it, while his neighbor is forced to plow his field only when the plow is available. We have ignored lending of implements and have treated capital as an input for the owner only.

Labor

Labor used in producing each crop has been classified according to: (1) the group performing the labor; (2) the time at which the work was performed; and (3) the farm operation performed. The hours performed by the different groups were added to form a composite labor index. In doing so, the hours worked by male and female adult members of the family, and by hired workers, were weighted equally; child-hours and social-hours[24] were each weighted by one-half the value of a man-hour.

Next, consider the timing of farm operations. An hour worked at one time of the year need not be worth the same as an hour worked in a different time period. On the contrary, there is a definite time pattern that labor use must

[23] This presents no problem if the allocation among crops of services from a given stock of capital is the same on all farms.

[24] See Chapter 4 for a definition of social-hours.

follow. Although some variation may be permissible, a severe penalty will attach to sharp deviations from the pattern.

With sufficient data, one could estimate a set of time coefficients that could be used to weight each unit of labor input. The limitations of the data did not permit this to be done here. Instead it was assumed that the timeliness of carrying out different farm operations did not lead to significant differences in output among farms.

Third, consider the distinction among farm operations. In the Chiweshe sample, for each crop, we have data on planting (including plowing); weeding (including cultivating and transplanting); and harvesting. For corn, there is also information on the time spent on manure application. For Darwin, there is a similar breakdown of labor-hours, except that plowing and planting data were considered insufficiently reliable to use in the model.[25]

One way to construct a labor index is simply to add the hours spent on each operation to obtain the total hours worked by each farm on each crop. However, there is reason to believe that this would yield misleading results. Consider, for example, a simplified Cobb-Douglas production function, written in the logs,

$$Q^* = \alpha L^* + \beta T^* \tag{6.1}$$

where Q = output, L = labor, T = land, and where * denotes a log. Consider also that $L = L_1 + L_2$, where L_1 = weeding hours, and L_2 = harvesting hours. Then by writing the function as in (6.1) one implies that the cross partial derivative between land and either weeding or harvesting is positive, but the cross partial between weeding and harvesting is negative. In other words, it is assumed that the marginal productivity of a given amount of harvesting labor is increased by an increase in land, but reduced by an increase in weeding. The former is plausible, but the latter is not. It appears more realistic to treat weeding and harvesting not as substitutes but as complements (where the cross partial is positive).

In the case of different time periods and different groups, aggregating by addition makes good sense. If men work more hours, the marginal return to a woman-hour is reduced—assuming that men and women do approximately the same kind of farm work. Similarly, if more time is spent weeding in January, the return to a weeding hour in February is likely to be reduced. But if more time is spent weeding, the return to harvesting time should *increase.*

The method of aggregation would be immaterial if each farm spent the same proportion of its time on each operation. In this case, any one operation, or their sum, could equally well be used as an index of labor use. But this is not the case in the samples discussed here. Consequently, we decided to regard the four principal operations as separate inputs.

First, consider the application of organic manure. This consists of carting manure compost from the cattle *kraal,*[26] to the field and applying it to the soil. It is obvious that the amount of manure used and labor time spent in applying it are highly complementary inputs. One may argue that there is some tech-

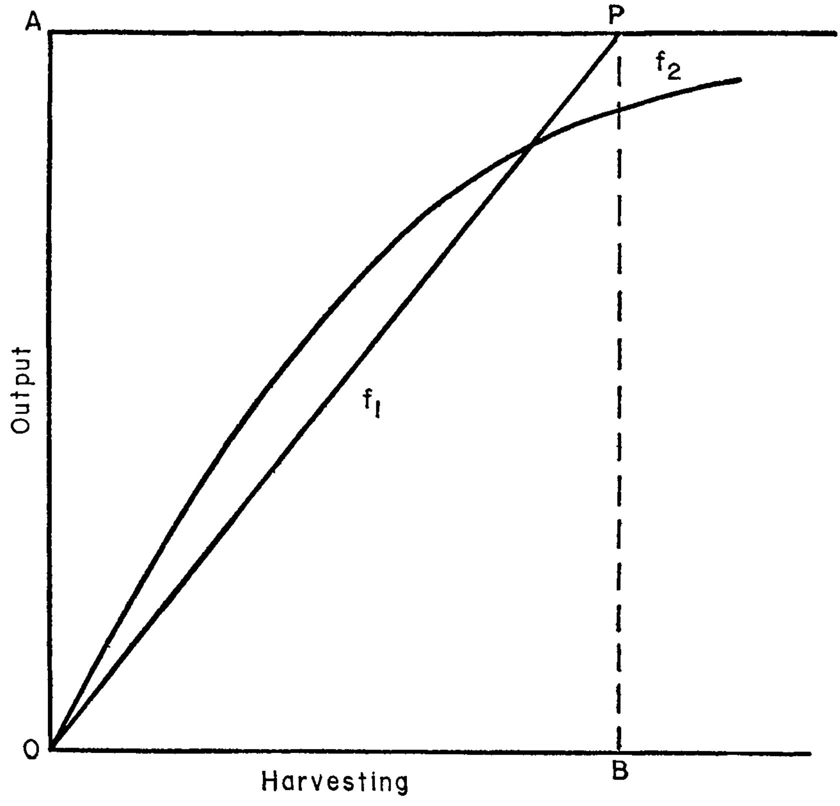
[25] The average figures discussed in Chapter 4 are probably reasonably reliable; but there were discrepancies in the figures for individual farms, making it unwise to use plowing or planting in the regression analysis.

[26] The enclosure where cattle are kept at night.

nological tradeoff between them: perhaps more time spent applying a given amount of manure results in a greater output. But, even if such tradeoffs exist, they are unlikely to show up in the data, given the "noise" level. More likely, differences among farms in time spent applying a ton of manure represent extraneous factors: intensity of effort, availability of a scotch cart for transporting the compost, and distance from the *kraal* to the fields. As a result of these considerations, it was decided to regard manure and manure application as used in fixed proportions,[27] and to delete manure application from the production function.

Next, consider harvesting. It is convenient to distinguish between actual and potential output. Potential output can be defined as the maximum output a farm can obtain, however much time it spends on harvesting. This is shown in Figure 1 as the distance OA. Potential output is the amount of crop that matures in the fields, whether or not harvested. Actual output is only that part of potential output that is harvested; in Figure 1, actual output is related to harvesting by two alternative functions: f_1 and f_2. Curve f_2 is asymptotic to the horizontal line extending from point A. This function implies forever diminishing returns to harvesting so that actual output is always less than potential output for any finite

FIGURE 1.—ACTUAL AND POTENTIAL OUTPUT



[27] Some heuristic calculations supported this view.

amount of time spent harvesting. Curve f_1 implies constant returns to harvesting up to point P and zero returns beyond that point; if harvesting times equals OB, actual and potential output are equal.

In both samples harvesting is done by hand, without the aid of complementary inputs. Constant returns to harvesting is probably a fairly realistic assumption. Moreover, in both samples virtually all of the potential output on each farm was harvested. The return to harvesting was sufficiently high that nothing was left in the fields.[28] Therefore, each farm's actual output can be regarded as equal to its potential output and one can regard harvesting as perfectly complementary with, and determined by, the levels of use of the other inputs. It would consequently be redundant to include harvesting in the production function as a separate input.

Perhaps a more important reason to omit harvesting from the production function derives from the identification problem that would result. Letting $Q =$ actual output, $Q_p =$ potential output, $H =$ harvesting labor, and $x =$ a vector of inputs other than harvesting, we can write

$$Q_p = \phi(x) \tag{6.2}$$
$$Q = \psi(Q_p, H) \tag{6.3}$$
$$H = H(Q_p) \tag{6.4}$$

With observations on all variables, both (6.2) and (6.3) would be identified. However, in the absence of observations on Q_p, the best we can do is to combine (6.2) and (6.3) to obtain

$$Q = f[H, f(x)] \tag{6.5}$$

Now (6.5) would be identified if H were exogenous. However, consider that nearly all of the potential output was harvested, so that Q and Q_p were nearly equal. Then it would be approximately correct to regard H as a function of Q, in which case (6.5) would be underidentified. Clearly, the extent of this difficulty depends on the extent to which Q and Q_p tend to be equal. In the absence of direct observations on Q_p, this must remain a matter of judgment. In our view, the unharvested output was sufficiently small in both samples to justify leaving harvesting out of the production function.

That leaves weeding and (in the case of Chiweshe) planting. Unlike manure application and harvesting, weeding is only imperfectly complementary with other inputs. The amount of time a farm devotes to weeding is likely to be related to the farm's acreage, but there is scope for substitution between weeding and other inputs. If more time is spent weeding, the yield obtainable from a given acreage will be greater. It follows that weeding should be explicitly included in the production function.

We would expect planting (and plowing) time to be less variable than weeding time: given the number of acres and the type of soil, planting requirements might be fairly well fixed. However, there is some possibility that greater care

[28] Note in Chapter 4 that the peak labor input was reached in Chiweshe during weeding time (January) rather than harvesting time, suggesting that labor was not a limiting factor at harvesting time. Although this is due in part to the greater presence of men in the reserve in January than in April and May, women also worked longer hours in January. In Darwin, the peak labor use was in May, so the assumption of no labor shortage at harvesting time is subject to greater doubt.

in preparing the soil is rewarded by a higher yield. Thus we tentatively included planting in the Chiweshe production functions.

Both weeding and planting can be expected to be complementary with land. We believe that they are likely also to be complementary with each other, at least in the relevant range of the production function. We therefore entered the two uses of labor multiplicatively, in the labor index,

$$L_{ij}^* = \lambda_{1i} L_{1ij}^* + \lambda_{2i} L_{2ij}^* \qquad (6.6)$$

where L_{ij} is farm j's labor used in producing crop i; L_{1ij} is farm j's weeding time spent on crop i; L_{2ij} is farm j's planting time spent on crop i; and * denotes a logarithm.

For all three crops, planting made only a negligible contribution to the explained variance, and had the wrong sign in two of the three production functions. For this reason planting was excluded from the final formulation of the production functions.

One interpretation of the insignificance of planting in the three production functions is that this activity is carried to the point where its marginal productivity is very low—possibly even zero. A more plausible explanation, though, is that there is multicollinearity in each production function. Possibly, given the technique of production available to Chiweshe farmers, there is little or no opportunity for substitution between planting and other inputs. Alternatively, and more likely, certain procedures may have become so fixed over time by custom that substitution, although technologically possible, did not take place.

Organic Manure and Chemical Fertilizer

As we discuss below, the production function used in this study is a modified Cobb-Douglas. In a Cobb-Douglas function, no output is obtainable if any input takes on a zero value.[29] This assumption is plausible with respect to labor and land, but is implausible with respect to organic manure and chemical fertilizer. We know that some output can be obtained without the use of either of these inputs. These are *inessential* inputs, and must be handled differently from more conventional inputs such as land and labor.

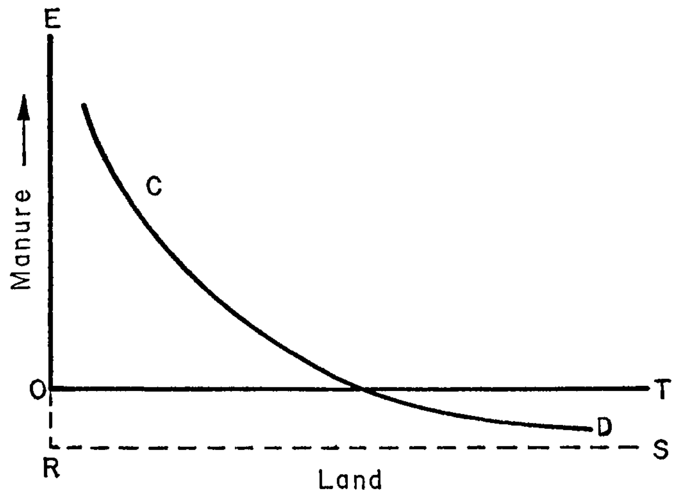
Consider first manure. Let M' = the number of tons of manure compost applied to the soil. Then let $M = M' + C$, where C is some positive constant. Then M will be positive for all observations, and its log will be defined even when $M' = 0$.

In Figure 2, manure is measured along the vertical axis, OE; and land along the horizontal, OT. The curve CD is a Cobb-Douglas isoquant showing the tradeoffs between manure and land for fixed quantities of other inputs. Instead of being asymptotic to OT, the isoquant is asymptotic to RS. The distance $RO = C$ is a measure of natural soil fertility.

Ideally, one would estimate C and the regression coefficients simultaneously. But such a procedure is expensive to program for a computer, especially using the analysis of covariance model set out in Chapter 7. Consequently, we followed

[29] The practical counterpart of this point is that the log of zero is not defined, so that the regression equation cannot be estimated if (as is the case here) any variable takes on zero values.

FIGURE 2.—A MODIFIED COBB-DOUGLAS ISOQUANT



the somewhat less satisfactory procedure of trying several arbitrary constants, inspecting the residuals in each case, and choosing the constant that seemed best to explain output when no manure is used. The constant chosen was 100. As noted earlier, manure is used only in the corn production function.

In the Chiweshe corn production function, fertilizer is handled in the same way as manure. Letting $F' =$ pounds of fertilizer, we defined $F = F' + C$, where $C = 100$.

Because so few farms in the Darwin sample used fertilizer, we decided against using the value of fertilizer as a variable in the Darwin corn production function. Instead, we employed a dummy variable, taking on the value unity for a farm that used fertilizer, and zero otherwise.

Management

Management is the most difficult input to deal with, both conceptually and empirically. The concept can embrace a variety of characteristics of a farm. First, there is technical efficiency, which refers to output per unit of input, where the inputs are aggregated in some manner. For example, yield and the output-labor ratio are measures of technical efficiency, as is a residual from the production function. A different characteristic is allocative efficiency, which refers to the efficiency with which inputs are combined. An efficient farmer in this sense is one who allocates resources so that each marketed resource is used up to the point where its marginal value product is equal to its price; and each resource available in fixed supply is allocated among crops so as to equate its MVP in each use. In African peasant agriculture, a farmer who allocates resources efficiently is one who takes advantage of opportunities for substituting one input for another. Although one would expect to find a high correlation between technical and allocative efficiency in a cross-section of farms, this need not be the case.

Two measures of management are employed in the present study: (1) the government rating and (2) estimated residuals from the production function.

The second measure is discussed in Chapter 7; we shall discuss the government rating here.

In the Chiweshe sample, as noted in Chapter 4, farmers have been grouped into three categories—skilled, semiskilled, and unskilled—according to their rating by the agricultural extension service.[30] The classification relates to the farmer's overall skill in conducting crop and animal husbandry. In classifying a farmer, the extension worker considers whether the farmer uses a government-approved pattern of crop rotation, whether he plants corn and peanuts in rows (rather than merely broadcasting the seed), and other objective criteria.

It is reasonable to accept the skill category of a farmer as an index of farm management, as defined above. Farmers with a higher government rating are likely to be both technically and economically more efficient. In Chapter 4 we noted that the total value of crop output was highest for the skilled farmers and lowest for the unskilled farmers, as one would expect.

A farmer's skill rating can be used as a proxy for management by defining three dummy variables to denote unskilled, semiskilled, and skilled farmers, respectively.

[30] Actually, as noted in Chapter 4, there are four categories: Master Farmers, Plotholders, Co-operators, and ordinary farmers; we have grouped Master Farmers and Plotholders together as skilled farmers.

Chapter 7

PROBLEMS OF STATISTICAL ESTIMATION

An extensive literature treats of the problems of estimating the parameters in a production function (*12, 17*). Without trying to survey this literature here, we shall note briefly a few points that are germane to the present study.

Identifiability

Consider the Cobb-Douglas function, written in logarithmic form,

$$\log y_j = \Sigma\, \alpha_k \log x_{kj} + u_j \tag{7.1}$$

where

$y_j =$ output of firm j,
$x_{kj} =$ amount of input k used by firm j,
$u_j =$ a stochastic term,
$\alpha_k =$ the elasticity of production of input k.

One can estimate the coefficients in equation (7.1) by conducting an experiment in which arbitrary sets of values are assigned to the x_{kj}. Provided there is sufficient independent variation in the inputs, consistent estimates can be obtained from ordinary single-equation least-squares. However, such an experiment is frequently impossible or very expensive. Instead, the investigator collects data on a number of firms operating with different sets of input values.

If the input combinations were generated by a stochastic process that led to independent variation among firms in the x_{kj}, consistent estimates of the α_k could still be obtained by least-squares. But firms do not select input levels randomly; rather, they choose inputs according to some set of decision rules. In this case, the production function must be viewed as part of a larger system of equations in which output and inputs are jointly determined. It is then possible that there is little or no interfirm variation in the x_{kj}. If all firms use the same decision rule, they may tend to produce at the same point on the production function.

Suppose that each firm chooses inputs so as to maximize profits. Then

$$\frac{\delta y_j}{\delta x_{kj}} = \frac{\alpha_k y_j}{x_{kj}} = P_{kj} \tag{7.2}$$

where $P_{kj} =$ the price of input k to firm j, divided by the price of output. With competitive pricing in factor markets, each input is priced the same to all firms, so that (7.2), written logarithmically, and with an error term added, becomes

$$X_{kj} = -\log P_k + Y_j + \log \alpha_k + w_{kj} \tag{7.3}$$

where $X = \log x$, $Y = \log y$, and w_{kj} is the error term. Then (7.1) is unidentifiable (*10*, pp. 193–96, *5*).[31]

Now suppose that firm j determines its level of input k according to the following decision rule,

$$X_{kj} = -\log P_k + Y_j + \log \alpha_k + \log v_{kj} + w_{kj} \tag{7.4}$$

where v_{kj} is a multiplicative constant that firm j associates with input k. Equation (7.4) may obtain instead of (7.3) because of differences among firms in attitudes toward risk, differences in the values of fixed factors, or differences in the elasticity of supply of input k among firms. With restricted profit maximization according to (7.4), firms will tend to operate on different points on the production function, and (7.1) is identifiable.

Unidentifiability is not a problem in the present study. A number of factors are specific to the firm: soil type, total arable acreage, and management are examples. Moreover, even the variable inputs are likely to have different elasticities of supply for different firms. For example, the elasticity of supply of fertilizer for a firm will depend to some extent on the firm's liquidity position and the firm's ability to obtain credit. Competitive factor pricing surely does not obtain in factor markets in Chiweshe or Darwin.

Simultaneous Equation Bias

Even if the production function is identifiable, it does not follow that single-equation least-squares will yield consistent estimates of the coefficients. Even if (7.4) holds, the use of single-equation methods of estimation in (7.1) will result in what has been termed simultaneous equation bias; that is, the estimates will be inconsistent (*5*). To see this, note that the X_{kj} are statistically related to Y_j by equation (7.4); it follows from (7.4) together with (7.1) that the x_{kj} are functionally related to the u_j in (7.1), violating a condition for least-squares estimators to be consistent.

It has been shown that, if certain conditions are satisfied, simultaneous equation bias will not result (*4*). Consider that equation (7.4) can be rewritten

$$X_{kj} = -\log P_k + Y'_j + \log \alpha_k + \log v_{kj} + w_{kj} \tag{7.5}$$

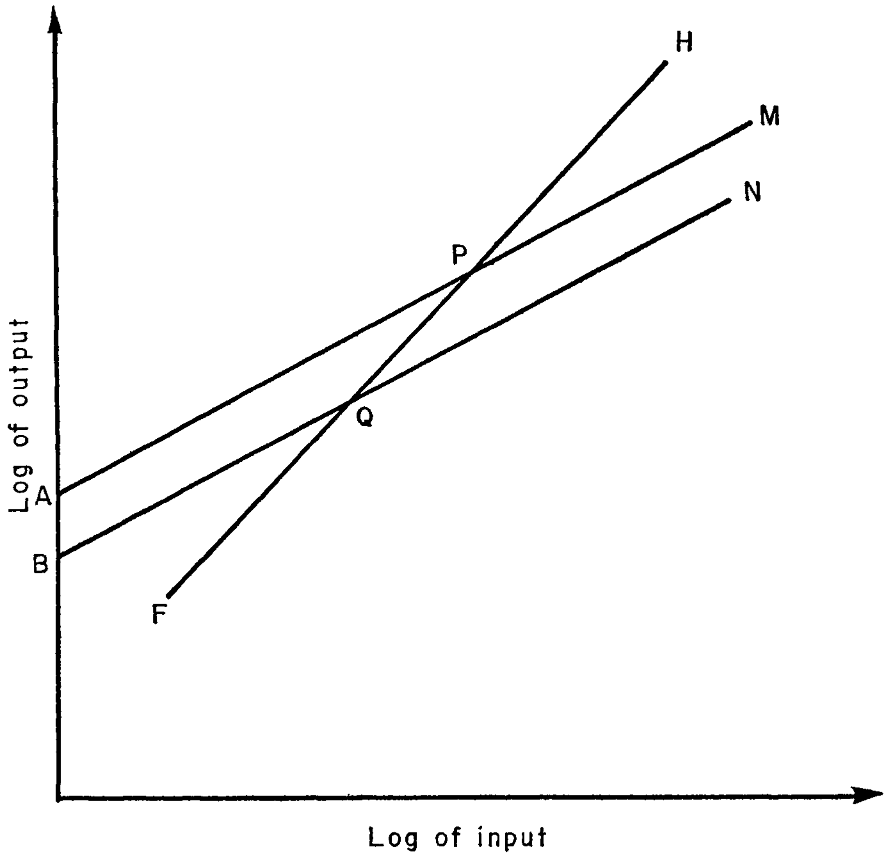
where $Y'_j = Y_j - u_j$. Let us refer to Y'_j as the log of firm j's *anticipated* output. It is clear from inspection of (7.5) and (7.1) that the X_{kj} are not functionally related to the u_j, the disturbance term in equation (7.1), provided that w_{kj} and u_j are uncorrelated. Consequently, simultaneous estimation is unnecessary.

Equation (7.5) may be expected to hold, rather than (7.4), if a firm chooses inputs so as to maximize anticipated, rather than realized, output. This may be the case if inputs are chosen before realized output is known, as in agriculture. We assume this to be the case in the present study.

[31] In this situation, consistent estimates of the production coefficients can be obtained from

$$\alpha_k = \prod_{j=1}^{n} w_{kj}^{1/n}, \text{ where } w_{kj} = \text{the share of output paid to factor } k \text{ by firm } j.$$

FIGURE 3.—INTERFIRM AND INTRAFIRM PRODUCTION FUNCTIONS*



* Based on Y. Mundlak, "Empirical Production Functions Free of Management Bias," *Journal of Farm Economics,* Vol. 43, February 1961, pp. 44–56.

Management Bias

Even if there is no simultaneous equation bias, there may still be a specification bias. Although the X_{kj} are not functionally related to the u_j, both the X_{kj} and the Y_j may be functionally related to a nonobservable input. An example of this is a situation in which both output and inputs are functionally related to the farm's management ability; this creates what is termed "management bias" (*4, 3, 11*).

To see this, suppose that instead of (7.1), we have

$$Y_j = \log A_0 + \log A_j + \Sigma\, \alpha_k X_{kj} + u_j \tag{7.6}$$

where A_j is a multiplicative index of farm efficiency or management ability and A_0 is a constant. From (7.6) it follows that better managers will obtain larger inputs, and from (7.5) it follows that better managers will also tend to use more of each input.[32] If differences in farm efficiency are not taken into account in estimating the coefficients in (7.6), the estimates will not be consistent.

This can be seen in Figure 3. Firm 1 is operating on the production function

[32] Because the cross partial derivates between the X_{kj} and log A_j will be positive.

AM, and firm 2 on *BN*. Written in logarithmic form, the functions differ only by the additive constant, $\log A_1 - \log A_2$, which is equal to the distance *BA* in Figure 3. Because firm 1 is more efficient, it chooses to operate at point *P*, while firm 2 operates to the left of this, at point *Q*. If A_j is unobservable, ordinary least squares will yield estimates of the interfirm function, *FH*, whereas it is the intrafirm functions, *AM* and *BN*, that one is interested in.

This problem was discussed independently by Y. Mundlak and I. Hoch (*11*, *4*). Both authors suggested that to eliminate management bias, time series and cross-section data could be pooled, using analysis of covariance, to obtain consistent estimates of the coefficients in (7.6). Following Hoch (and using our notation), one can write,

$$Y_{jt} = \alpha_{00} + \alpha_{0j} + \bar{\alpha}_{0t} + \alpha_1 X_{1jt} + \ldots + \alpha_p X_{pjt} + \varepsilon_{jt} \qquad (7.7)$$

where

$$\begin{aligned} Y_{jt} &= \text{the log of output of firm } j \text{ in year } t, \\ X_{kjt} &= \text{the log of input } k \text{ used by firm } j \text{ in year } t, \\ \alpha_{0j} &= \log A_j, \text{ and} \\ \alpha_{00} + \bar{\alpha}_{0t} &= \log A_0. \end{aligned}$$

In (7.7) it is assumed that the $\alpha_1, \ldots, \alpha_p$ are not functions of time, and that the "time" and "firm" coefficients, $\bar{\alpha}_{0t}$ and α_{0j}, respectively, are separable. Then interfirm differences that persist over the time period observed in the sample are assumed to reflect differences in the nonobservable variable, farm management.

In both Chiweshe and Darwin, it is reasonable to expect there to be interfirm differences in efficiency. It follows from the preceding discussion that ordinary least-squares may yield inconsistent estimates of the production function coefficients. However, because the data in each sample are for a single year only, the Hoch-Mundlak model cannot be used.

Management Bias and Multi-Product Firms

In the discussion thus far, no mention has been made of the fact that both the Chiweshe and Darwin samples contain multiproduct firms. With multiproduct firms, if the production functions for different items are not interrelated, one can fit a function for each activity. Moreover, by pooling product and firm data, and regarding each firm-product combination as a separate observation, analysis of covariance can be used, as above, to eliminate management bias if certain conditions are met.

Write

$$Y_{ij} = \alpha_{00} + \alpha_{0j} + \bar{\alpha}_{0i} + \alpha_{1i} X_{1ij} + \ldots + \alpha_{pi} X_{pij} + \varepsilon_{ij} \qquad (7.8)$$

where α_{00} and α_{0j} are, as in (7.7), the general mean and the "firm" variable, respectively; $\bar{\alpha}_{0i}$ is a constant associated with crop i; y_{ij} is the log of output of crop i produced by firm j; and x_{kij} is the log of input k used by firm j to produce crop i. In equation (7.8), the $\alpha_{1i}, \ldots, \alpha_{pi}$ are the production elasticities associated with the independent variables in the production of crop i.

As contrasted with equation (7.7), the production elasticities in (7.8) have a crop subscript. Although it may make economic sense to assume that the elasticity of production of input k is constant over time (especially if the period is relatively short), it makes much less sense to assume that input k's elasticity of production is the same for all crops. Subscripting the elasticities creates no difficulty; but more degrees of freedom are used to estimate the coefficients in (7.8) than in (7.7). If there are n farms, m crops, and p_i inputs in the i^{th} production function (exclusive of management and the crop constant), the number of coefficients to be estimated in (7.8) is

$$n + m + \sum_{i=1}^{m} p_i.$$

The total number of observations is simply mn. Use of equation (7.8) requires the assumption of no interaction between farm efficiency and crop.

Equation (7.8) is a general expression for the production function. In this study, a modified Cobb-Douglas function is used, and can be written

$$Q_{ij}^* = \beta_{1i} T_{ij}^* + \beta_{2i} L_{ij}^* + \beta_{3i} F_{ij}^* + \beta_{4i} M_{ij}^* + \beta_{5i} K_j^* + \beta_{6i} S_j + \alpha_{00} + \alpha_{0j} + \bar{\alpha}_{0i} + \varepsilon_{ij} \tag{7.9}$$

where:

Q = output,
T = land,
L = labor (weeding),
F = fertilizer-plus-constant (discussed above),
M = manure-plus-constant (also discussed above),
K = fixed capital,
S = soil type dummy variable,

and where the α's and ε are defined as above, i = the crop, j = the firm (which in this study is a farm), and $*$ = a logarithm.

A difficulty arises in estimating equation (7.9). Note that soil type is a "farm" variable, i.e., that it takes on the same value for all three crops. Accordingly the intrafarm moments matrix contains a row of constants and is singular. The same difficulty applies to fixed capital. Although the flow of capital services is in principle different from one crop to another, we have information only on the farm's capital stock as a whole, and do not know how the capital is allocated among crops. Thus in practice, if not in theory, capital is also a "farm" variable, resulting in another row of constants in the moments matrix.

To circumvent this problem, a two-stage estimation procedure is used. First, estimate the coefficients for each crop separately, using ordinary least-squares. If farm efficiency is uncorrelated with soil type and fixed capital, then ordinary least-squares will provide consistent estimates of β_{5i} and β_{6i}. Denoting these estimates $\hat{\beta}_{5i}$ and $\hat{\beta}_{6i}$, one can define a new variable,

$$Z_{ij}^* = Q_{ij}^* - \hat{\beta}_{5i} K_j^* - \hat{\beta}_{6i} S_j \tag{7.10}$$

Then Z_{ij} is an estimate of the output of crop i obtained by farm j, net of farm j's soil type and capital stock. It follows that Z_{ij} can be substituted in equation (7.9) to estimate the remaining coefficients.[33]

[33] In estimating the coefficients in equation (7.10), output of each crop was weighted by the crop price, as discussed above. The choice of price weights does not affect the estimates of the elasticities of production, but does affect the estimated marginal productivities. The marginal productivity of an input in producing crop i is directly proportional to crop i's price.

The statistical independence between efficiency and both capital and soil type is a necessary condition for the estimates to be consistent. There is no reason to expect quality of management to be correlated with soil type. The government allocated land to the farmers, giving no consideration to differences in management abilities. Some farmers found themselves on high-quality land, others on poorer land. Of course, the better farmers might be more proficient at soil conservation, and consequently obtain larger yields from a given type of land. This return to investment in the land will accordingly be included in the α_{0j}.

One might expect better managers to use more fixed capital. However, in the opinion of government officials, this was not the case to any appreciable extent. The stock of capital tends to be determined to a great extent by tradition and historical accident. The empirical results below support this view, in suggesting that both Chiweshe and Darwin are overcapitalized.

An Alternative Model

In Chapter 6 we discussed the concept of management and suggested that the term relates to both technical efficiency (output per unit of input) and economic efficiency (efficiency in the allocation of resources). The concept of efficiency as denoted by the α_{0j} in equation (7.8) is not synonymous with management. Ideally, the α_{0j} would measure the technical efficiency component of management. In practice, however, α_{0j} includes in addition any factors that affect a farm's technical efficiency but that do not appear explicitly as arguments in the production function. Without further knowledge of what these factors are, and of their importance, it is difficult to know how well α_{0j} serves as a proxy for a farm's management ability in the narrow sense.

It is also difficult to know whether to expect an interaction between the α_{0j} and the crops. On the one hand, farming in both Chiweshe and Darwin requires no specialized skills that would enable a farmer to become significantly more efficient in producing one crop rather than another. Techniques are straightforward so that a farmer with better than average ability is likely to be more efficient in crop production generally. On the other hand, farmers with better than average performance are likely to be those who have most readily accepted the advice of the agricultural extension service; and this advice has focused on corn and (to a lesser extent) peanuts. Millet has received relatively less attention. Also, as noted in Chapter 4, men tend to spend relatively more time on some crops and women on other crops. As a result, the sex composition of a farm's labor force may affect the farm's relative efficiency in producing the different crops.[34]

If farm efficiency is crop oriented, so that there is a farm-crop interaction effect, a farmer may exploit his relative advantage.[35] In this case, two farms with the same level of efficiency as measured by α_{0j} can then be expected to choose to allocate inputs differently, so that the usefulness of the model is greatly reduced.

For Chiweshe, although not for Darwin, we can use an alternative model to estimate the production relationships, even if there is a crop-efficiency interaction.

[34] To the extent that the α_{0j} measure the influence of factors excluded from the production function, these factors may be either crop oriented or not, depending on what the factors are and how they are used.

[35] In view of the considerations raised in Chapter 5, this may be much less of a problem in Chiweshe than in Darwin (because of the Chiweshe farmer's emphasis on self-sufficiency).

This method involves adding a set of dummy variables relating to the government rating of farmers.[36] The production function is then written

$$\begin{aligned} Q_{ij}^* = \gamma_{0i} + \gamma_{1i} T_{ij}^* + \gamma_{2i} L_{ij}^* + \gamma_{3i} F_{ij}^* + \gamma_{4i} M_{ij}^* \\ + \gamma_{5i} K_j^* + \gamma_{6i} S_j + \gamma_{7i} A_{1j} + \gamma_{8i} A_{2j} + w_{ij} \end{aligned} \qquad (7.11)$$

where A_1 and A_2 are dummy variables for skilled and semiskilled farmers respectively, w_{ij} = the disturbance, and where the other symbols are defined as above. The coefficients γ_7 and γ_8 are a measure of the net contribution to output of "skill" and "semiskill" relative to lack of skill. If the dummy variables adequately summarize farm efficiency, the coefficients in equation (7.11) can be estimated consistently with ordinary least-squares. If, however, there is variation in efficiency within the three government-rated groups, then although this method is a step in the right direction, it will not yield consistent estimates. It is worth noting that this model contains the advantage of using outside information on farm management.

[36] The dummy variables serve as an index of management in the broader sense of both technical and economic efficiency. Moreover, they exclude factors other than management that affect a farm's technical efficiency.

Chapter 8

ESTIMATES OF THE PRODUCTION COEFFICIENTS

In the preceding chapter, we discussed two alternative methods—based on different assumptions about the structure of production—for obtaining consistent estimates of the production function coefficients. We shall refer to the method based on equations (7.9) and (7.10) as Model 1, and the equation (7.11) method as Model 2. Model 1 estimates will be obtained for both Chiweshe and Darwin, and Model 2 estimates will be obtained for Chiweshe only.

Chiweshe—Model 1

Model 1 estimates were obtained for Chiweshe. The residuals were inspected for outliers (there were none), and were plotted against the independent variables; examination of these plots revealed no evidence of heteroscedasticity or of nonlinearity. Standard errors of the estimates were calculated, assuming homoscedasticity and independence of the residuals. The estimated coefficients, together with their standard errors (shown in parentheses), are shown in Table 8:1. Note *a* denotes statistical significance at the 5 per cent level, using a one-tail t-test.

To test for the significance of interfarm differences in efficiency, an F-test was used. The null hypothesis is that all of the α_{0j} in equation (7.9) are equal to zero —that is, that all farms are equally efficient. An F value of 1.269 was obtained, with 55 and 102 degrees of freedom. This value of F is not significant at the 5 per cent level, indicating that the results are consistent with the null hypothesis.

Chiweshe—Model 2

The insignificance of the interfarm difference in the α_{0j} may lead to the interpretation that farms are equally efficient. An alternative interpretation is that the assumptions underlying the analysis of covariance model do not hold, so that the α_{0j} are not a good measure of farm efficiency. This would be the case if there

TABLE 8:1.—ESTIMATED COEFFICIENTS: CHIWESHE MODEL 1*

Input	Corn	Peanuts	Millet
Land	.248 (.232)	.263 (.200)	.482[a] (.193)
Weeding	−.065 (.241)	.148 (.162)	.208[a] (.119)
Fixed capital	.031 (.089)	.324[a] (.122)	.024 (.132)
Soil type	.156[a] (.078)	.018 (.094)	.167[a] (.096)
Chemical fertilizer	.534 (.369)	—	—
Manure	.244 (.162)	—	—

* Blanks (—) indicate that the input is not used in producing the specified crop. Regression coefficients are stated first, followed by the respective standard errors in parentheses.
[a] Significant at the 5 per cent level, using one-tail test.

TABLE 8:2.—ESTIMATED COEFFICIENTS: CHIWESHE MODEL 2*

Input	Corn	Peanuts	Millet
Land	.507[a] (.153)	.280 (.178)	.478[a] (.193)
Weeding	.068 (.156)	.180 (.144)	.255[a] (.110)
Fixed capital	−.062 (.095)	.220[a] (.132)	.102 (.135)
Soil type	.382[a] (.186)	.014 (.209)	.310 (.221)
Chemical fertilizer	.168[a] (.064)	—	—
Manure	.198[a] (.076)	—	—
Skilled management	.179 (.253)	.626[a] (.359)	−.697 (.368)
Semiskilled management	−.046 (.179)	.334 (.242)	.196 (.248)
Multiple correlation coefficient	.754	.554	.597

* Blanks (—) indicate that the input is not used in producing the specified crop. Regression coefficients are stated first, followed by the respective standard errors in parentheses.
[a] Significant at the 5 per cent level, using one-tail test.

is an interaction between efficiency and crop. Suppose that farm 1 is efficient in producing corn but inefficient in producing millet; and assume the reverse to hold for farm 2. Then the average efficiency of farm 1 in producing the two crops may equal the average efficiency of farm 2; yet for each crop individually there is (by assumption) a difference in efficiency. In the presence of crop-efficiency interaction, Model 2 is more appropriate than Model 1. The set of Model 2 estimates is presented in Table 8:2. Again, there was no evidence of nonlinearity of the residuals, of heteroscedasticity, or of outliers.

The proportion of the variance in crop output explained by the observed independent variables is not large. The multiple determination coefficients range from .554 (for peanuts) to .754 (for corn). Using a table of values of the correlation coefficient (for the null hypothesis of no correlation) the three regressions are significant at the 1 per cent level. Nevertheless, for peanuts and millet, less than half of the interfarm output variance is explained by the set of independent variables.

Darwin—Model 1

Next consider the estimates of the Darwin production coefficients, using Model 1. These are presented in Table 8:3. As with Chiweshe, there was no evidence of outliers, heteroscedasticity, or nonlinearity of the residuals. We tested the hypothesis of no farm effect (the $\alpha_{0j} = 0$). An F value of 2.103 was obtained which, with 19 and 30 degrees of freedom, is significant at the 5 per cent level. The data are therefore inconsistent with the hypothesis of equal farm efficiency.

There is no simple measure of the proportion of output of each crop that is explained by the inputs. However, in equation (7.10), multiple correlation coefficients of .821, .656, and .882 were obtained for corn, peanuts, and millet respectively. Although these are somewhat higher than the R^2s for Chiweshe, less than half of the interfarm output variance for peanuts is explained by the set of independent variables.

Explanation of Interfarm Differences

In this and the remaining chapters, we shall dismiss the Chiweshe Model 1 results and refer only to Chiweshe Model 2 and Darwin Model 1. We shall begin

TABLE 8:3.—ESTIMATED COEFFICIENTS: DARWIN MODEL 1*

Input	Corn	Peanuts	Millet
Land	.820 (.629)	.803[a] (.271)	.773[a] (.214)
Weeding	.060 (.161)	.065 (.140)	.296[a] (.154)
Fixed capital	.050 (.137)	−.151 (.180)	.173 (.162)
Soil type	.122 (.084)	.157 (.118)	.446[a] (.111)
Chemical fertilizer	.195[a] (.111)	—	—
Manure	.473 (1.126)	—	—

* Blanks (—) indicate that the input is not used in producing the specified crop. Regression coefficients are stated first, followed by the respective standard errors in parentheses.
[a] Significant at the 5 per cent level, using one-tail test.

by considering the factors that are most important (as evidenced by their *t*-ratios) in explaining interfarm differences in output. Land and weeding are statistically significant in millet production in both samples and soil type in the Darwin sample. Turning to peanuts, land is significant for Darwin and fixed capital for Chiweshe. Chemical fertilizer is significant in both samples in producing corn; in addition, land, soil type, and manure are significant in the Chiweshe corn function.

Overall, land appears to be a limiting factor, as one would expect, and chemical fertilizer also appears to be quite important. The results are more ambiguous regarding the other inputs. Manure, although significant in the Chiweshe corn function, is insignificant in the Darwin corn function. Labor is significant only in millet production. The results strongly suggest considerable multicollinearity reducing the significance of the individual inputs. For this type of exercise, the samples are rather small, especially for Darwin. Because of the low overall level of statistical significance, the results should be interpreted with caution.

Fixed capital is statistically significant in only one Chiweshe function and in no Darwin functions; the estimated elasticity is negative in two of the six cases considered. This may be due to multicollinearity. It may also be due to the imperfect measure of capital input used in this study. A measure of capital services used in producing each crop would undoubtedly provide a better fit.

Elasticities of Production

Ordinarily, in fitting a Cobb-Douglas function, the coefficients equal the elasticities of production of the respective inputs. One feature of the Cobb-Douglas function is that these elasticities are independent of factor ratios. In the function used here, the regression coefficients for land, capital, and labor are equal to the production elasticities, but for the remaining variables this is not the case.

In the case of variables to which a constant has been added—manure and fertilizer in the Chiweshe corn function and manure in the Darwin corn function —the elasticity is obtained by multiplying the regression coefficient by $\frac{x - c}{x}$ where x = the value of the variable-plus-constant, and c = the constant. These calculations were made at the geometric means of the respective variables.

For the dummy variables, which enter the production function as shift factors, the elasticity of production equals the regression coefficient multipled by the value

TABLE 8:4.—ESTIMATED ELASTICITIES OF PRODUCTION: CHIWESHE AND DARWIN*

Input	Corn		Peanuts		Millet	
	Chiweshe	Darwin	Chiweshe	Darwin	Chiweshe	Darwin
Land	.507	.820	.280	.803	.478	.773
Weeding	.068	.060	.180	.065	.255	.296
Fixed capital	0	.050	.220	0	.102	.173
Chemical fertilizer	.168	.059	—	—	—	—
Manure	.198	.106	—	—	—	—
Total	.941	1.095	.680	.868	.835	1.242
Soil type	.242	.073	.009	.094	.200	.268
Skilled farmer	.023	...	.076	...	−.097	...
Semiskilled farmer	−.009	...	.083	...	.048	...

* Blanks (—) indicate that the input is not used in producing the specified crop. Dots (...) indicate that data are not available.

of the variable; the elasticity of each dummy variable was calculated at the arithmetic mean of the variable. The two sets of estimated intrafarm elasticities are presented in Table 8:4. The table also contains the sums of the estimated elasticities of the variables in each production function (excluding soil and efficiency which are regarded as shift variables).

With decreasing, constant, or increasing returns to scale, the sum of the elasticities of production is less than, equal to, or greater than unity, respectively. In Chiweshe and Darwin, there are no significant indivisibilities that would provide a basis for increasing returns. Accordingly, one would expect the elasticities to be equal to unity.

To test for returns to scale, a two-tail t-test was used; the null hypothesis was that the elasticities sum to unity for each crop.[37] In the Chiweshe peanuts function, the sum of the estimated elasticities is significantly less than unity at the 5 per cent level; none of the remaining sums is significantly different from unity. The data are thus compatible with constant returns to scale in 5 of the 6 functions estimated. In the case of peanuts, there may be some unobserved factor such as labor quality that enters into the production function.

Marginal Productivities

From the estimated elasticities one can obtain a set of estimated marginal productivities. The marginal productivity of factor k in producing crop i is denoted by f_{ki} and is given by

$$f_{ki} = \frac{E_{ki} y_i}{x_{ki}} \tag{8.1}$$

where

E_{ki} = the elasticity of factor k in producing crop i,
y_i = the output of crop i, and
x_{ki} = the amount of input k used in producing crop i.

The estimated marginal productivities were calculated at the means of the vari-

[37] In calculating the t-ratios, the variance of the sum of the estimated elasticities includes the appropriate terms from the inverse of the moments matrix.

TABLE 8:5.—ESTIMATED MARGINAL VALUE PRODUCTIVITIES: CHIWESHE AND DARWIN*
(*U.S. dollars per unit of measure*)

Input	Corn		Peanuts		Millet	
	Chiweshe	Darwin	Chiweshe	Darwin	Chiweshe	Darwin
Land (*acre*)	3.04	21.59	2.96	27.99	4.28	22.21
Weeding (*hour*)	.012	.028	.031	.039	.036	.134
Fixed capital (*dollar cost*)	0	.099	.087	0	.025	.062
Soil type (*per acre*)	1.98	3.09	.46	5.00	2.39	10.70
Chemical fertilizer (*dollar cost*)	1.69	2.94	—	—	—	—
Manure (*tons*)	3.19	1.42	—	—	—	—
Skilled farmer	7.43	...	8.37	...	−5.77	...
Semiskilled farmer	−1.91	...	4.46	...	1.61	...

* Blanks (—) indicate that the input is not used in producing the specified crop. Dots (...) indicate that data are not available.

ables y_i and x_{ki} and consequently relate to the "average" farm.[38] These figures appear in Table 8:5.

To test for the significance of the difference among the marginal productivities of each factor in different uses, an F-test was used. Carter and Hartley (2) have shown that an estimate of the variance of a marginal productivity estimated from a Cobb-Douglas function is given by

$$\hat{\text{var}}(f_{ki}) = \left(\frac{y_i}{x_{ki}}\right)^2 \left(\hat{\text{var}}(E_{ki}) + \frac{(S_i)^2\,(E_{ki})^2}{n}\right) \tag{8.2}$$

where

$(S_i)^2 =$ the "unexplained" variance in $\log(y_i)$,
$n =$ the number of observations,

and where y_i and x_{ki} are chosen at their geometric means.

For each sample, equation (8.2) was used to calculate the estimated variances of the marginal productivities of land and weeding for each crop. These were used to test the hypothesis that each factor's marginal productivity is the same in all uses. In both samples, for both land and labor, the F ratio was significant at the 5 per cent level,[39] and therefore provide evidence that the marginal productivity of each input differs among crops.

[38] The geometric mean was used for logged variables and the arithmetic mean for the remaining variables.
[39] Also at the 1 per cent level.

Chapter 9

GAINS FROM REALLOCATION

The scope for raising output in either Chiweshe or Darwin hinges on opportunities for the profitable use of additional quantities of inputs, and on opportunities for using the given stock of resources more efficiently. The efficiency of resource use can be increased either by improving the level of technology or by reallocating existing resources. In this chapter we consider possible gains from reallocation.

Allocative efficiency relates to the degree to which the given stock of resources is used—given the level of technology—to maximize net output. A farmer achieves efficiency in this sense by allocating inputs among crops so as to equate the marginal productivity of each input in every use. Any discrepancy in the marginal productivities of a factor in different uses implies that output can be raised with no increase in resources.

But the allocation of a farmer's resources is based on the *anticipated* output obtainable from alternative sets of inputs. Realized output may of course differ from anticipated output. As a result, even if a farmer equates anticipated marginal productivities, there may be a dispersion in realized marginal productivities. Without knowledge of the time paths of yields of different crops, the equality of the anticipated marginal productivities cannot be tested.

In choosing input levels, farmers may consider not only the expected value of anticipated yields, but also the annual variation in yields. One crop may have a lower anticipated yield than another crop, but a more certain (less variable) yield. If farmers are concerned not only with the expected value of crop income but also with the reasonable assurance that this income will exceed some specified level (as is implied in Chiweshe by the assumption that farmers strive for self-sufficiency), then they may opt for a lower but more certain yield. In this case, a factor's (mean) anticipated marginal productivity may not be equated in each use.

Chiweshe Reserve

In Chiweshe, there is no presumption that farmers are, or try to be, efficient in the sense used here. On the contrary, if farmers strive for self-sufficiency, their use of resources need not maximize the market value of output—and in particular need not do so in any one year. This does not imply that farmers are ill-advised or "bad" managers; it does imply, however, that the chosen allocation of resources is unlikely to maximize the market value of net output. In a sense, a measure of allocative inefficiency in Chiweshe provides an index of the "cost" of self-sufficiency. With an appropriate change in institutions, resources, and opportunities, leading to new attitudes and objectives, and with efficient allocation with respect to these new objectives, the farmer can achieve a larger output, valued at market prices.

In Chiweshe, each farmer's arable acreage is exogenously determined. The farmer chooses how to allocate his land among crops. We have hypothesized that this decision reflects his preferred consumption pattern, as well as some notion of his anticipated yield of each crop. Anticipated yields are most likely to be a reflection of yields in previous years, which in turn were influenced by the factor combinations employed in those years. The extent to which the farmer is familiar with different points on his production isoquant depends on how much the factor combination has varied from year to year.

In deciding how much of the arable land to devote to each crop, the farmer is constrained by the need to look beyond the current year. Failure to observe an appropriate crop rotation will result in declining soil fertility over time and in lower yields. The farmer then must strike a balance between short-term and long-term considerations. Some Chiweshe farmers (notably those rated as Cooperators, Plotholders, and Master Farmers) do follow a rotation pattern.

The marginal productivities were presented in Table 8:5. The marginal productivity of land is highest in growing millet and lower for both corn and peanuts. This suggests that given the inputs of other factors, the value of output would be raised by shifting land from corn and peanuts into millet production, to equalize the marginal productivity of land in the three uses. However, the resulting gain is relatively small. The geometric mean of output was $63.04. By equalizing the marginal productivity of land in all three uses, the value of output is raised to $63.67, or by only 1 per cent.

Moreover, as millet is grown for home consumption, one must ask whether the additional millet grown could be marketed, and at what price. If it could be sold to other farmers in the reserve at the local price, in exchange for corn and peanuts, the farmer would benefit. If not, the only alternative might be to sell to the Grain Marketing Board at a much lower price; and at the GMB price, the marginal productivity of land in growing millet is *lower* than in either of the other uses. This suggests that, given the alternatives confronting the farmer, he may be wise in not growing more millet than he does.

The farmer can choose also how to allocate a given input of labor among crops. The marginal return to labor, measured at weeding time, is highest for millet and lowest for corn.[40] Consequently, given the allocation of land among crops, the results suggest that output could be raised by shifting labor from corn to millet. Again, however, the gains are quantitatively small. If labor is allocated so as to equalize its marginal product in all uses, total output is raised from $63.04 to $64.40, an increase of just 2.2 per cent.

Finally, one can reallocate both labor and land simultaneously so as to equalize the marginal productivities of each input in producing all crops. Shifting both land and labor into millet production results in a somewhat greater gain than reallocating either input alone. But the gain is not striking. The maximum output obtainable on this basis is approximately $67.00, a 6.7 per cent increase over actual output.

[40] But if millet is valued at the GMB price, the marginal productivity of labor in growing millet is lower than for peanuts and only marginally higher than for corn.

Darwin

One might expect farmers in Darwin, unlike those in Chiweshe, to aim at maximizing total output; consequently market prices are likely to play a greater role. It is plausible to expect farmers to attempt to allocate each input so as to equate its marginal productivity in every use. In the use of land, however, as was true in Chiweshe, the farmer is constrained in the short run by such factors as crop rotation, so that the optimal long-term pattern of land use may lead to discrepancies in the marginal productivities of land in any one year. Moreover for all inputs, realized and anticipated marginal productivities will not necessarily be equal.

With these qualifications in mind, we note that there is a substantial difference among the marginal productivities of land in different uses. The return to land is highest in peanut production and lowest in producing corn. These figures provide evidence that the total value of output would be raised by shifting land from corn into peanut production. Our calculations, however, show the potential gain to be only 3.1 per cent of the value of output.

Turning to labor (weeding), the return is highest for millet (by a considerable margin) and lowest for corn. This again suggests a potential gain from reallocating labor among crops, and particularly spending more time weeding millet. Again, however, the potential gain is quantitatively small: only 2.8 per cent of the value of output.

In Chiweshe, the gain from jointly reallocating labor and land among crops exceeded the sum of the individual gains from reallocating the factors separately. This was because, for both factors, the marginal product was highest in producing millet. In Darwin, the marginal product of labor is also highest in millet production but the marginal product of land is highest in producing peanuts. Consequently, a joint reallocation results in a gain that is less than the sum of the individual gains, or less than 5.9 per cent. Thus the potential relative gain from jointly reallocating land and labor among crops is less in Darwin than in Chiweshe.

Interpretation of the Results

The results presented in this chapter are inconclusive, for the reasons stated above. The scope for reallocation is almost certainly less than the calculations suggest, due to the constraints on resource use and due to the discrepancies between long-term and short-term optimization. Moreover, the figures are based on estimated marginal productivities, which can be expected to differ from actual marginal productivities. Even so, bearing all qualifications in mind, the gain from moving to an optimal allocation is only \$4.00 in Chiweshe, or less than 7 per cent of the ouput actually obtained. This does not suggest gross inefficiency in resource allocation. To a large extent, of course, the limited scope for gain is attributable to the low returns at the margin to both land and (especially) labor.

In Darwin, a reallocation of inputs would result in a substantially greater absolute gain (\$25–\$30), but a smaller relative gain (4–5 per cent of output). If each factor's anticipated marginal products were equated in all uses, one would not be surprised to find actual output in any one year to be 5 per cent below the optimal level, given the uncertainties involved. The results thus provide evidence that neither area deviates far from an optimal inter-crop allocation of land and labor.

It is important to note, however, that these results have been based on estimated marginal productivities calculated at the means of the variables. In examining allocative efficiency, not only the marginal productivity of each input for the average farm but the dispersion around this average is relevant. Efficient allocation on the average farm is a necessary but not a sufficient condition for efficiency on individual farms. For example, some farms may use too much land for one crop and other farms may use too much for another crop; yet the average allocation of land may fully conceal these inefficiencies. Although the results here provide little evidence of potential gains from reallocation on the average farm, there may be scope for considerable gain to individual farmers.[41] In this respect, there is a clear need to explain the dispersion of farms about the average. When we are able to understand the factors responsible for interfarm differences in resource allocation, then we will know a great deal more about how to increase farm output.

[41] One suspects that T. W. Schultz (*14*) failed to make this distinction in his discussion of David Hopper's study (*6*) of agriculture in an Indian village. Schultz writes, "The factors of production available to the people were allocated efficiently, and the test therefore strongly supports the hypothesis here proposed" (*14*, page 48). But it is significant that Hopper examined efficiency only on the average farm. His results are consequently consistent with inefficiency on individual farms, as is the case in the present study.

Chapter 10

RETURNS TO RESOURCES

The scope for using additional inputs to raise output depends on the returns to these inputs. In this chapter we consider the marginal returns to land, fertilizer, manure, fixed capital, and labor, comparing the returns to these resources in Darwin with the returns in Chiweshe. First, however, we begin with some remarks on the comparability of the two sample areas.

For several reasons the two areas are not directly comparable. First, it is always dangerous to compare two samples drawn from different parts of a country, and based on different years. In the present case, however, the danger may not be too great. The two areas are in roughly comparable natural regions; and both the 1960–61 season in Chiweshe and the 1961–62 season in Darwin were regarded as "average" with respect to amount and distribution over time of rainfall. Unfortunately, the soils were not classified in the same way in the two areas, so it is impossible to make a direct comparison of natural soil fertility. As noted earlier, the Chiweshe area has been cultivated for a much longer period and there is evidence that soil fertility has been reduced. At the time the surveys were conducted, soil fertility was undoubtedly higher in Darwin.

Apart from differences in soils and (possibly) rainfall, there are several reasons why the marginal productivity of an input might differ between the two areas. First, the factor ratios differ, as we have seen. For example, despite the larger holdings in the Darwin sample, the labor-land ratio is higher, tending to make the marginal productivity of land higher as well. Second, the level of management ability is probably higher in Darwin than in Chiweshe, tending to make the marginal productivities of all inputs greater in the Darwin sample. Most if not all of the Darwin cultivators are Master Farmers, while in the Chiweshe sample there are only three Master Farmers and four Plotholders, out of a total of 56 farms. Third, the unobserved inputs differ among the two areas. In particular, we know that Darwin farmers spend more time on land conservation and improvement. For this reason also, the marginal productivities of all of the observed factors will tend to be higher in Darwin.

Land

The marginal productivity of land ranges from \$2.96 to \$4.28 in Chiweshe and from \$21.59 to \$27.99 in Darwin. The substantially greater marginal productivities in Darwin are probably due to a mixture of the factors noted above. Better soil and management both raise the return to land in Darwin. So does the greater use of complementary inputs: labor, capital, and manure.

Although the Chiweshe farmer used all of the land at his disposal, there is some opportunity for the Darwin farmer to increase his cultivated acreage. However, the uncultivated land in Darwin is covered with big trees, which must be costly to clear. Perhaps the Darwin farmer operates with a high labor-land ratio due to habits acquired when he worked in the reserves. If so, then the pattern of production may alter over time as the farmer becomes more aware of the opportunities available to him on a Purchase Area farm. But on the other hand, he may simply be balancing the cost of clearing new land against the cost of maintaining and improving land already cleared of trees. In this case, perhaps the farmer may be maximizing his output by refraining from bringing more acres under cultivation; or he may, because of the teachings of the agricultural extension agents, be spending too much time on land conservation. Given the high return to arable land, one would expect the farmer to bring more acres under cultivation, and to spread his labor and capital more thinly over this larger acreage. It would be surprising if there were no opportunities to substitute land for labor.

Fertilizer

In Chiweshe, a dollar's worth of fertilizer contributes $1.69 at the margin to the output of corn. However, in the United States, the marginal productivity of fertilizer typically falls within the range of $1.50–$2.00 per dollar spent,[42] so that the Chiweshe results need not reflect much scope for greater fertilizer use.

In Darwin, output on farms using fertilizer is $75.59 higher than on farms using no fertilizer. The mean expenditure on fertilizer was $7.71. As only 30 per cent of the farms used any fertilizer, then, of those farms that did use it, the mean expenditure was $25.70. Dividing this figure into the marginal productivity figure, we can obtain an estimated "average-marginal" product per dollar of fertilizer used of $2.94 (as shown in Table 8:5). Although we have no figures for the time spent applying fertilizer, this is known to be very small—a few hours only.

Because of the difference in the way in which fertilizer enters the production function between Chiweshe and Darwin, the marginal productivities are not fully comparable. With this disclaimer in mind, we note that the marginal productivity of fertilizer is substantially higher in Darwin. In part this is because the ratio of cooperating factors to fertilizer is higher in Darwin; in part, too, perhaps because Darwin management is better. The high marginal productivity of fertilizer in Darwin suggests that there is considerable scope for raising output through increased fertilizer use; and that fertilizer can be more economically used in Darwin than in Chiweshe.

Fixed Capital

Our measure of the capital stock is based on a "gross" capital concept, in that items of equipment are valued at their undepreciated cost. In examining the rate of return on capital, it is more interesting to use a net capital concept, that is, one based on depreciated cost. The net stock will be less than the gross stock. In the extreme case of a stationary state, the net stock will be one-half of the gross stock.[43] In a rapidly growing economy, the net stock will be more nearly equal in value to the gross stock.

We do not have detailed information on the rate of growth of the capital stock in the sample. It is probably reasonable to assume that the equipment has

[42] We are indebted to Vernon W. Ruttan for this figure.
[43] Assuming linear depreciation.

an average life of approximately 10 years, and that the stock is growing slowly. Under these assumptions, we can say that (using linear depreciation), depreciation is roughly equal to 10 per cent of the value of the gross stock; and the net stock in Chiweshe may be some 55 per cent of the gross stock. These figures represent only informed guesses.

Table 8:5 presented the gross rate of return to capital. Summing the return for the three crops gives a figure of 11 per cent in Chiweshe. Subtracting for depreciation, and converting to a net measure of capital, the net rate of return figures out to 2 per cent. If we regard this as a measure of the annual marginal return to investment in equipment in the area, then this return must be judged low relative to the cost of capital in African countries.

As we noted above, much of the equipment is in a bad state of repair. The return to capital expenditure on new implements, if these implements are properly maintained, is doubtless substantially higher than the results here suggest. Moreover, investment in some types of equipment is probably more profitable.

Nevertheless, the results convey the impression that fixed capital is not a limiting factor—that the area is perhaps even overcapitalized with respect to implements. Compared with the returns to manure and to fertilizer, capital implements would appear to represent a poor investment. Admittedly, this conclusion is based on very tentative information. We believe that this hypothesis has important implications and deserves further intensive study.

The gross rate of return on capital in Darwin is 16 per cent. Making the same adjustment as in Chiweshe, we can convert this to a net rate of return. Assuming that depreciation is equal to 10 per cent of the gross capital stock, and assuming the stock to be growing somewhat more rapidly than in Chiweshe, the net stock may be some 75 per cent of the value of the gross stock. The net rate of return is approximaly 8 per cent, four times as high as in Chiweshe, despite the larger capital-land ratio in Darwin. Although a return of 8 per cent does not suggest much scope for further investment in fixed capital in Darwin, the figures suggest that fixed capital constitutes a better investment in Darwin than in Chiweshe.

Labor

The data distinguish among four types of labor use: planting, weeding, manure application, and harvesting. We have already discussed the return to manure application. The returns to plowing and harvesting are included in the returns to other inputs. Table 8:5 presented estimates of the return to weeding.

The peak period in Chiweshe is the month of January, when all three crops are weeded. Women especially perform more work in January than during other months. For this reason, one might expect the return to weeding to be high. This is not the case, however. The estimated marginal productivity of weeding ranges from 1.2 cents to 3.6 cents per hour. Although the fact that the marginal productivity appears to be greater than zero implies that output could be raised by using more labor, the return may well be too low to justify the additional effort. And this return relates only to weeding which is undertaken during just a part of the year. Because of the low return to labor on the farm, many farmers spend a considerable part of the year away from the reserve working for wages.

The average annual earnings of all Africans in wage employment in Rhodesia in 1960 were $237.20, higher in the cities and lower for African workers on European farms. This includes some persons who worked less than a full year. If we take 40 weeks as the average worked in the year, the average weekly wage figures out to $6.00. And if we take 50 hours as the average workweek, the average hourly wage amounts to 12 cents. Even allowing for the fact that many wage earners live in the city, where the cost of living is higher, the return to wage labor exceeds the return from working on one's own plot. This is likely to be especially true for farmers with only a small landholding.

However, jobs are not plentiful in Rhodesia, especially for women and children. Although the farmer may be able to find work for himself, he is less likely to find jobs for his family. It therefore pays him to leave the farm to seek wage employment, while leaving his wife and children behind to work on the family farm.

The return to weeding all three crops is greater in Darwin than in Chiweshe. The large standard errors of the estimated labor coefficients make comparison hazardous for corn and peanuts. In producing millet, the marginal productivity of labor in Darwin is 13.4 cents compared with only 3.6 cents in Chiweshe. With this exception, though, the return to labor is low in Darwin. Of course, the labor-land ratio is much higher than in Chiweshe. There may be some scope for raising output by a still more intensive use of labor (were additional labor available) but, except in the case of millet, the opportunities are not outstanding.

In both Chiweshe and Darwin, the marginal return to labor is greater than zero. In Darwin, labor is genuinely scarce. The size of the holdings and the amount of capital is greater than in Chiweshe. As a result, the family works long hours on the farm. Any increase in farm output would require either more labor or else a substitution of other inputs for labor. Even with an improvement of farm technology, such as the use of pesticides or better seed, the larger output would require more labor at harvest time than the farm family is able to provide. An increase in output could be brought about only with a greater use of hired labor or with the use of harvesting equipment to reduce the labor requirements.

Before the return to labor reaches zero, people refuse to work. There is ample evidence of people in the Chiweshe area working short hours, even during the seasonal peaks. In other words, they remain idle rather than work for a very low return. Thus, the positive marginal product means that there is no disguised unemployment as such; but there is evidently surplus labor in the sense that more work would be forthcoming at a more reasonable rate of return. The Chiweshe labor force is not by any means fully employed, even during seasonal peaks.

Although many of those who are unable to keep occupied full time remain in the area for at least a substantial part of the year, others migrate out of the area to seek employment. In Darwin, where the opportunities on the farm are much greater, there is no migration—even though there are equally good opportunities to find paid employment. In Chiweshe, there is some evidence that migration is related to the economic opportunities on the farm. Migration appears to be greater on farms with a low ratio of arable acreage to family size. Migration is clearly regarded as an alternative to working on the family holding. As such, it helps provide a floor to the marginal return to labor.

Our estimates suggest that in Chiweshe, only a very modest increment in output can be achieved through the addition of labor input alone. And this increment is not achieved because the rewards are insufficient to call forth the additional effort. In Darwin, the returns to labor are somewhat higher, although not striking. They are not high enough to justify a greater use of hired labor. Yet, a decrease in output would result if labor were removed. The supply of family labor in Darwin appears to reflect a realistic assessment of the alternatives.

In Darwin, a farmer can invest in the land, and has more land to work with. He can work throughout the year, so that seasonal unemployment is not a problem. There is greater scope for useful application of labor. In the purchase areas, a stable population has developed, committed to farming. The turnover rate in these areas has been impressively low.

In Chiweshe, migration is a necessary phenomenon, given the limited opportunities in agriculture. If migration were to cease, the area could not support the labor force without driving the marginal product of labor even closer to zero.

Manure

The marginal return to a ton of manure in corn production in Chiweshe is $3.19. It should be borne in mind that there is a complementary input—labor—associated with the application of manure to the soil, so that the return relates to manure-plus-labor. If manure is regarded as a "free good," we can treat its marginal productivity as a return solely to labor allocated to manure application. As an average of 16 hours was spent applying a ton of manure, the return to this labor is equal to 20 cents per hour. Two points are worth noting. First, the return to manure application is considerably greater than the return to weeding. Second, manure application is undertaken early in the season, when the opportunity cost of labor is low in terms of other operations foregone. This suggests that it would pay for farmers to use more manure—up to the point where the marginal return to manure application equals the marginal return to weeding. The fact that less than this optimal amount of manure was used suggests that livestock availability was an effective constraint. There is evidence that some farms could—given their livestock—have used a greater amount of manure. But the regression results are consistent with livestock being a limiting factor on some farms even if it was not a limiting factor on all farms.

The marginal productivity of manure in Darwin is only $1.42 per ton, less than in Chiweshe. Our figures indicate that an average of 9.3 hours was used to apply a ton of manure (less than in Chiweshe, probably because of the greater availability of capital in Darwin). The return to this labor works out to 15 cents per hour, as compared with 20 cents per hour in Chiweshe. The lower return to manure in Darwin is due in part to the fact that much more manure was used, so that the ratio of manure to cooperating factors is greater. Perhaps also the return to manure is lower at the margin in Darwin because of the greater natural soil fertility.

The results are consistent with our hypothesis that manure and fertilizer are complementary inputs. The higher manure-land ratio in Darwin, coupled with the lower fertilizer-land ratio, led to a higher marginal return to fertilizer, together with a lower marginal return to manure. Were the two inputs substitutable, the greater intensity of use of manure would have reduced the marginal return to both inputs.

Chapter 11

MANAGEMENT

Chiweshe

The relationship between output and management is complex and deserves detailed consideration. We noted in Chapter 6 that management embraces economic efficiency, defined roughly as efficiency of allocation, and technical efficiency, or output per unit of input. In Chapter 7, we suggested that the classification of Chiweshe farmers as skilled, semiskilled, and unskilled corresponded roughly to management in both senses. Accordingly, in obtaining the production function estimates in Chapter 8, two dummy variables were used to estimate the net performance of skilled and semiskilled farmers, respectively, relative to unskilled farmers. This section compares the three groups with respect to technical efficiency, output, inputs, and economic efficiency.

The net marginal productivities associated with each level of skill were presented in Table 8:5. These figures measure technical efficiency only, and do not reflect any differences among groups in the use of observed inputs. For example, the figure for skilled farmers in the corn production function is $7.43; this means that, net of all other observed inputs, skilled farmers on the average obtained $7.43 more corn output than unskilled farmers.

The estimated marginal productivities were summed over crops to obtain an estimated total marginal product for each degree of skill. This sum measures the total differential efficiency of the average member in the group relative to the average unskilled farmer. The sums are $10.03 for skilled farmers and $4.16 for semiskilled farmers (see Table 11:1).

Table 11:1 presents summary data relating to the average farmer in each skill group. Relative to farmers in the other groups, the average skilled farmer obtained larger outputs of corn and peanuts, but a lower millet output. For the three crops combined, the skilled farmer obtained 47 per cent more output than the semiskilled farmer and more than twice as much output as the unskilled farmer.

On a per farm basis, semiskilled farmers obtained a larger output of each crop than unskilled farmers. For all crops combined, the output of the semiskilled farmer was 40 per cent greater.

Much of the intergroup difference in output (particularly between skilled farmers and the other groups) is due to differences in acreage. The acreage per farm of skilled farmers was 70 per cent greater than that of unskilled farmers. Semiskilled farmers had an average of 11 per cent more land than unskilled farmers.

But part of the intergroup differences in output was due to differences in yields. The figures for peanut yields are striking. Despite a larger acreage planted, skilled farmers obtained a much higher yield than farmers in the other groups—

TABLE 11:1.—MEAN ECONOMIC PERFORMANCE OF SKILLED, SEMISKILLED, AND UNSKILLED FARMERS: CHIWESHE

	Skilled	Semiskilled	Unskilled
Technical efficiency relative to unskilled farmers (*dollars*)	10.03	4.16	—
Output (*dollars*)			
Corn	80.96	58.04	43.13
Peanuts	47.00	21.93	13.21
Millet	11.01	14.83	11.30
Total	138.96	94.80	67.64
Acreage			
Corn	11.76	7.91	7.22
Peanuts	2.31	1.57	1.37
Millet	2.13	1.12	.94
Total	16.20	10.61	9.53
Yield (*dollars per acre*)			
Corn	6.88	7.34	5.98
Peanuts	20.35	13.97	9.64
Millet	5.17	13.24	12.02
All crops	8.58	8.93	7.10
Yield (*pounds per acre*)			
Corn	506	540	440
Peanuts	374	257	176
Millet	120	310	280
Adjusted yield (*dollars per acre*)			
Corn	7.13	6.68	6.20
Peanuts	20.53	13.48	9.73
Millet	5.33	12.17	12.38
All crops	8.80	8.26	7.32

more than twice the yield obtained by unskilled farmers. The intergroup differences in corn yield are much less; yields were greatest among semiskilled farmers and lowest for the unskilled farmers. The millet figures are curious; semiskilled farmers received a slightly higher yield than unskilled farmers but both groups did much better than skilled farmers. Regarding overall yield (value of all crops per cultivated acre), both skilled and semiskilled did better than unskilled but, surprisingly, semiskilled farmers obtained a higher yield than skilled farmers.

It is of interest to try to reconcile the small intergroup yield differences in the Chiweshe sample with the large differences for Rhodesia as a whole, shown in Table 2:2. The Table 2:2 figures show that skilled farmers (Master Farmers and Plotholders) obtained significantly higher yields than semiskilled farmers (Cooperators), who in turn obtained higher yields than ordinary farmers. It is possible that these figures may contain a bias. The figures were obtained by agricultural extension workers, who may have overstated the yields of skilled farmers relative to unskilled farmers. Moreover, although Chiweshe can be regarded as a typical reserve, our sample is too small to be representative of Chiweshe as a whole. Probably of more importance, though, the figures in Table

2:2 relate to all—purchase area as well as reserve—farmers. Settlement in purchase areas has been restricted mainly to Master Farmers. Therefore the figures in Table 2:2 may reflect the yield differences between purchase areas and reserves. What appears to be a significantly superior economic performance of skilled farmers may largely be the result of the larger proportion of skilled farmers in the purchase areas. This explanation, if correct, is important; it would imply that the agricultural extension program has been given credit for yield differences that are at least partly attributable to other factors.

The intergroup differences in yield can also be attributed to differences in inputs used and in technical efficiency. First, consider soil type. We noted in Table 8:5 that, net of other inputs, output of each crop was higher on red loam than on sandy soil; the contribution of red loam is especially great for corn and millet. It is then noteworthy that the percentage of farmers on red loam differs among skill groups: 57 per cent of the skilled and unskilled farmers, but 86 per cent of the semiskilled farmers.

To adjust for the intergroup differences in soil type, we weighted red loam and sandy soil by their estimated marginal productivities (Table 8:5) to obtain an index of land of equivalent fertility units. On the basis of this land index, adjusted yields were calculated; a comparison of adjusted yields among groups is then taken net of intergroup differences in soil composition.[44] The adjusted yields appear in Table 11:1. Skilled farmers obtained a larger adjusted yield than semiskilled farmers in both corn and peanuts, and in overall crop output.

Factors other than soil type may also help explain yields. Table 11:2 presents figures on the use per farm of fertilizer, manure, and fixed capital, by skill group.

TABLE 11:2.—MEAN USE OF INPUTS BY MANAGEMENT GROUP: CHIWESHE

	Skilled	Semiskilled	Unskilled
Fixed capital (*dollars*)			
Total	114.80	48.00	37.00
Per acre	7.09	4.52	3.90
Chemical fertilizer (*dollars*)			
Total	7.36	6.42	4.20
Per acre of corn	.63	.81	.58
Organic fertilizer (*tons*)			
Total	6.80	4.20	2.82
Per acre of corn	.58	.53	.39
Labor (*weeding hours*)			
Corn	294	297	259
Peanuts	114	107	94
Millet	122	77	88
Total	530	481	441
Per acre	32.7	45.3	46.3

[44] In other words, keeping the total acreage constant, the semiskilled farmers' acreage was increased and the skilled and unskilled farmers' acreage was reduced. The amount of the increase and decrease varied among crops, depending on the differential marginal productivity of good over bad soil. The total acreage of skilled and unskilled farmers was reduced by 3.6 per cent for corn, 0.9 per cent for peanuts, and 3.0 per cent for millet. The total acreage of the semiskilled farmers was increased by 9.0, 3.5, and 8.1 per cent for corn, peanuts, and millet respectively.

Skilled farmers used more of all three inputs than semiskilled farmers, who in turn used more than unskilled farmers. On a per-acre basis, however, it is noteworthy that semiskilled farmers used the most fertilizer.

Of some interest, the three groups planted the same proportion of their land to each of the three crops. And this is despite the difference among groups in the total value of output per farm. This suggests to us that there are strong forces (perhaps tradition) determining the crop mix.

There is some intergroup difference in the allocation of labor among crops. Skilled farmers spent a smaller proportion of their total planting and weeding time on corn than either of the other groups. They spent a larger proportion of their planting time on peanuts and (surprisingly) a larger proportion of their weeding time on millet. The semiskilled and unskilled farmers differed little in their allocation of labor among crops.

The following broad picture emerges from the preceding discussion. Net of observed inputs, the average skilled farmer obtained a larger output than the average semiskilled farmer; his technical efficiency is higher by $5.87. However, technical efficiency is only one aspect of economic performance. There are also differences among the groups in the use of inputs. Skilled farmers, on the average, obtained $44.16 more output than semiskilled farmers. Much of this was due to differences in acreage. On a per-acre basis, the skilled farmers obtained a slightly lower output than semiskilled farmers. If differences in soil type are taken into account, the skilled farmer obtained a 6.5 per cent higher average yield than the semiskilled farmer. On a per-acre basis, also, skilled farmers used more manure but less fertilizer and labor. Of particular interest, skilled farmers obtained much higher peanut yields but much lower millet yields than semiskilled farmers.

There is less difference between semiskilled and unskilled farmers. Net of all inputs, the average semiskilled farmer obtained $4.16 more output. However, total output per farm in the semiskilled group was $27.16 more than among unskilled farmers. Semiskilled farmers obtained higher yields of all three crops than unskilled farmers, and 12.8 per cent greater overall yield. Semiskilled farmers also used more fertilizer per acre and more manure per acre, but slightly less labor per acre.

The results strongly suggest the presence of an interaction between technical efficiency and crop. The skilled farmers were most efficient in peanut production, but least efficient in growing millet. This is confirmed by yield figures, even when land is adjusted for differences among groups in soil type. As noted in Chapter 7, the techniques of farming are fairly straightforward in an area like Chiweshe Reserve, so that there is little basis for crop specialization. However, agricultural extension workers have tended to focus on corn and peanuts, to the neglect of millet. Their rating of farmers may reflect this emphasis, and may take into account only factors related to the farmer's performance on corn and peanuts. Our results seem to call into question the usefulness or relevance of the government rating scheme. It would be of interest to examine these relationships in greater detail, using a controlled sample.

Possible shortcomings in the government rating scheme—or in the agricultural extension program—may explain why a farmer who is efficient at growing corn and peanuts is not especially efficient in growing millet; however, it fails to explain why he obtains below-average millet yields. We believe that this is simply a result of the small sample size. There were only seven skilled farmers in the sample, two of whom obtained very low millet output.

Economic Opportunity and Management

The size of a farmer's plot of arable land is fixed by a complex set of factors governing land rights in the reserve. A more skilled farmer cannot, by virtue of his greater skill, choose to cultivate a larger holding. From the farmer's point of view, acreage and soil quality are fixed. So, to a large extent, is his fixed capital stock. The larger holdings of arable land and the larger capital stock of the skilled and semiskilled farmers cannot be said to result from the farmer's skill.

However, one can more plausibly turn the causation the other way round. Farmers with a larger acreage have a better opportunity to earn an income from crop production. Farmers with a smaller holding of land have less opportunity to support their families from farm income alone, and may accordingly spend a larger part of the year in the employment centers, working for wages. Farmers with greater economic opportunities on the farm are likely to become more committed to good farming, and to spend more time trying to make a success of the farm venture. If a farmer has a greater economic opportunity on his farm, he can be expected to take farming more seriously: to be more responsive to agricultural extension advice, for example, and more willing to use fertilizer and to adopt improved patterns of crop rotation. In other words, he is likely to be more committed to good farm management.

To test the hypothesis that farm size is an important determinant of absenteeism from the farm, we ran a simple regression. The regression equation is written

$$N = a_0 + a_1 T^* + u \tag{11.1}$$

where $N =$ the number of months the head of household was absent from the farm for 15 or more days,[45] $T =$ the total arable acreage, $u =$ a stochastic term, and the asterisk denotes a logarithm.

The value of r^2 is .16, indicating that acreage explains only a small part of the interfarm variation in number of months absent from the farm. However, the regression coefficient is highly significant; the estimated value of b is —3.47, with standard error 1.10, giving a t-ratio in excess of three. The elasticity of N with respect to T (calculated at the mean of N) equals -1.12. Therefore, a reduction of acreage by one-half can be expected to be accompanied by approximately a doubling in number of months absent.

These results provide evidence that farm size influences commitment to farming; this may help explain the association between acreage and farming skill. A larger acreage provides a greater incentive to develop one's own farm and this creates a willingness to learn and to develop management skills. This interpretation is consistent with the results obtained above. Farm size is a determinant of the level of management. And farm size, together with quality of management, influences the inputs of chemical and organic fertilizer, fixed capital, and labor.

This interpretation also accounts for the difference among management groups

[45] If absent for this long, he can be assumed to be working (or seeking employment) for wages.

in absenteeism from the reserve. Looking at heads of households, unskilled farmers were absent from the reserve an average of 4.2 months during the year, whereas semiskilled and skilled farmers were absent 1.9 and 0.3 months, respectively. The figures thus suggest a relationship between management and commitment to farming.[46]

Darwin

There is a conceptual difference in the measurement of management in Chiweshe from that in Darwin. The Chiweshe management index is directly observed, is based on objective criteria, and encompasses both technical and economic efficiency; the Darwin measure is estimated and is based on technical efficiency only. Moreover, the Darwin management index includes the contribution of unobserved variables that constitute a "farm" effect. Although differences among farms in soil type and in observable inputs have been netted out, there likely remain other factors accounting for interfarm differences that one would ideally wish to isolate from management. For example, investment in land improvement, selection of seeds, or use of pesticides will be reflected in a farm's management index, as measured by the α_{0j}. The α_{0j} measure output per unit of observed input, where the inputs are combined multiplicatively and weighted by the coefficients in the intrafarm production functions.

Setting the average α_{0j} equal to zero, the estimated α_{0j} ranged from —.0310 to 3.00. Taking antilogs of these figures, the best farm could, with given inputs, obtain just twice the output of the average farm, which, in turn, could obtain twice as much output as the worst farm.

As in Chiweshe, it is of interest to examine the characteristics of good managers and, in particular, the tendency for better than average managers to use more (or less) of any of the productive inputs. Management (as estimated by the α_{0j}) was regressed against each factor input in each of the three production functions. Table 11:3 shows the estimated simple correlation coefficients between management and the factor inputs. Although none of the coefficients is signifi-

TABLE 11:3.—SIMPLE COEFFICIENTS OF CORRELATION BETWEEN MANAGEMENT AND FACTOR INPUTS: DARWIN*

Inputs	All crops	Corn	Peanuts	Millet
Fixed capital	—.10	...	...	...
Soil type	.02	...	...	...
Land	—.03	—.08	—.04	.08
Weeding	.16	.27	—.01	.05
Fertilizer	.21	.21	—	—
Manure	.10	.10	—	—

* Dots (...) indicate that data are not available; blanks (—) that the input was not used on the specified crop.

[46] The average age of skilled, semiskilled, and unskilled farmers, respectively, was 54, 49, and 49. Older farmers are usually absent from the area less than younger farmers; but it appears unlikely that age accounts for more than a small part of the difference in absenteeism between skilled farmers and the other two groups.

cant at the 5 per cent level, the results suggest that better managers use more fertilizer and spend more time weeding corn.

For the Darwin data, we also examined the relationship between management and years in the area. One would expect two factors to be operative here. First, as noted earlier, the fertility of virgin soil is typically high; the longer the land is cultivated, unless adequate soil conservation measures are undertaken, the greater the reduction in soil fertility. For this reason, one might expect those most recently settled in the area to obtain larger output per unit of input.

On the other hand, perhaps there is a "learning" factor. A farmer settled on a purchase area farm is cultivating a larger holding, using more capital implements than before. This represents a new experience for him. One might expect farmers to learn new techniques as a result of (1) exposure to the new form of farming, (2) agricultural extension service, and (3) trial and error. In this case, those who have been in the area longest would tend to be the best managers.

We calculated the mean management index for groups of farmers arranged by length of tenure on their farm (see Table 11:4). The results are inconclusive. However, with the exception of the first group, there is little suggestion of a systematic pattern. An F test shows no significant difference among the means. The first mean is considerably lower than the others, suggesting that it may take more than a year for a farmer to adjust to the new routine.

TABLE 11:4.—MEAN MANAGEMENT INDEX BY YEARS ON THE FARM: DARWIN

	Number of years on the farm				
	1	2	3	4	Over 4
Mean management index	49	132	141	107	123
Number of farms in group	4	4	5	3	4

Chapter 12

CONCLUSIONS AND IMPLICATIONS FOR POLICY

Qualifications

There are several reasons why too much weight should not be placed on the empirical results, and why therefore policy conclusions should be phrased in terms of questions for further study rather than firm statements. These reasons can be grouped under three headings: conceptual problems, data limitations, and statistical problems. We have referred to these in the preceding chapters, but will draw together our remarks here.

A number of conceptual problems were only partly resolved in conducting the analysis. These problems relate largely to the specification of the production function. It would be useful to investigate further the treatment of soil types and nonessential inputs. It would be especially useful to consider alternative ways of specifying labor in the production function. Perhaps alternative ways of weighting hours worked by men, women, and children would provide a better fit. Perhaps weeding hours should be weighted according to the time at which the weeding was carried out. Perhaps also, although planting hours are not significant as an explanatory variable, time of planting would be significant. We were constrained by the availability of time and money to make certain arbitrary assumptions. It would be desirable for other researchers to consider alternative ways of dealing with these problems.

In principle, one can include all relevant variables in a multiple regression or analysis of covariance model. In practice, some variables are difficult to quantify or to measure. Other variables were just not observed in the two samples. For example, interfarm differences in labor intensity, in the use of pesticides, and in quality of seeds used were all excluded from the analysis. This is probably why only a small proportion of the variance in output is explained by the observed inputs.

It is well known that inclusion of a large number of variables in a multiple regression model tends to create multicollinearity. If the investigator is free to choose input levels as he sees fit, then this problem can be averted. But the investigator typically has to take what he can get. And it is one of the economic facts of life that samples frequently do not permit observation of independent variation in a large number of variables. In the present case, this helps explain the relatively low level of significance of the independent variables.[47]

The measurement of capital services employed in this study raises a number

[47] Vernon Ruttan suggested in a private communication that one can get around this problem by drawing on experimental results. For example, if one knows the relationship between fertilizer and corn output, the relevant parameters can be introduced into the corn production function, obviating the need to estimate these parameters. This procedure works if results obtained experimentally continue to hold in actual farm situations. There is some doubt whether this is the case in African smallholder agriculture.

of issues. For one thing, many farms had unserviceable equipment that should ideally be excluded from the capital index. Second, capital-sharing in Chiweshe presents serious measurement problems. If two farms share a set of implements, how much use does each farm obtain? Third, it was noted that a farm's capital stock included not only implements but also livestock (used, among other things, as draft power) and land improvements. Yet data were not available on these inputs.

It is worth noting that the two samples drawn on here were not collected specifically for the present study; the authors had to take the data as given. If one were collecting data expressly to estimate production function coefficients, one would doubtless proceed differently.

In this sense, we hope the present study will serve as a guide for further investigation of production relationships, economic efficiency, and the returns to productive factors in underdeveloped agriculture. Perhaps the principal value of our work is in showing how limited data, collected for other purposes, can be used effectively to shed light on the economics of agricultural underdevelopment. A vast amount of data has been collected relating to agricultural production in many parts of the underdeveloped world. Although some of this material has been processed, a great deal more information can still be extracted. Unfortunately, there are many gaps. However, one is seldom able to find "ideal" data upon which to base a study. Instead, the investigator has to use what information is available, filling in the gaps and making adjustments as best he can. He has to make do with methods that allow for the inadequacies of the data, and that nevertheless permit one to estimate the underlying economic relationships, albeit in a less-than-perfect way. The results thus obtained, while far from ideal, are nevertheless the best we can obtain, and can still be useful in forming conclusions and making policy recommendations. This monograph outlines procedures for extracting this additional information from sketchy data, and for developing conclusions from this data.

Statistical estimation of production function parameters has been the subject of extensive criticism in the economic literature. We believe that in the present case, reasonably good estimates have been obtained of at least some coefficients. We believe that the estimates are largely free of specification and simultaneous equation bias. However, as noted, we have run into considerable multicollinearity. The standard errors of the estimated coefficients for many of the productive inputs are high. Because the estimates of the elasticities and marginal productivities are accordingly subject to large error, it is hazardous to base firm conclusions on these figures.

Role of Present Analysis

Having dutifully stated our reservations, and the reasons why too much weight cannot be placed on the quantitative results, let us point out why the study may nevertheless be of some interest.

First, some of the results are statistically significant. Even bearing in mind the qualifications raised above, the results have at least a heuristic value. Many of the conclusions derived from these results are interesting and have important implications of both intellectual interest and policy relevance. While one would be unwise to base policy recommendations solely on the results of this analysis, the conclusions derived here provide some useful insight into the problem of raising agricultural output; and in this sense the conclusions provide one input in the policy maker's decision function.

As was mentioned in Chapter 1, an important contribution that production analysis can make is to provide hypotheses for further investigation. Some of the results contained here are sufficiently important to warrant further experimentation at the agricultural research stations. The methodological discussion and the problems encountered in building the model may provide useful information for other economists conducting empirical research on underdeveloped agriculture. Accordingly, the conclusions and recommendations set out in the following pages are not intended as positive answers to intellectual questions or as concrete recommendations to policy makers. Rather the conclusions are advanced as a set of hypotheses for further research.

Scope for Improvement in the Reserves

Chiweshe Reserve is probably reasonably typical of the reserve areas in Rhodesia, with respect to economic performance and opportunities. It is closer to Salisbury than most reserves, so that opportunities to work for wages for very short periods are greater. The resource endowment, in terms of land and capital, is probably not far from the average. The prospects for improving productivity in Chiweshe can be taken as fairly representative of the reserves as a whole.

However, it is important to bear in mind a qualification stated earlier. The Chiweshe sample is biased upward due to the exclusion of farms not growing all three of the major crops. These tended to be smaller farms, using smaller quantities of inputs and obtaining less output. Our conclusions, then, apply only to the larger farms in the reserve areas, growing the three staple crops. We do not know how much relevance the conclusions have to reserve farmers as a whole.

The conclusions provide no evidence, on the average, of inefficient resource allocation. The results show that a reallocation of inputs would provide very little gain in output. And this gain can easily be explained by measurement errors or by factors (outside the model) specific to the particular sample year. There is no evidence that a reshuffling of inputs among crops would provide a long-term increase in output.

Of course, the methods used here focus only on average farm performance in the sample, and do not examine the scope for gain on individual farms. This could be done with linear or nonlinear programming techniques using the parameter estimates obtained here. One of the authors did some work relating to individual farm performance, using linear programming based on assumptions different from those made here. His results are presented elsewhere (*9, 9a*). The possible gains that they revealed from reallocation were not large.

As illustrated by the present study, there is limited scope for raising output in the reserves through use of additional inputs. The marginal productivity of land in Chiweshe is positive, so that increasing the size of an individual's holding, keeping other inputs constant, will raise the farm's output. However, land is scarce in Rhodesia, so that one holding cannot be increased without decreasing the size of a holding elsewhere. The question then is one of evaluating changes in the allocation of land between reserves and purchase areas (which we consider below), and considering the allocation of land among farms within the reserves.

There is evidence that if more land is given to a farmer he will put in longer hours, use more manure and fertilizer, and improve his technique of production. Despite a decline in the use of labor per acre, yields are greater on large than on small farms in Chiweshe. Thus some increase in output would result from land consolidation. Although this rise in output would easily outweigh the resulting cost of increased fertilizer use, the reallocation of land would reduce the number of persons employed on the land and consequently increase unemployment. Whether the rise in output would be worth this increase in unemployment is moot. Moreover, as we show below, if changes are to be made in the pattern of landholding, it would be more economic to create additional purchase area farms.

Given the present pattern of landholding in the reserves, output can be increased only by raising yields on individual farms. We have seen that some modest increase in output can be obtained through a more intensive use of labor; the marginal product of labor exceeds zero for all three crops. But reserve farmers will not put in this extra work unless it is worth their while. The improvements in yields cannot be brought about at the cost of a reduced marginal productivity of labor. Rather, improvement must be such as to raise output both per acre and per hour worked. Indeed, it is noteworthy that the skilled farmers, with their larger acreage, greater skill, and greater inputs of capital, fertilizer, and manure, worked only 14 per cent more than the unskilled farmers, and worked less on a per-acre basis. Given the value of leisure and the opportunity to work for wages outside the reserve, it seems unlikely that reserve farmers will work longer hours without a greater incentive.[48]

The results suggest a low return to investment in fixed capital in the reserves. This supports the view, frequently expressed to us by agricultural extension workers, that farmers frequently buy equipment more as a status symbol than as an economic factor of production. This view is given further support by the bad state of repair of many implements in Chiweshe.

In Chiweshe, the gains from using more fertilizer are probably too small to justify the expenditure. On an individual farm basis, however, one would suspect that those farms not using any fertilizer, or using very small quantities, would benefit from fertilizer use. Similarly, some farms may be using an uneconomically large quantity of fertilizer.

There is evidence that more manure is obtainable on many farms, and that the farmers frequently do not make the effort to prepare compost. As the marginal return to manure is high in Chiweshe, and as manure is applied during a time when labor is otherwise largely idle, farmers should be made aware of the potential gains from greater use of compost, and should be encouraged to make the additional effort. Moreover, manure has a residual effect on crop output in subsequent years, so that the return is greater than the results suggest.

Output can also be raised by improving farm management. On the basis of

[48] Such an incentive would be provided by an increased population relative to opportunities for employment outside the reserve. In this case, it is doubtless true that the intensity of cultivation would increase simply to avoid starvation. However, the gains achievable from more intensive cultivation are small unless soil conservation measures are undertaken. And this would appear to require some institutional change.

the classification of Chiweshe farmers according to government rating, skilled farmers obtained larger yields than unskilled farmers. But the difference was not dramatic. The yield differential was $1.48, compared with a mean yield of $7.10 for unskilled farmers. Part of this was due to differences in inputs used. If we focus on differences in output net of differences in inputs, the average skilled farmer obtained 14.8 per cent more output than the average unskilled farmer.

The results suggest that extension work may be wasted on a farmer with limited resources. The skilled farmers may have adopted improved techniques, and, in particular, a greater use of inputs, because of their larger holdings. It follows that agricultural extension work is unlikely to have an impact on the farmers with small holdings. To ensure the effectiveness of extension work, it is necessary to provide the farmers with an incentive to take farm management seriously. This may be much easier in a purchase area, where the farmer has an opportunity to make a good living from farming. Unless the reserve farmer can make a reasonable living from crop production, he may be little interested in an opportunity to achieve marginal economic gains. Given the effort involved and the uncertainty associated with any change in his cropping pattern, he may be reluctant to alter his ways.

Purchase Areas as an Alternative

Although modest increases in output can be obtained in Chiweshe Reserve, resources can more profitably be used in Darwin. Output per farm is nine times as high in Darwin as in Chiweshe. And, as a consequence, sales per farm are 150 times as high. While Chiweshe is almost exclusively a subsistence economy, at least regarding the principal crops, Darwin has moved far toward becoming part of the money economy.

Part of the difference in output is due to the size of the holdings. Cultivated acreage per farm is more than twice as great in Darwin as in Chiweshe. But yields per acre of each crop are higher in Darwin as well.

To some extent, the Darwin farmers may represent a different group of people: those with enough initiative (and, in some cases, capital) to leave the reserve and carve out new lives for themselves. This factor may be of some importance, but we do not have enough information to be able to make an assessment.

To some extent also, the higher yields in Darwin are attributable to a greater per-acre use of manure, labor, and implements. This partly explains the higher marginal productivity of land in the Darwin sample. But it is interesting to note that the marginal productivity of labor, fertilizer, and fixed capital are all higher in Darwin as well, suggesting that part of the difference in economic performance between the two areas is explained by factors not explicitly introduced into the analysis. The superior performance of Darwin farmers may be due in part to their greater management ability, but this is unlikely. More likely, the better performance of the Darwin farmers is due to the fact that they have made a larger investment in land improvement and in soil conservation measures, and have devoted more time to weeding.

In Rhodesia, as in most African countries, there is population pressure on the land. Agricultural policy is aimed at obtaining a larger output from the country's limited land and capital resources. Policy is aimed also at alleviating the serious unemployment generated by the rapid rate of population growth, the much lower rate of increase of jobs in the urban areas, and the limited amount of good agricultural land.

If we take Chiweshe and Darwin as representative of reserves and purchase areas, respectively, then the purchase areas clearly represent a better use of both land and capital than do the reserves. Yields are much higher in Darwin than in Chiweshe. Similarly, the marginal (and average) returns to equipment and fertilizer are higher in Darwin. Furthermore, soil conservation measures are better in Darwin, so that the area's long-term potential can be expected to rise relative to that of Chiweshe. Transforming the reserves into purchase areas would bring about a net economic gain.

However, the purchase areas do not appear to provide greater employment opportunities. Admittedly, the labor-land ratio is much higher in Darwin than in Chiweshe. But this results from the longer hours worked by members of the farm family. More people are actually employed on an acre of land in Chiweshe than in Darwin. Moreover, it is noteworthy that the Darwin family makes little use of hired labor, despite the abundance of persons willing to work. The Darwin farmer cultivates as much land as he and his family can manage, and little more. Thus, if Darwin is at all typical, transferring land from reserves to purchase areas will not permit the absorption of additional people into agriculture. It will, however, enable those with land to obtain a substantially higher income and to work productively more hours per day and days per year.

Comparison of Darwin Average Farmers with Chiweshe Skilled Farmers

As noted earlier, Darwin was settled mainly or exclusively by Master Farmers which, in our discussion of Chiweshe, were classified as "skilled." Thus differences between Chiweshe skilled farmers and Darwin average farmers cannot easily be attributed to management ability.

Table 12:1 presents figures for the average Chiweshe skilled farmer and the

TABLE 12:1.—COMPARISON OF ECONOMIC PERFORMANCE OF CHIWESHE SKILLED FARMERS AND DARWIN AVERAGE FARMERS

	Chiweshe skilled farmers	Darwin average farmers
Area per farm (*acres*)	16.2	23.7
Output (*dollars*)		
Per farm	139.0	757.4
Per acre	8.6	32.0
Fixed capital (*dollars per acre*)	7.1	11.3
Chemical fertilizer (*dollars per acre of corn*)	.63	.50
Manure (*tons per acre of corn*)	.58	1.96
Labor—weeding (*hours per acre*)	32.7	70.1
Output (*dollars*)		
Per hour of weeding	.26	.46
Per hour on all jobs	.11[a]	.15[b]

[a] Based on the assumption that skilled farmers spent the same percentage of their time weeding as the average of all farmers, i.e., 41.8 per cent.

[b] Excluding hours spent on land improvement; including hours spent on land improvement the figure is .09 dollars per hour.

average Darwin farmer. Although the Darwin farmer has only 46 per cent more land, he obtains 5.4 times as much output, so that his yield is 3.7 times as great. On a per-acre basis, he uses slightly less fertilizer but 59 per cent more capital, 3.4 times as much manure, 2.1 times as much weeding labor, and 4.0 times as much total labor (including time spent on land improvement). Because of the substantially larger labor-land ratio in Darwin, differences in output per hour worked are much less than the difference in yields. Output per weeding hour in Darwin is only 80 per cent greater than that of the Chiweshe skilled farmer, and output per total hour only 36 per cent greater. It is noteworthy that the purchase area farm is apparently able to absorb a significantly greater labor input; the farm family can devote a larger proportion of its time to productive agricultural work.

Scope for Raising Output in the Purchase Areas

As in Chiweshe, there appears to be little scope for raising output in Darwin by reallocating inputs among crops. There is, however, greater scope in Darwin for increasing output through using more of each input.

Some increase in output can be obtained by using more labor. The marginal return to labor is, however, not much higher in Darwin than in Chiweshe. Moreover, as the farm family is fully utilized, an increase in labor input would necessitate a greater use of hired workers.

The higher level of capitalization of the purchase area farm must certainly contribute to the larger output vis-à-vis the reserve holding. But differences in output among farms within the Darwin area do not appear to be directly attributable to differences in capital stock. This leads one to conclude that some farms may be overcapitalized.

The return to fertilizer is high in Darwin, so that there is scope for greater fertilizer use. The high percentage of farms not using fertilizer would derive particularly great benefit from its use. It would be worth further study to determine why farmers in a purchase area fail to use fertilizer. Is it because of the unavailability of credit or some other reason? Perhaps it is because the Darwin farms are on virgin soil.

The Darwin farmer uses appreciably more manure (per farm and per acre) than his Chiweshe counterpart. Because of the relatively large manure application, the return at the margin to manure is lower in Darwin than in Chiweshe. It may not be worth while for the Darwin farmer to invest additional time in manure preparation and application—even if more manure is obtainable from the farm's given stock of cattle.

In Darwin, land, labor, and fertilizer are all scarce resources. We have noted that more land is available, but only at the cost of removing large trees and stumps. This, in turn, requires a considerable expenditure of time and effort. And to use the land economically, while maintaining soil fertility, more labor would be required to work the additional acres. The Darwin family, already working at capacity, cannot be expected to do this additional work.

One alternative is to increase the use of hired workers. The constraint operative may be the supervisory talent of the purchase area farmer. If he were able to supervise the clearing and cultivating of additional land by hired labor, it would be in his interest to do so. There is certainly an abundance of labor in the neighboring reserves available to work on purchase area farms. The purchase area farmer would increase his income and make a contribution to Rhodesia's unemployment problem by hiring additional help. It would seem to be of great concern to determine why more hired labor is not used, and to take measures to remedy the situation.

As noted earlier, the farms in the Darwin sample averaged 200 acres, including about 70 arable acres, of which less than one-third was actually cultivated. It might pay to consider the establishment of smaller purchase area farms—especially farms with less arable land. As the marginal product of cultivated land is so great in a purchase area, it would pay to use this land more intensively by raising the proportion of arable that is cultivated. Perhaps increasing the density of settlement in the purchase areas would result in a substantial rise in output. This bears further investigation.

Increasing the proportion of arable to total acreage may have an adverse effect due to the reduced carrying capacity of the land and the effect of this on income from livestock. However, we note that income per acre from arable was much greater than from pasture land. Therefore, there may be merit in creating smaller purchase area holdings, so that more of the land will be cleared and planted. Perhaps holdings of 100 acres would provide the farmers with adequate incentives, and provide enough grazing land, while permitting cultivated acreage of the area as a whole to double.

Purchase area farms, although larger than reserve holdings, are still regarded as smallholder agriculture. The arable acreage is small, and the level of mechanical cultivation is low. They are principally family farms run on a simple basis.

Nevertheless the economic performance of these farmers is impressive. With a modest investment in fixed and working capital, and with the use of the family labor, the average Darwin farmer was able to earn a gross income of $757 from the three principal crops alone, plus some additional income from minor crops and his livestock enterprise. This contrasts favorably with the average family crop output of only $83 in Chiweshe. The purchase area represents an improvement in institutional form compared with the reserve. The purchase area farmer is brought into the market economy and given an opportunity to make a reasonable living from farming, without the need to leave the farm to seek wage employment.

Although some economists argue that agriculture can be improved only through a major transformation, the performance of the Darwin purchase area offers evidence to the contrary.

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