COSTS, ECONOMIES OF SIZE AND RESOURCE USE RELATIONSHIPS IN WHEAT PRODUCTION IN NAKURU DISTRICT, KENYA.

by

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A thesis submitted in partial fulfilment of the requirements for the degree of Master of Science in Agricultural Economics of the University of Nairobi.

Nairobi, December 1995.

DECLARATION

I, Wekesa, Linus Chesoli, do hereby declare that this thesis is my original work and has not been presented for a degree in any other University.

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ABSTRACT

Wheat production in Kenya has slumped during the last two decades due to among other factors the high cost of production and subdivision of former large-scale wheat farms. The broad objective of this study was to examine cost behaviour under the prevailing production environment of wheat industry to help identify ways of overcoming this discouraging situation. Three hypotheses were tested. These were: that rate of wheat output has no significant effect on cost; that size of wheat enterprise does not significantly affect cost; and that degree of wheat specialization has no significant effect on cost. Both primary and secondary data were used for the analysis. The secondary data was obtained from national agricultural reports while primary data was obtained from a farm survey using a questionnaire administered on a sample of 80 wheat farmers in Nakuru District. The method of Ordinary Least Squares (OLS) was used to estimate the cost functions using cross-section data of the wheat industry over the 1992 production season.

Results showed that costs of wheat production on small-scale farms are high compared to production on large-scale farms. Average costs per tonne of wheat produced on small- and large-scale were Kshs 12,666.40 and Kshs 502.60 respectively. This average cost declined significantly for the rising size of wheat enterprise, level of managerial skills of entrepreneur, dairy activities on wheat farms and usage of own machinery. Average cost also decreased with increasing output level implying that increased yields lead to low costs. However, average cost rose significantly with increasing crop activities on wheat farms. The significant costs in wheat production were found to be on land preparation, harvesting and labour. Wheat exhibited complementary and supplementary

relationships with dairy enterprise in the use of resources. However, the combination of the wheat enterprise and other crop enterprises exhibited competition in use of most resources apart from machinery and labour where supplementary relationship was observed. Wheat was found to be a decreasing cost industry demonstrating existence of substantial economies of size. The wheat industry achieved both pecuniary economies and real economies. Pecuniary economies were realised from paying lower prices for the factors used in wheat production due to bulk-buying by the farmer as the enterprise size increased. The significant real economies realised in wheat production arose from labour (labour economies), fixed capital (machinery economies) and land (land economies).

It was recommended that production at reduced cost can be carried out by adopting several alternative types of farm organisational adjustments. These involve seeding of more land under wheat to exploit the substantial economies of size that exist in wheat farming, combination of wheat with complementary enterprises like dairy that lead to saving and optimal utilization of resources, and ownership of machinery used in wheat production. Appropriate technology suited for small-scale wheat production conditions should be designed and farmers should be encouraged to increase their operational scales through lease or purchase to exploit economies of size that exist in the industry.

ACKNOWLEDGEMENTS

I am greatly indebted to my supervisor Dr. H.O. Nyangito of the Department of Agricultural Economics, University of Nairobi for his stimulating criticisms, helpful suggestions, encouragement and careful scrutiny of the work. To Dr. K.C. Sharma, I say lots of thanks for his careful scrutiny and amplification of the idea during the research proposal preparation stage.

My sincere gratitude goes to the University of Nairobi for the award of a two year scholarship which enabled me to carry out this study. I acknowledge and appreciate the tireless efforts made by Prof. Ackello-Ogutu in making sure the scholarship was forthcoming.

I am also indebted to the following for the assistance they rendered to me during different stages of this work:

a) The Nakuru District Agricultural Extension Staff

b) Mr. D. Muchene of the Department of Agricultural Economics

c) Dr. Chandaria of the University Health Services for rehabilitating me back to studies

d) Fellow colleagues in the 1991 Msc. Agricultural Economics class.

Last but not least I wish to express my deep and sincere appreciation to my parents for their commendable role in my success. They have jealously ensured my success through their patience, encouragement and support in all ways. Special thanks to my dear wife Enid who through her constant companionship and encouragement made this be a reality. Glory and honour be to the Lord Jesus Christ for directing this work.

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Acronyms and Abbreviations

AEC --------- Agro-Ecological Zones

^{0}C --------- Degrees Centigrade

HA --------- Hectare = 2.471 Acres

Kg --------- Kilogramme

KSH -------- Kenya Shilling(s)

mm --------- millimetre

MOPND ------ Ministry of Planning and National Development

PAM -------- Policy Analysis Matrix

NPBRC ------ National Plant Breeding Research Centre

OLS -------- Ordinary Least Squares

UH --------- Upper Highland

UM --------- Upper Midland

CHAPTER ONE

1.0 INTRODUCTION

1.1 A General Review of Wheat Industry in Kenya

The role played by the agricultural sector in the Kenyan economy merits a lot of attention since the sector is the prime mover of the economy. The sector contributes about 27 percent of gross domestic product (GDP), accounts for 60 percent of Kenya's export earnings and absorbs about 70 percent of the country's labour force (Kenya, 1993). Essentially, priority ranking in the Agricultural sector centres on food production, generation of raw materials for local industries and graduated processing of production for export (Kenya, 1993).

Wheat, though consumed more in urban areas than rural areas, is one of the seven crops that are central to achieving the development goals established for the agricultural sector in Kenya (Kenya, 1981; 1986 and 1988). Wheat is the second most important cereal grown in Kenya occupying 2.2 per cent of the total area of crops and dairy pasture compared with 22.6 per cent taken by maize and beans (Kenya, 1992a). About 125 000 ha were sown to wheat in 1990 which contributed about 3 per cent of the total value of marketed agricultural production (Kenya, 1991a).

The main wheat growing areas in Kenya are Uasin Gishu, Narok, Nakuru and Trans Nzoia in the Rift Valley and Nyandarua in Central Province. Uasin Gishu has been the leading wheat producer in the country upto 1991/1992 period (Table 1.1).

Table 1.1: Wheat production and area in four districts in Kenya, 1970 - 1991

Year	Trans Nzoia		Uasin Gishu		Nakuru		Narok	
	Area[1]	Prod[2].	Area	Prod.	Area	Prod.	Area	Prod.
1970/71	6,230	10,341	48,000	55,019	36,460	61,008	5,708	12,844
1971/72	3,300	5,240	41,150	48,146	31,000	56,845	10,000	13,500
1972/73	3,840	7,650	33,700	43,810	30,060	-	7,800	21,064
1973/74	3,670	5,800	45,465	65,469	27,540	32,222	12,000	39,980
1974/75	5,000	7,875	32,986	47,520	28,850	45,439	12,990	23,382
1975/76	6,180	11,902	41,860	64,836	30,000	35,100	24,000	37,800
1976/77	6,500	12,870	49,720	67,122	35,000	47,250	24,155	43,475
1977/78	6,550	9,618	37,920	42,430	37,545	47,307	24,520	33,102
1978/79	5,000	621	31,430	58,571	28,644	25,780	13,124	25,986
1979/80	5,924	6,089	36,155	63,000	19,202	17,280	3,300	7,785
1980/81	5,300	15,454	37,600	86,303	26,322	54,975	13,300	21,909
1981/82	7,269	12,985	41,358	73,382	31,319	66,010	17,492	28,501
1982/83	4,419	9,902	40,767	95,557	35,680	64,497	16,080	34,733
1983/84	6,046	10,883	50,350	36,450	28,000	63,000	16,036	33,986
984/85	4,095	7,371	40,500	36,450	24,525	16,554	19,325	12,175
1985/86	3,497	7,238	40,770	91,732	22,512	70,913	29,300	92,295
1986/87	4,000	9,981	41,100	111,132	27,240	74,448	39,500	53,305
1987/88	10,000	18,000	42,210	103,202	29,000	65,250	40,960	92,160
1988/89	28,991	78,278	44,000	99,000	43,642	137,473	46,000	103,500
1989/90	3,100	6,975	52,532	118,197	29,104	62,867	49,000	132,300
1990/91	3,800	9,120	47,713	78,249	31,256	51,060	41,815	68,377

1Areas in Hectares

[2]Production in Tonnes

Source: Agricultural Production Data, MOPND, 1992.

In 1990/91 period, Uasin Gishu produced 41.2 percent of the total wheat production in Kenya. Narok District was second producing 34 percent while Nakuru was third contributing 27 percent of the total wheat output in the same period.

1.2 A Historical Perspective of the Wheat Industry

1.2.1 Pre-independence Wheat Production Era

Wheat was introduced into Kenya early this century by missionaries who grew patches of wheat in the highlands of Rift Valley Province for their own consumption (Odingo, 1971). Their success attracted the attention of the white settlers on the possibility of wheat production on large-scale. Several areas were sown with various varieties of wheat mainly of Australian origin (Kere, 1986). By 1908 over 4,000 acres of land was under wheat around Njoro, mainly grown by Lord Delamere. Over the years upto independence, wheat farming was restricted to white settler farmers. Production was concentrated on large-scale farms with cultivated area of 121 hectares considered as a reasonable minimum to justify ownership of a combine harvester (Odingo,1971).

The colonial government kept domestic prices of wheat high by restriction of supply into the local markets, and the competition from overseas countries was prevented by the imposition of import duty (Kere, 1986). Under Ordinance No.7 of 1942, amended by No.13 of 1943 (the increased production of crops Ordinance), the area under wheat was to be greatly increased. The Ordinance provided for issuing planting orders on the basis of which short-term credit and

Guaranteed Minimum Return (GMR) loans were advanced. In the latter scheme, advances of money were given to cover a good percentage of production costs of maize and wheat. The repayment was after harvest. If the yields were below the agreed minimum, and certified by an Agricultural Officer to be so, part or all of the advance could be waived depending on the seriousness of the crop failure.

The area under wheat more than doubled between 1942 and 1961 (Table 1.2). In 1942, there were 49 550 ha under wheat which gave 421 175 bags (90 kg) with an average yield of 8.5 bags (90 kg) per ha. By 1952, the area had expanded to 115 020 ha yielding 1 293 975 bags with an average yield of 11.25 bags (90kg) per ha (Table 1.2). The erratic yield levels between 1952 and 1961 could be attributed to the liberalization of the industry during this period leading to inexperienced producers entering the industry.

1.2.2 Post-Independence Wheat Production Era

After Kenya's political independence in 1963, the Government formulated land settlement policies that resulted into subdivision and redistribution of former European owned large-scale farms to small- and large-scale African farmers. Thus, today there exists a dual wheat production structure comprising both smallholder and large-scale producers (Hassan et al, 1992).

Between 1960-70, only 7 percent of the total wheat area was under smallholder production but this increased to 20 percent by the seventies. The proportion of wheat area under smallholder cultivation was expected to level off at around 25 percent as land

Table 1.2: Total area under wheat and wheat yields in the highlands, 1942 - 1961

Year	Area Planted ('00'ha)	Yields (Bags of 90.8 Kg per ha)	Total output (Bags of 90.8 Kg)
1942	495.5	8.5	4,211.75
1943	566.3	14.00	7,928.2
1944	648.8	9.25	6,001.4
1945	789.3	11.75	9,274.28
1946	806.4	10.25	8,265.6
1947	783.7	9.00	7,053.3
1948	806.4	12.75	10,281.6
1949	910.0	13.50	12,285
1950	1,070.8	13.50	14,455.8
1951	1,188.7	10.75	12,778.53
1952	1,150.2	11.25	12,939.75
1953	1,171.7	11.50	13,474.55
1954	1,178.6	12.75	15,027.15
1955	1,396.8	9.75	13,618.8
1956	1,278.2	11.00	14,060.2
1957	958	______	_______
1958	952.6	11.50	10,954.9
1959	1,035.6	13.75	14,239.5
1960	890.2	12.75	11,350.05
1961	920.6	10.25	9,436.15

Source: Odingo, 1971.

sub-division declined (World Bank, 1989). Unfortunately, there is little up-to-date information available on the distribution of wheat farms by size and region, contribution to the total wheat production and the number of smallholder and large-scale wheat farmers.

The World Bank (1982) reported that in 1971, wheat production on farms less than 20 ha was just over 20,0000 tonnes or about 10 percent of the total production. From a sample taken in Nakuru District, one of the major wheat growing districts, and the area of this study, Mulamula (1983) estimated that smallholder farms (less than 20 ha) occupied no more than 15 percent of the total wheat area, but represented over 70 percent of the total number of wheat farmers.

The sub-division and redistribution of former large-scale wheat farms not only led to mushrooming numbers of smallholder wheat farms, but also resulted in changes in the structure of wheat production (Hassan et al, 1992). The fact that maize and animal protein rather than wheat were the basic food for the new land owners, coupled with their in-experience in wheat farming, led to a relative decline in the total area under wheat and deterioration of yields (Hassan *et al, 1992*). Hence maize and dairy have tended to replace wheat in most smallholder land units.

The post-independence period of wheat production has been marked with erratic trends in production (Table 1.3 and Figure 1.1). There were large increases in wheat area in the period 1965 to 1969 probably as a result of allocation of new land to the

Table 1.3: Wheat production, yield and area in Kenya, 1963-92

Year	Area '000' Ha	Yield '000' Tons/ha	Gross Production '000' tons
1963/64	116.7	1.11	128.9
1964/65	119.7	1.20	143.0
1965/66	129.8	1.02	132.2
1966/67	136.2	1.32	179.1
1967/68	150.9	1.58	238.9
1968/69	167.3	1.33	222.6
1969/70	128.1	1.38	176.9
1971/72	115.1	1.48	170.3
1972/73	104.4	1.43	149.6
1973/74	107.4	1.28	137.9
1974/75	105.1	1.50	157.8
1975/76	117.3	1.38	161.9
1976/77	119.7	1.51	180.7
1977/78	137.8	1.20	165.9
1978/79	119.0	1.32	157.5
1979/80	87.2	1.78	155.1
1980/81	99.9	1.89	188.8
1981/82	99.7	2.23	225.7
1982/83	118.8	2.05	243.6
1983/84	120.0	2.09	251.3
1984/85	110.3	1.31	144.4
1985/86	118.8	1.70	201.1
1986/87	136.5	1.85	252.0
1987/88	145.1	1.40	207.0
1988/89	148.2	1.58	234.0
1989/90	153.4	1.59	244.2
1990/91	138.2	1.38	190.1

Source: Statistical Abstracts, various issues (1962-92): Central Bureau of Statistics (Ministry of Planning and National Development).

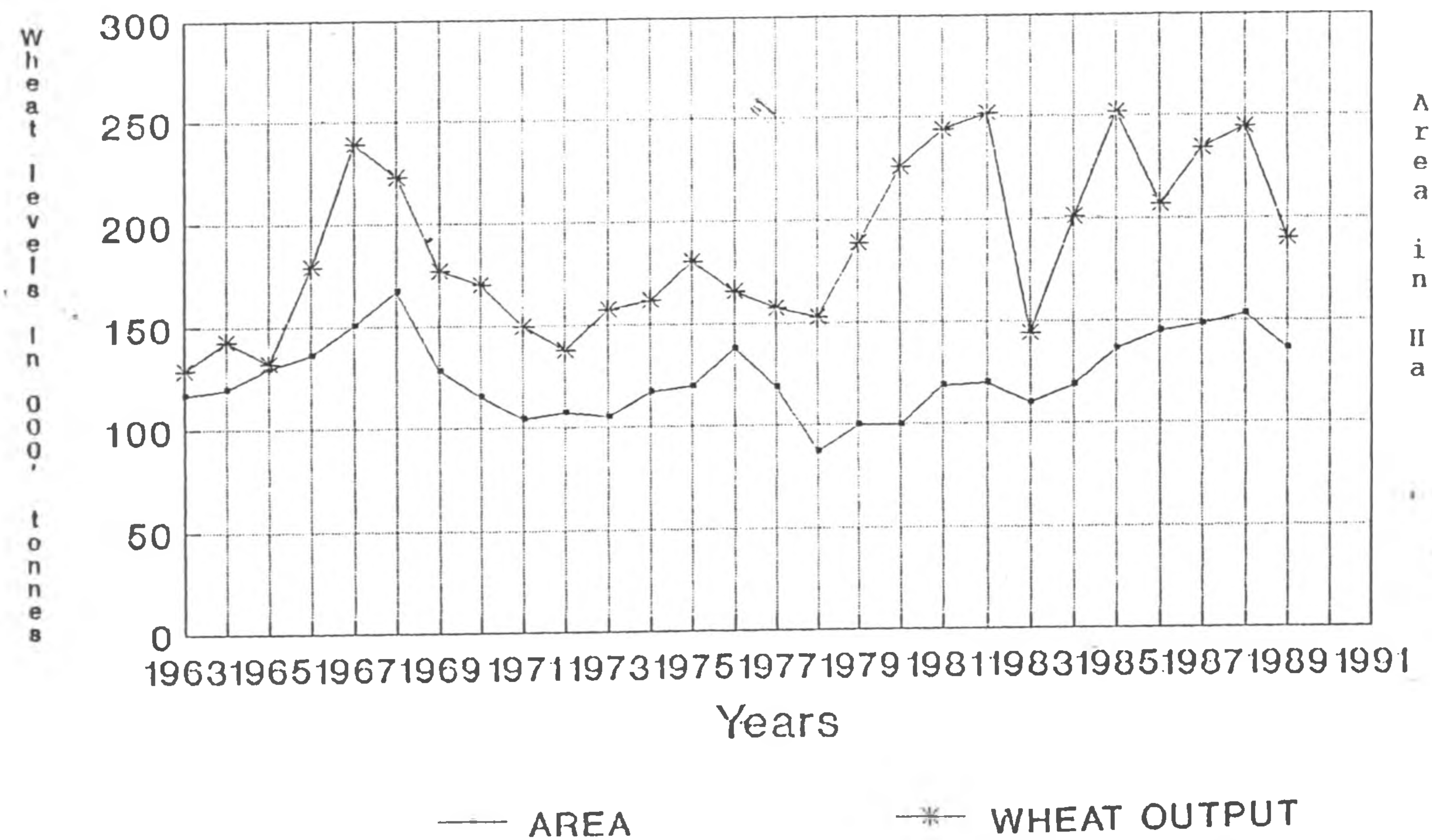


Fig 1.1: Wheat output, yield and area in Kenya, 1963/64 to 1990/91

landless in the 1960's. These new farmers entered into wheat production because of the remunerative package offered to them in terms of loans under the Guaranteed Minimum Return (GMR) scheme. Generally, wheat production and area declined by 1 percent per year over the period 1969-70, whereas yields remained relatively stagnant. The period 1979-89 registered positive growth rates for production and area while yields declined by 0.3 percent per year. This increase is attributed to introduction of wheat production in non-traditional wheat areas mainly in the marginal lands of Narok/Trans Mara region (Hassan et al, 1992). However, there was a general decline in both production and area under wheat in high potential area (area receiving over 900mm of rainfall) probably due to land subdivision and increased cost of wheat farming inputs (Kenya, 1986; 1991a).

The increased cost of wheat farming has largely been due to rapidly rising prices over the past few years of the inputs used in wheat production such as improved seeds, fertilizers, chemicals and machinery. The major reason was the depreciation of the Kenyan shilling against the major international currencies (Kenya, 1992a). This was exacerbated by the upsurge of petroleum prices affecting the input prices particularly those of mechanization services. The price of seed increased from Ksh 10.90 in 1990 to Ksh 14.60 per kilogram (kg) in 1992, an increase of 33.9 percent. The price of fertilizer (DAP) per 50 kg bag increased by 15.3 percent from Ksh 390 in 1990 to Ksh 450 in 1992 (Kenya, 1992a).

The low level of domestic wheat production compelled the government of Kenya in 1974 to start wheat importation each year to meet a high and rising local demand driven by a burgeoning population (3.5 percent annum), increased urbanization (7 per cent per annum) and incomes and a change in food preference from traditional cereals towards wheat and wheat products (World Bank, 1989). The level of wheat imports rose from about 33,000 tonnes in 1977 to approximately 218,000 tonnes in 1987, an increase of over 500 percent in a decade (Hassan et al, 1992). Import figures for 1988, 1989 and 1990 were 75,600 tonnes, 123,500 tonnes and 322,600 tonnes respectively (Kenya, 1991a). With this trend of import growth, the import bill is projected to reach US$545 million over the 1992-2000 period (Hassan *et al*, 1992).

To streamline and accelerate wheat production, information and data is needed on priority problems and possible solutions. Though some constraints have been studied and solutions defined, still some of the constraints lack comprehensive treatment to provide the necessary tools and theoretical framework with which to approach and manage them with more realism. This study is an attempt towards assembling information on cost as a production constraint.

1.3. Problem Statement

Kenya has a great potential for wheat production (Hassan *et al*, 1992) yet it can not grow enough to feed itself. Out of its annual consumption of 500,000 tonnes, the country only grows 200,000 tonnes (Kenya, 1992a). One of the problems leading to this state is the high cost of wheat production. This is brought about by the rapid rise in prices of agricultural inputs used in wheat production such as improved seeds, fertilizers, chemicals and mechanization costs over the past few years (Kenya, 1992a; Hassan et al, 1992; and Gitu and Sangori, 1992).

The high cost of wheat production has made producers to reduce the quantity of inputs they apply or made them to give up growing the crop leading to reduction in the volume of wheat produced in the country (Kenya, 1992a). This is being exacerbated by the subdivision of the wheat farms to economically un-viable sizes because of diseconomies of size especially with the use of machinery (Longmire and Lugogo, 1989). In 1990/91 season alone, wheat production declined approximately to 2.0 million bags and was projected to decline more in future due to such production constraints (Kenya, 1992a; and Gitu and Sangori, 1992).

Some attempts have been made towards understanding wheat production constraints and how they can be alleviated (Van Eijnatten, 1976; Ashcraft, 1977; Longmire and Lugogo, 1989; and Hassan et al, 1992). But there is paucity of literature oriented towards understanding cost as a constraint in wheat production. Accordingly, cost structure in wheat production is not well documented leading to lack of realistic measures aimed at alleviating cost as a production constraint. In addition, empirical studies or data to approve or disapprove existence of economies of size in wheat farming are scant. The available studies treat the issue superficially because of lack of empirical verification. This study attempts to fill this twofold gap.

To enable analysis of cost structure, a number of cost determinants derived from the prevailing socio-economic circumstances under which wheat is produced in the country are considered. That average cost would vary depending upon such factors as the size of wheat enterprise, level of individual managerial skills, degree of wheat specialization and the use of own machinery. This study breaks changes in costs along these lines to enable empirical study of both the sources and consequences of variation in these sources over costs.

1.4. Objectives

The purpose of this study is to analyze cost structure of wheat production industry in Nakuru District. The specific objectives are:

1.4.1. To establish the average production cost model of the wheat farming industry in Nakuru District.

1.4.2. To determine the short-run cost function i.e how cost vary with the rate of wheat output in the short-run.

1.4.3. To investigate how various elements of cost vary with rate of wheat output.

1.4.4. To estimate the long-run cost function and verify the existence of economies of size in wheat farming.

1.4.5. To establish the effect of degree of specialization in wheat production on the cost of wheat production.

1.4.6 To formulate policy measures that can lead to reduced cost of wheat production.

1.5. Hypotheses to be Tested

The hypotheses to be tested in this study are based on the specific objectives of the study. The following hypotheses will therefore be tested:

1.5.1. The cost of wheat production is not significantly influenced by the volume of wheat produced.

1.5.2. There are no economies of size in wheat production in Nakuru District.

1.5.3. The degree of wheat specialization has no significant effect on cost of wheat production.

1.6. Justification of the study

The wheat industry has a vital role to play in the growth and development of the Kenyan economy. According to the 6th National Development Plan (Kenya, 1988) the overall thrust of Kenya's agricultural policy is to achieve self-sufficiency with surplus stocks for strategic reserves. This points to the need for continued research to identify how productivity can be increased by identifying possible solutions to the specific constraints facing the sector.

Increased cost of wheat production is one of the major constraints faced by wheat farmers. Wheat farmers are operating behind a background of increasing cost of farm inputs. Inflation, both locally generated through fiscal and monetary policies, and imported through the exchange rate, has dramatically changed the cost of producing wheat. A cursory analysis of Policy analysis matrix (PAM) and maize data project (MDP) data reveals that at the prices announced in 1992 as the 1993 floor prices, wheat production is unprofitable.

Secondly, the structural changes that have occurred in the wheat production sector leading to a dual production structure comprising both smallholder and large-scale producers have made the question of economies of size be of great interest. This interest in economies of size stems from two directions. First is the need of assembling and providing evidence about existence, extent and sources of economies in wheat production. A second reason for looking at economies of size is a growing public and professional interest in establishing a wheat production system that strongly encourages growth in output and investment. This is because wheat in Kenya is asserted as a large-scale crop unlike many other parts of the developing world such as China, South Asia, parts of West Asia and North Africa and Ethiopia where it is a smallholder crop.

The discouraging state in the wheat production sector calls for research to identify ways to overcome it. The costs of production must be minimised, logistics of production must be optimized and the production environment must be taken into consideration. This study is an attempt in this direction. The behaviour of costs is diagnosed and solutions sought to help alleviate the problem of increased production costs. Finally, the study tries to provide evidence, extent and types of economies of size in wheat production. This will provide direction for re-orientation of policies and re-organization of wheat production aspects that can lead to increased production. The area of the study was justified by its national output of wheat as indicated in Table 1.1.

1.7. Area of Study

This study was carried out in Nakuru District in Rift Valley Province. The district covers the highest part of Rift Valley and includes the bordering escarpments and plateaus. The western plateau (the Mau Hills above the Mau Escarpment) rises to nearly 3 000 m within the district territory. The climate is cold and wet within a mean temperature of 10 to 15 °C and annual average rainfall of about 1 200 to 1 400 mm. The area mainly belongs to the Upper Highland Agro-Ecological Zone 1 (UH1). The western escarpment bordering the Rift Valley floor is divided into two levels, with a small but long plateau at an elevation of about 2 300 m stretching from Molo to Njoro. This is mainly a Wheat/Maize-Pyrethrum zone, Lower Highland zone 2 (LH2). The higher parts form the Wheat-Pyrethrum zone, Upper Highland zone 2 (UH2), because maize grown here is affected by cold weather and frost. At slightly lower altitudes, is the Wheat- Barley zone, Lower Highland zone 3 (LH3), which is mainly situated between 2 100 and 2 300 m. On the floor of the Rift Valley, wheat is only promising on the highest parts (near the escarpments north of Nakuru or around Menengai volcano), otherwise elsewhere it is too dry or too hot.

Nakuru District includes ranching and mixed farming areas. The district was originally farmed by large-scale enterprises each compromising of 500 to 600 ha. Currently, the area under large-scale farms has dropped due to subdivision of these farms.

Administratively, the district is divided into eight divisions namely: Bahati, Gilgil, Mbogoini, Molo, Municipality, Naivasha, Njoro and Rongai. All these divisions produce wheat and the production for 1992 is shown in Table 1.4 below.

Table 1.4: Wheat seeded area and achieved yield for Nakuru District in 1992.

	Area (Ha)	Achieved Yield/Ha	Target Area(Ha)	Expected Yield/Ha
Bahati	3 018	28	3 050	30
Gilgil	1 440	20	1 450	22
Mbogoini	155	22	150	24
Municipality	360	22	410	24
Molo	890	30	2 000	32
Naivasha	2 689	28	3 000	30
Njoro	8 789	25	9 500	30
Rongai	5 400	28	6 400	30

Source: Nakuru District, Ministry of Agriculture Annual Report, 1992b.

From the Table, Njoro, Rongai and Bahati divisions are important wheat producers accounting for more than 75% of Nakuru's wheat output. Because of this, these three divisions were selected for the study.

The achieved acreage under wheat in Nakuru District has dropped over the recent years due to land subdivision and increased cost of production. The prices of fertilizers, seed, labour and land preparation charges have increased rapidly over the last few years making wheat farmers in Nakuru District produce behind a background of increased cost of production (Kenya, 1992b).

1.8. Organization of the study

The text of this study is organised into five chapters. The first, introduction, covered: general information, a historical perspective of the wheat industry covering pre-independence wheat production era and post-independence wheat production era, the problem statement, the objectives and hypotheses, justification of the study, the study area and the organization of the study. In the second Chapter, relevant literature on the specifics of the problem, costs and related studies are reviewed. The methodology is outlined in chapter three. In Chapter Four, the empirical results of the study are presented and discussed. The last Chapter covers summary, conclusions and policy implications of the study.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1. Review of the Wheat Industry in Kenya

Cost analysis is of relevance to the farmer and policy makers since a knowledge of the basic cost conditions underlying the operations of the farm is a *sine qua non* for building both a microeconomic theory of price and output behaviour and also for many specific designs of optimal operating policies (Johnston, 1960). The short-run costs are the costs at which the farmer operates in any one season. The long-run costs are planning costs or *ex ante* costs, in that they represent the optimal possibilities for expansion of the output and thus help the farmer to plan the future activities. Amid this, the farmer is more interested in the cost per tonne of produce. The farmer wants to make sure that costs per tonne of wheat grain are lower than the expected return - plus an extra margin for labour and management for uncertainty (Osburn, 1978). However, when the costs rise sharply to levels that reduce returns drastically, the farmer is compelled to change the production surface to more remunerative enterprises in order to maintain the predetermined income levels. Studies carried out (van Eijnatten, 1976; and Ashcraft *et al*, 1977) for wheat farmers in Kenya identify high production costs as one of the priority problem leading to poor performance of the wheat industry.

Van Eijnatten (1976) in his study on production of wheat in Naro-moru and Waraza settlement schemes in Central Province noted a decline in the number of farmers growing wheat after initial increase shortly after the establishment of the settlement schemes from 1964 to 1969. The yields were on average 1034 kg per ha leading to a gross output of Ksh 1 178 compared to a total input cost of Ksh 1 534. Thus there was a negative gross margin for most of the small-scale producers. One of the important input contributing highly to the input costs was the use of combine harvester costing Ksh 152 per ha. Thus at an output of 1 034 kg per ha, the cost of use of combine harvester amounted to almost Ksh 0.15 per kilogram of wheat produced or 12 to 15 per cent of money realised by farmers.

Ashcraft *et al* (1977) study on Wheat production problems in Kenya indicated that wheat production in Kenya faced a decline. The decline was attributed to the fact that the wheat input prices had continued to rise. He noted that although producer prices were announced at the beginning of each season, this did not help in curtailining the decline in production. It was the profitability of the enterprise that was moving the farmers to respond.

Hassan *et al* (1992) survey on constraints on wheat production ranked machine rental costs followed by fertilizer costs as some of the most serious problems facing farmers in wheat production. The high cost of machinery services ranked top in both high potential and low potential zones, whereas it was less serious for large farms compared to small producers. Fertilizer cost was the second most serious problem for the low potential area and third in the high potential zone.

Though these studies demonstrated how cost contributed to the sluggish growth in wheat production, they failed to provide sufficient information on cost behaviour in wheat production under the prevailing socio-economic circumstances. In addition, attempts to analyze economies of size in the industry were lacking to verify the assertions held about its existence. This called for various studies to be conducted as part of the effort to define conditions under which such production constraints could be alleviated.

Longmire and Lugogo (1989) study on comparative advantage of small-scale wheat production in Kenya focused on the timeliness of four major operations namely: ploughing, harrowing, planting and harvesting of wheat. They found out that the smaller the field the more the extra machinery time was required to finish a given area. Compared to large fields, it was found that on small fields more time was lost in turning, headland overlap, setting up machinery in each field and moving from field to field. The analysis suggested that on very small fields of 0.4 ha, 28 percent more time was required to plough a given area compared with ploughing the same area on very large fields. For combine harvesting, 54 percent more time was required. From these findings they concluded that large-scale farms exhibit economies of size with the use of large machinery.

Policy Analysis for Rural Development (PARD) Project Team (1992) observed that large-scale wheat production systems in Kenya were more profitable than the small-scale systems. They noted that the advantage to large-scale system resulted partly because the large farmers owned most of the machinery necessary for cultivation, whereas the small-scale systems depended almost entirely on hired machinery services. Rented services were more costly than owned machinery and often were difficult to obtain in a timely manner during peak season demands. Their conclusion was that farmers using their own machinery stood a big advantage compared to those depending on rented machinery services.

The Group Farms Rehabilitation Project (1977) carried out a detailed survey of some 88 large farms in the Rift Valley Province, all but 4 of them mixed farms. The broad objective of the survey was to identify the main problems and constraints in wheat farming and to establish the levels of performance. The farms were grouped into three categories of management: good, average and poor. The criteria used included the utilization of recommended techniques and general impression gained from visits to farms. On good farms, the annual machinery costs averaged Kshs 692 per cultivated ha. The machinery costs, however, on average and poor farms were generally higher than on the good farms and averaged Kshs 856 per cultivated ha (i.e an increase of 25 percent). From this survey, they concluded that good managerial skills lead to reduced costs.

Hassan *et al* (1992) performed a profitability analysis on wheat technologies in Kenya. Average technology levels employed by sampled wheat farmers were computed in terms of units of labour and machine time and material inputs of operation. The analysis showed that the highest net returns were obtained under the best recommended technology, which was about three times the net revenue for the average farmer. Production methods employed by large-scale farmers in the low potential zone were the most efficient type of wheat farming system in profitability terms.

Although these studies raised important aspects about conditions of efficient wheat production, very few inferences could be drawn on how to alleviate cost as a production constraint. However, a mention was made on the effects of farm size, machinery ownership and owner's managerial skills on costs of production. In order to define conditions under which wheat production cost can be alleviated, a consistent analysis of cost structure to reconcile all these aspects is necessary.

2.2. Empirical Cost Studies

Studies on quantitative description of cost functions require good data especially time series covering a long period of time. Many developing countries have not been able to keep good time series data, and as such, few studies have been carried out. In developed countries such as United States of America and Britain, good long-term data have been available for some time now, and the current ideas regarding cost are based on studies in those countries.

Opinion on shape of the average cost curve and thus economies of size is far from being unanimous in cost studies. There is a general agreement that with factor prices, long run average cost falls for increasing ranges of output. Walters (1963) suggested that this is due to economies of scale that arise because of three reasons: dealing with large quantities, spreading of risks and reduction of costs of uncertainty and finally the existence of indivisibilies in both labour and capital equipment.

There are three distinct hypotheses about the nature of cost-output variations in the short-run period. The first commands widespread support and its explanation is given by Johnston (1960). It postulates that the average variable cost (AVC) and marginal cost (MC) are inversely related to the average and marginal products of the variable factor respectively. Symbolically, the relationships are given as:

$$AVC=\frac{px}{y}=\frac{p}{AP}$$

and,

$$MC=\frac{d(px)}{d(y)}=\frac{p}{MP}$$

where x = number of units of variables factor

P = price per unit of variable factor

AP = average productivity of variable factor

MP = marginal productivity of variable factor

y = number of units of output

AVC = average variable cost per unit of output

MC = marginal cost.

In deriving the above relationship between production functions and short-run cost function, it is assumed that the production function contains only two inputs, one fixed and one variable; diminished marginal and average product after some point for the variable factor; and finally a constant price for the variable factor.

Since AP generally rises and then falls with increases in output and since price per unit of variable factor (P) is constant, AVC must decrease and then rise with increases in output. Since MP generally increases, attains a maximum, and declines with increases in output, MC normally decreases, attains a minimum. and then increases. This behaviour gives the traditional U-shaped costs curves (Johnston, 1960).

The removal of the assumption of constant factor prices would not materially alter the shape of the cost curves; the only difference would be to make the rise in MC and AVC earlier and greater.

A second hypothesis about the nature of cost-output variation is provided by Davis (1941). Denoting output by U and total costs by Q(u); he indicates that:

$$Q\ (U) = aU^2 + bU + c$$

so that average cost has the form

$$q\ (U) = aU + b + \frac{c}{U}$$

He noted that such data as exists on cost functions show that the above two functions are essentially correct representation of total and average cost functions.

This second hypothesis advanced by Davis (1941) is without any empirical evidence or supporting rationalization. However, it does not differ essentially from the first since it gives rise to a U-shaped average cost curve (Johnston, 1960).

The third hypothesis is the most recent hypothesis and has been suggested to be the most plausible by the accumulating empirical evidence (Johnston, 1960). The hypothesis has been expounded mainly in the writings of Andrews (1949). His conclusion from analysis of the short-period situation is that "in general, average direct costs per unit of product will be expected to remain constant over large ranges of output, so long as the business continues to employ the same methods of production, and the total of such costs will vary proportionately with total output".

Although costs at first decrease with output there is very little agreement on the shape of the curve as the output goes on increasing. Walters (1963), argues that the coordination of management and control becomes increasingly less efficient and so rising cost of management gives rise to increasing long run average costs. Sargent *et al* (1963) on the other hand criticized this school of thought on the grounds that the proportions were not tested in any systematic empirical study.

Due to this, many attempts have been made to establish the shape of the average cost curves using various methods: engineering method, survivor technique, questionnaire method, statistical cost analysis and production function method.

The engineering method is based on the technical relationship between inputs and output levels included in the production function (Chenery, 1949). The first stage in the engineering method involves the estimation of the production function, that is, the technical relation between inputs and output. The second stage is the estimation of the cost curve from the technical information provided by the engineering production function. These costs of producing various levels of output are obtained by multiplying the technically - optimal input combinations with the prices of inputs (factors of production) (Cookenboo, 1955).

Cookenboo (1955) used the engineering method in his study of the costs of operation of crude-oil trunk-lines. He measured crude-oil trunk-lines output (X) as barrels of crude oil per day. The main inputs in a pipeline, system were 'pipe diameter', 'horse-power of pumps' and 'number of pumping stations'. From his study, he concluded that the long-run costs fall continuously over the range of output covered by his study.

The engineering cost studies are mainly concerned with the production costs and pay little attention to the selling and other administrative - managerial expenses. Given their nature, their findings are not surprising and cannot seriously challenge the U-shaped long run curve of the traditional theory. Another limitation is the under estimation of costs of large-scale plants obtained from extension of the results of the studies to levels of output outside their range. Usually engineering cost studies are based on small-scale pilot plants. The final limitation is that engineering cost studies are applicable to operations which lend themselves readily to engineering analysis. This is the reason why such studies have been of great value in estimating cost functions of oil-refining, chemical industrial processes, nuclear-power generation etc. However, elsewhere the technical laws underlying the transformation of inputs to outputs are not known, thus making it hard for its application to other sectors.

The survivor technique was developed by Stigler (1958) and is based on the Darwinian doctrine of the survival of the fittest. The method implies that firms with the lowest costs will survive through time. The basic postulate of the survivor technique is that competition of different sizes of firms sifts out the most efficient enterprises. Thus by examining development of the size of firms in an industry at different periods of time, one can infer what is the shape of costs in that industry. Presumably, the survivor technique traces out the long-run cost curve, since it examines the development over time of firms operating at different scales of output (Koutsoyiannis, 1988).

Stigler (1952) used the "survivor technique" on economies of scale of the steel industry of the United State of America. He noted that during the two decades covered by his study there was a continuous decline in the share of the small and the large firms in the steel industry of the United States of America. Thus he concluded that the small and the large firms in the steel industry of United States of America were inefficient (have high costs). The medium-size firms increased or held their market share, so they constitute, according to Stigler, the optimum firm size for the steel industry in the United States of America.

The survivor technique, although attractive for its simplicity, suffers from serious limitations. Its validity rests on the following assumptions, which are rarely fulfilled in the real world. It assumes that: (a) the firms pursue the same objectives; (b) the firms operate in similar environments so that they do not have locational advantages; (c) prices of factors and technology are not changing, since such changes might well be expected to lead to changes in the optimum plant size; (d) the firms operate in a very competitive market structure, i.e, there are no barriers to entry.

In the questionnaire method attempts are made to draw inferences about the shape of the cost curves by the method of questionnaires (Eitman and Gouthrie, 1953). Selected firms are presented with various graphs of costs and are asked to state which shape they think their costs are.

Eitman and Guthrie (1953) in the United States of America applied the questionnaire method and most of the firms reported that their costs would not increase in the long run, while they remain constant over some range of output. However their work received a lot of criticism on the grounds that they did not ask the appropriate questions and did not interpret their results correctly. In particular it has been argued that businessmen might have interpreted the term 'capacity' to mean 'optimum operating capacity' or 'absolute capacity'. Thus major limitations with this method are on the appropriate questions to ask and interpretation of results obtained.

Statistical cost studies consist of the application of regression analysis to time series or cross-section data. Time series data include observation on different magnitudes (output, costs, prices etc) of a firm over time. Cross - section data give information on the inputs, costs, outputs, and other relevant magnitudes of a group of firms at a given point of time (Koutsyoniannis, 1988).

Statistical cost analysis method has been widely used in empirical analysis of costs in farming. Hopkin (1958) used it in his analysis on economies of size in feedlots for California. His study showed that cattle feeding as predominantly practiced in california was a decreasing cost industry within size range of organization per that time. He used the quadratic form of the cost equation.

Fleming and Uhm (1982) applied statistical cost analysis in analyzing the economies of size in Grain Farming in Saskatchewan and the potential impact of Rail Rationalization Proposals. They tried various types of mathematical forms using ordinary least squares for goodness of fit and prediction capability in the average production cost model at the preliminary stage and hyperbolic function was found to be the best.

Ray (1982) analyzed the structure of agricultural production in the United States using the translog approximation to the cost function. Neoclassical duality results were extensively used for this purpose. He concluded that "the overall scale economies computed from the cost function indicate that while the United States of America agriculture operated under diminishing returns, the returns to scale factor increased over time".

A comprehensive summary and critique of a wide range of statistical cost studies is given by Johnston (1960). The evidence from most statistical studies is that in the short run the average variable cost is constant over a considerable range of output, while in the long run the average total cost is in general L-shaped. The results of statistical cost studies have been criticised on grounds of their interpretation, data limitations, and omission or inadequate treatment of important explanatory variables (mis-specification of the cost function).

From the available literature on these analytical methods, there is evidence that no single analytical procedure can be considered the best. Fleming and Uhm (1982) argued that the optimal method depends upon the specific situation involved - the nature of the production process being considered and the kind of questions the study is supposed to answer. Taking these into consideration, the statistical cost analysis method was used for this study because this method is most suited to the data available from the survey of farms.

CHAPTER THREE

3.0 METHODOLOGY

3.1. Theoretical Background to the Methodology

The term "costs" has been interpreted so diversely by accountants, businessmen and economists that a preliminary review of the economic theory of costs is imperative for an appraisal of the results and empirical methods of this study. Economic theory defines cost as measure of what must be given up in order to obtain something whether by way of purchase, exchange or production (Pearce, 1987). Economists usually employ the concept of opportunity cost which measures costs as the value of all the things which must be foregone, lost or given up in obtaining something. The opportunity cost measure may, but will not always, coincide with the money outlays which an accountant would measure as cost (Pearce, 1987). Economists sometimes distinguish between the private costs of a good or activity to the consumer or producer and the costs known as social costs imposed on the community as a whole.

Both in the short-run and the long-run, total cost is a multivariable function, that is, total cost is determined by many factors e.g rate of output and prices of factors (Koutsoyiannis, 1988). Although many conditions influence costs, only a few simple relationships are selected in practice to depict the decisions of entrepreneurs. Thus costs per unit of output for an existing enterprise are treated as depended upon: (a) the rate of output, (b) the prices of input factors, (c) the physical productivity or efficiency of management, labour, and the other factors which combine to produce output, (d) the size or scale of enterprise and (e) the stage of technology (Mason, 1943; Walters, 1954; and Koutsoyianis, 1988). Symbolically the total cost function can be written as follows:

$$C = f(Q, Pf, Z, T,)$$

where C = total cost

Q = output

Pf = prices of factors

Z = size or scale of enterprise

T = technology

This study determined the total cost function by examining the relationship between average cost and four important cost determinants that were derived from the prevailing socio-economic state of the wheat production sector. These factors were the wheat output, wheat enterprise size, the degree of specialization in wheat production, managerial skills of the entrepreneur and usage of own machinery. The factor technology which is itself a multidimensional factor, determined by the physical quantities of factor inputs, their quality and the efficiency of the producers (Koutsoyianis, 1988) was measured by the degree of specialization, farmer's managerial skills and usage of own machinery. Symbolically the average total cost function was summed up as follows:

$$AC_i = f(Z_i, DP_i, CEI_i, MU_i)$$

where i = farms 1,2,3,... 80.

AC_i = Average cost of wheat production in thousands of Kenya shillings (000' Kshs) for the ith farm. This was measured as total production costs (both variable and fixed costs) per tonne of wheat produced.

Z_i = The size of wheat enterprise for the ith farm. This was measured as total wheat output in tonnes from each farm.

DP_i = Degree of specialization in wheat production on the ith farm. This was measured as the percentage of total income from wheat to the total farm income (receipts from all farm activities).

CEI_i = Cost Effective Index for the ith farm. This was used to measure the level of the farmer's managerial skills. It was considered that, all other things being equal, a higher level of management would be reflected in a lower cost per unit of output. The cost effective index was defined as the predicted average cost per tonne of wheat produced divided by the actual average cost per tonne of wheat: the higher the index, the higher the level of managerial skills. The predicted average cost per tonne used here was estimated by the method of Ordinary Least Squares (OLS) using farm survey data.

MU_i = The level of usage of own machinery of the ith farm. This was measured as the ratio of total machinery expenses (depreciation, fuel and oils, repairs and maintenance and operator labour costs) to the fixed expenses of each farm. It was considered that a farm that uses its own machinery for the farm operations incurs high machinery expenses. Thus the higher the ratio, the higher the level of use of own machinery.

The study also examined the single relationships between costs and wheat output, wheat enterprise size and other farm enterprises using various functional relationships. The aim here was to segregate and measure the effects of these factors in the economist's scheme of cost determinants.

This study also estimated the short-run cost function. Economic theory designates the relationship between total cost and output as cost function. A short-run cost function implies that all other considerations which are specified as cost determinants are assumed to be unchanged (Mason, 1943: and Koutsoyianis, 1988). This is intended to show what costs would be at various rates of output if there were no changes in the factor prices, the selling expenses and the level of physical input-output relationships (the technological horizon is unchanged). Such a cost function excludes not only autonomous variations in these other determinants of costs, but also any secondary or derived influences, in particular cost fluctuations induced by simultaneous changes in the output of other firms. Symbolically, the short-run cost function is written as:

C = f(Q)

where C = Cost and

Q = Output.

This denotes that cost is a function of output, other factors which determine costs being held constant. Theoretically, cost function is quadratic though other forms exist depending on the underlying nature of production (Johnston, 1960). The possible functional forms of cost that can exist are:

(i) Linear:

$$C=a+bQ$$

(ii) Quadratic:

$$C=a+b_1Q+b_2Q^2$$

(iii) Cubic:

$$C=a+b_1Q+b_2Q^2+b_3Q^3$$

(iv) Reciprocal:

$$C=a+\frac{b}{Q}$$

(v) Reciprocal log:

$$C=a+\frac{b}{\ln Q}$$

(vi) Logarithmic:

$$C=a+b\ln Q$$

Since the underlying nature of production of wheat is not known, all the above functional forms were examined and the form giving the best results based on statistical criteria was adopted for analyzing the cost output relationship. The statistical criteria used were the coefficient of determination ($\bar{R}^2$) value, consistence in the signs of coefficients with a *priori* expectation from theory and significance of independent variables as indicated by the t-test.

The task of approximating a cost function is a question of choosing the appropriate statistical technique whereby the influence of one variable may be isolated from among many. As *a priori*, this study aimed at examining how various components of costs are related to variations in output in order to evaluate the relative merits of different means of varying output.

The estimation of the cost-output variation in the short-run involve the assumption that the firms' activities are constrained by some fixed capacity limit (Johnston, 1960). Thus one should ideally look at a series of paired observations on costs and output which satisfy the following conditions.

1) The basic observations should be one in which the observed output was achieved by the uniform rate of production within the period. If this condition is not met, averages are obtained which might obscure the time underlying cost curve.
2) The observation on cost and output should be properly paired in the sense that the cost figure is directly associated with the output figures. This condition would not

be satisfied for example, if we paired accounting data for weekly periods, where the wages paid in any given week were, in fact, based on the number of hours worked in the previous week.

3) There must be a wide spread of output observations so that cost behaviour could be observed at widely differing rates of output. This result could be achieved by having a very large number of environmental firms all of the same fixed capacity, and instructing each to produce at a certain rate, these arbitrary rates being chosen to give the desired range of output levels.

4) The experimental data should be uncontaminated by the influence of factors extraneous to the cost-output relationship itself. For example, cost observations which were influenced by variations in the prices paid by the firm(s) for factors of such as labour, raw materials, etc should not be recorded. Secondly, different observations should not relate to different environments of technical knowledge and expertise; instead each firm in each period should have at its disposal the same stock of technical knowledge.

To examine the long-run relationships, essentially similar requirements apply. The basic unit of time should again be short enough to avoid possible averaging effects, and the cost-output observation should again be properly paired.

3.2. Functional Forms

3.2.1. Estimation of important cost Determinants

According to studies carried out on Kenya's wheat industry, it appears that economies of size prevail in wheat farming in Kenya (Longmire and Lugogo, 1989. Thus, this study aimed to do a quantitative analysis to test the hypothesis that economics of size exist. The hypothesis tested was whether the size of wheat enterprise and the average cost of production were inversely related (i.e. whether economies of size exist), or in other words, whether the average cost decrease as size increases. Thus the wheat enterprise size (Z) was fitted in the model as an inverse (1/Z).

An average production cost model was constructed for wheat production industry in Nakuru District. To take into consideration the diverse nature of the individual wheat farms in Nakuru District, the hypothesis was made that given the size of wheat enterprise, the unit cost of wheat production would vary depending upon such factors as the wheat enterprise size, farmer's managerial skills, the degree of specialization in wheat production and the usage of own machinery. This was summed up as follows:

$$AC_i = f(Z_i, DP_i, CEI_i, MU_i)$$

where i = farms 1,2,3,......80

and AC_i, DP_i, CEI_i, Z_i and MU_i as defined earlier on pages 32 to 33.

3.2.2. Cost Functions for Wheat Production

The first specific objective from this part involved the approximation of the short-run cost function. This involved the application of statistical techniques of cost as a function of output in order to isolate the effects of variations in the rate of output from other factors presumed to influence costs. In calculating this short-run cost function, the assumption was made that the scale of operation was fixed. Thus the short-run cost function was written as:

$TC_i = f(Q_i)$

where

TC_i = Total cost of wheat production on the ith farm.

Q_i = Total wheat output on the ith farm.

From this relationship, the quadratic functional form was used to estimate the total cost function and hyperbolic form was used to estimate the average cost function. These forms can be summarized as follows:

Quadratic:

$$TC=a+b_1Q+b_2Q^2$$

and hyperbolic:

$$AC=a+\frac{b}{Q}$$

where TC = total cost

AC = average cost

Q = output

and a and b = estimated coefficients.

The second specific objective involved estimation of the long-run cost function. In estimating this function the scale of operation was assumed to be not bounding. The function was expressed mathematically as:

$TC_i = f(Z_i)$

where TC_i = Total cost of wheat production on the ith farm;

and Z_i = Wheat enterprise size in tonnes of wheat output for ith farm.

From this relationship, the quadratic functional form was used to examine the long-run total cost function.

3.2.3 Measurement of Economies of Size

This is the measure of the *ceteris paribus* long-run relationship between average cost and size of wheat enterprise written as:

$AC_i = f(Z_i)$

where AC_i = Average cost (total cost per output of wheat enterprise of the ith farm).

and Z_i = Size of wheat enterprise in tonnes of wheat output of the ith farm.

From the above relationship, the hyperbolic functional form was used to measure economies of size in wheat production sector. This form was summed up as follows:

$$AC = a + \frac{b}{Z}$$

where AC = average cost of wheat production.

Z = size of wheat enterprise.

and a and b = estimated coefficients.

3.2.4 Resource Use Relationships in Wheat Production and other farm enterprises

This specific objective involved the determination of various relationships that exist between wheat and other farm enterprises in resource usage. The study used the effect of level of output of other farm enterprises on cost of wheat production to determine the relationships that prevail between wheat and the other farm enterprises.

Thus the measure of the complementary and other relationships between wheat and other farm enterprises was the measure of the *ceteris paribus* relationship between average cost of wheat production per unit of output and levels of outputs of other farm enterprises as opposed to wheat output in monetary worth. The function was expressed mathematically as:

$$AC_i = f(LW_i,\ OC_i)$$

where AC_i = Average cost of wheat production per tonne of output on ith farm.

LW_i = level of output of livestock (dairy) as opposed to wheat output on ith farm.

OC_i = level of output of other crops as opposed to wheat output on ith farm.

3.3. Estimation Problems in Ordinary Least Squares (OLS)

There are a number of statistical estimation problems which may arise in regression analysis. These are: autocorrelation, heteroscedasticity and/or multicollinearity in the estimated cost function.

Autocorrelation may occur in time series as well as the cross-section analysis. It is where independent variables are correlated i.e. violates the assumption of zero covariance. The problem is common in time series data analysis. It may represent effect of some excluded variable in model changes over time, smoothing of data or mispecification of the functional form of the regression model. Autocorrelation tends to make the variance of the error term (or the standard error of the estimate) relatively large. This, in turn, will cause a large standard error of the coefficient, which leads to inefficient estimation. The statistical inferences also become invalid in such a situation. One of the tests for this is Durbin-Watson test. This test was used to detect autocorrelation in the estimated model.

Multicollinearity is a phenomenon that occurs in a regression model when two or more independent variables tend to move in the same pattern (Klein, 1977). In other words, the variables are so highly correlated that it is difficult to separate their respective effects on the dependent variable. When multicollinearity exists,61 the fit of the regression equation result in high values of $\bar{R}^2$, but there are no statistically significant coefficients different from zero. To scan for multicollinearity, the simple correlation matrices of the variables were used. Klein (1977) states that " so long as the simple correlation x, y, between two explanatory variables x and y is less than multiple correlation, $\bar{R}^2$, there is no serious collinearity between them". This rule of thumb was used to scan for multicollinearity in this study.

Heteroscedasticity occurs when error terms are not independently distributed with zero mean and constant variance i.e violates the assumption of constant variance. The main effect of heteroscedasticity is not on the biasness of the estimated regression coefficient but on efficiency - the variance of the estimated regression coefficient. The classical least squares estimation for the variance of the estimated regression coefficient is overestimated. To test for heteroscedasticity, variance - covariance matrix of the disturbance vector is used. The residuals are plotted on a graph against the independent variable to which it is suspected the disturbance variable is related. Each diagonal term gives the variance of the disturbance associated with one of the sample observation. Same diagonal terms indicate homoscedasticity while diagonal terms that are not same indicate heteroscedasticity. This method was used to test heteroscedasticity.

3.4. Hypothesis Testing

Statistical criteria were used to test the hypotheses. The hypotheses typically tested were the null hypotheses expressed as:

$$H_0 : \beta = 0$$

The beta (ß) is the estimated coefficient of the function. This null hypothesis where ß is equal to zero means that the independent variable has no influence on the dependent variable.

The null hypotheses were tested against either one- or two-tailed alternative hypotheses depending on prior theoretical reasoning. For a positive relation, H_0 was tested against the one-tailed alternative hypothesis expressed as:

$$H_1 : \beta > 0$$

meaning that a positive relationship exists between the independent and dependent variables; while for a negative relation, H_0 is tested against another one-tailed alternative hypothesis expressed as:

$$H_1 : \beta < 0$$

meaning that the negative relationship exists between the independent and dependent variables.

For cases where prior guidelines do not exist, i.e on theoretical grounds one can not state whether effect is a positive or negative one, then H_0 is tested against two-tailed alternative hypothesis expressed as:

$$H_1: \beta \neq 0$$

meaning that either a positive or negative relationship exists between the independent and dependent variables.

3.4.1. Volume of wheat output and cost

Null hypothesis: Rate of wheat output has no significant effect on cost.

$$H_0: \beta = 0$$

Alternative hypothesis: Rate of wheat output has a significant effect on cost.

$$H_1: \beta \neq 0.$$

Total cost is regressed against rate of wheat output in order to test null hypothesis. If the estimated coefficient of output is statistically significant at 5% significant level, then the null hypothesis is rejected.

3.4.2. Economies of size i.e effect of size on average cost

Null hypothesis: The size of wheat enterprise does not significantly affect cost i.e there are no economies of size in wheat farming.

$$H_0: \beta = 0.$$

Alternative hypothesis: Economies of size exist in wheat farming i.e size of enterprise affects average cost of wheat production.

$$H_1 : \beta \neq 0$$

The estimated results bearing a significant coefficient at 5% level leads to rejection of null hypothesis in favour of alternative hypothesis.

3.4.3. Cost and degree of wheat specialization

Null hypothesis: Degree of wheat specialization (DP) has no significant effect on cost.

$$H_0 : \beta = 0 .$$

Alternative : wheat specialization has a significant effect on cost.

$$H_1 : \beta \neq 0 .$$

The null hypothesis is tested by regressing total cost against degree of wheat specialization. Statistical significance of the estimated variable of 5% significant level leads to rejection of null hypothesis.

3.5. Data Collection

3.5.1. Data

Both primary and secondary data were used in this study. Secondary data on wheat output, hectarage and yield were obtained from four sources.

i) Central Bureau of Statistics Publications

ii) Ministry of Agriculture Publications

iii) International maize and wheat improvement Centre (CIMMYT) Publications.

iv) World Bank Publications

Primary data was collected from a survey of 80 wheat farmers in Nakuru District. The data collected included the costs of wheat production, wheat output and outputs of other farm enterprises.

The main sources of data from farms were records kept by farmers. These included financial details shown on traders invoices or statements, cheque book stabs, and the farmers' own book-keeping records. Farmers' memory was relied upon where records were not available. The data were recorded using a questionnaire (Appendix ix) and included the following:

a) Labour: covering cash wages, food, medicines and treatment charges, uniforms and clothing, gifts etc offered to workers.

b) Contracted transport for inputs used in wheat crop

c) Machinery repairs: in every case the entry showed the machine, implements or vehicle to which the expenses related.

d) Spare parts of machinery: in the same detail as repairs.

e) Fuel: recorded separately according to type in wheat production.

f) Fertilizer: according to type used in wheat production.

g) Wheat seed for planting.

h) Wheat crop sprays, dusts and seed dresses.

i) Contract work of all kinds for wheat enterprises.

k) Wheat sundries including bags, twine and costs for bags.

l) Prevailing land rent.

m) Bank interest on borrowed capital.

n) Machinery insurance and income.

o) Implements, machines and vehicles on the farm.

Other data collected included outputs of wheat and other enterprises on the farm (both quantity in tonnes and monetary worth in Kshs) and contract receipts for any work done for others with the farm equipment.

3.6. Survey Design and Sampling Procedures

Farmers producing wheat in Nakuru district formed the population from which units for this survey were sampled. Multi-stage stratified random sampling procedure was used. The district was first divided into divisions. From this list, 3 divisions with highest wheat seeded area (ha) and production output levels were selected. These divisions in the descending order were: Njoro, Rongai and Bahati.

For the second stage selection, a list of all locations in the selected divisions was compiled. The locations were then stratified by scale of production operation into large- and small-scale farming categories based on wheat production and area. Seven locations with highest seeded wheat acreage and output were selected from the two groups in order to represent small and large-scale farms. These locations were Njoro, Lare, Mau-Narok, Bahati, Rongai, Kampi ya Moto and shawa (Table 3.1).

Table 3.1: Multi-stag sampling of wheat farmers

Sampling Stage	Sampling frame	Description	Selected units		
Stage 1			Divisions		
			Njoro	Bahati	Rongai
Selection of divisions	List of all divisions	% of district wheat area	35	18	24
		no. of wheat farmers	950	360	480
Stage II					
Selection of locations	List of all locations		Locations		
		Large-scale	MauNarok	Bahati	Rongai
			Njoro		Kampi ya Moto
		Small-scale	Lare	Bahati	Rongai
			Njoro		Shawa
		Total	50	10	20
Stage III Selection of farmers	List of all farmers in selected locations	Large-scale	15	2	10
		Small-scale	35	8	10

Source: Pilot Survey, 1992.

For the final stage selection, a discussion was held with the Agricultural Extension staff. From the information given on wheat output and estimated number of wheat farmers in each location, variable sampling fractions were used to allocate the 80 farmers among the locations. Sampling fractions were calculated by dividing the estimated number of wheat farmers in the district by the estimated number of wheat farmers in each selected location. The number of farmers to be selected from each location was obtained by multiplying the total sample size of 80 and the sampling fraction of each of these locations.

3.7. Sample size and Fractions

The size of the sample of this survey was determined on the basis of time and financial resources required to complete this survey with this design. Given resources available for this survey, 80 farmers were sampled.

Sampling fraction based on the information from the Divisional Administrative and Agricultural Offices on estimated number of farmers in each location was used to allocate the sample farmers for each location. The sampling fractions used to allocate the sample of 80 farmers among the selected 7 locations were: 0.288 for Njoro (23 farmers), 0.213 for Lare (17 farmers), 0.125 for Mau-Narok (10 farmers), 0.125 for Bahati (10 farmers), 0.125 for Rongai (10 farmers), 0.063 for Kampi ya Moto (5 farmers) and 0.063 for Shawa (5 farmers). Farmers were then selected (stage III) randomly from each of the 7 locations according to the sampling fractions indicated above. Purposive stratification of the farmers to represent both small- and large-scale wheat farms in the sample of the locations with both small- and large-scale wheat farms was done. The list for these farmers was arranged purposively in order of seeded acreage under wheat before randomly selected.

3.8. Organization of the Field Work

Reconnaissance study / pilot survey was carried out in the study area prior to the formal survey. This was to help identify the important enterprises competing with wheat, help develop the content and focus of the sample survey framework and survey questionnaire, and familiarize the researcher and enumerators with the area of study. The questionnaire developed for the formal survey were tested for a random sample of wheat farmers in the Municipality Division of Nakuru District. This exercise was to test the adequacy of the questionnaire, help in establishing common measures, deciding on best time for interviewing, estimating time and financial costs of the survey, learning about possible types of non-response farmers and providing a training opportunity for interviewers.

In addition to these arrangements prior to the execution of the field work, a reserve list to minimize the problem of non-available farmers was formulated. The selected farmers were approached through area frontline agricultural extension staff, who were provided with names and time schedules for the planned field visits in each location ahead of time.

3.9. Allocation of costs

The expenses on the wheat farm were basically of three types, namely :-

i) Those expenses that are directly concerned with a wheat enterprise and which could be fully charged to it.

ii) Those expenses generally concerned with the productive aspects of farming, but which could only be charged to wheat enterprise on the basis of supplementary physical records.

iii) Those expenses that can not be avoided on the farm business, but which are not directly attributed to any direct productive process, and for which, there is, therefore, no satisfactory basis for allocation to the separate enterprises like wheat.

Direct expenses which were allocated to a wheat enterprise without much ado were: land preparation costs, purchased seed, farm grown seed, fertilizer, sprays, dusts and seed dressing, contract work, transport of inputs, bags and twine.

Expenses groups which were grouped on the basis of supplementary physical records were: labour, tractors, cultivation and planting machinery and combine harvesters' costs. These are discussed in turn.

Labour

Hired labour is generally treated as a direct variable cost. On wheat farms, the physical work was done by workers, some whose responsibility was generally restricted to wheat crop while others worked in wheat enterprise and did other general (i.e unallocatable) farm work. The farmer was requested to give an account of the wages paid to all these workers. For the ones undertaking unallocatable farm work, the farmer was requested to give an accurate estimate of the number of mandays these workers worked in the wheat enterprise. This information provided a basis for the allocation of this labour doing unallocatable farm work to wheat enterprise by multiplying the number of mandays worked in wheat enterprise with the wage rate per manday.

Tractors

In the same way as a few farmers kept a record of labour work, the same or other farmers recorded the number of hours that each tractor spent working on each enterprise. From these records, the tractor expenses were allocated to wheat enterprise on the basis of actual number of tractor hours spent on wheat farm. Where no such records were available, tractor expenses were allocated to wheat enterprise on the basis of required tractor hours as calculated from the average tractor input records and data presented by Longmire and Lugogo (1989).

The Depreciation of Machinery

During the survey, a full list of all machines and implements on each farm was made. In calculating machinery depreciation some problems were faced. There was the problem of finding from the farmer when each item was purchased and what it costed so that depreciation could be estimated.

In these circumstances, a simple but realistic and practical system was adopted. The assumed life of each item used in wheat production was based on the Ministry of Agriculture Reports. The annual depreciation charge was then calculated using the straight line method. The hourly depreciation was calculated by taking the difference between the new purchase price and the current second hand value (assumption of 33 percent of new value adopted from Longmire and Lugogo, 1989) and dividing this by the total working hours of the machine (hours per year multiplied by number of years of work). Machinery depreciation expenses were then allocated to wheat crop on the basis of required machinery hours as given by the farmers' information or as from the average machinery input records.

This system was used for all farm machinery used in wheat production except tractors and combined harvesters. The life of these machines cannot be measured only in years, but must be related to the amount of work done (Kenya, 1963). Therefore, for tractors, the average number of hours worked annually by each machine were calculated. This average figure was expressed as a percentage of the estimated life of 15,000 hours and this percentage used as the depreciation rate.

Combine harvesters were assumed to have a working life of 30,000 ha harvested. The actual average annual wheat area harvested was therefore expressed as a percentage of this to derive an annual depreciation rate with a minimum charge of ten per cent per annum.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Cost Structure of Wheat Production Industry in Nakuru District

Information was taken from the records of a survey of 80 wheat farmers in Nakuru District. The total number of the sample dropped to 69 due to 11 incomplete cases. Wheat production costs were classified into variable and fixed costs. The cost components under variable costs included cost items that were avoidable. These were the costs of land preparation, seed, planting (drilling), fertilizers, pesticides, spraying, harvesting, labour wages and transport of inputs. The fixed costs on the other hand were those which were unavoidable. These were costs of permanent labour, interest on farm investments, land rents, depreciation and repairs and maintenance of capital items.

The sampled wheat farms were categorized into three classes; small (less than 5.00 ha), medium (5.1 - 60 ha) and large wheat farms (more than 60 ha) (Table 4.1). The small wheat farms formed 50 percent of the sample while the medium and large ones formed 35 percent and 15 percent, respectively.

Table 4.1 indicates that small wheat farms on average incurred higher costs in their wheat production than the large wheat farms: their total costs were greater per ton of wheat produced. The average total costs per tonne of wheat were Ksh 12,666.40 and Ksh 502.60 for the small scale wheat farms and large scale wheat farms, respectively. The average variable cost per tonne of wheat were

Table 4.1: Wheat Farm Categories, their Costs and output

Farm Size Category	Average Variable Cost per tonne	Average Seeded ha	Total Wheat Yield Output/ha (tonne)	Average Total Cost
Small Farms/ha 0.1-5.0	5045.20	1.6	1.53	12666.40
Meduim Farms 5.1-60.0	342.50	23.3	2.01	459.60
Large Farms 60.0	364.20	130.5	2.28	502.60

Source: Author's survey, 1992.

Ksh 5,045.20 for small scale wheat farms and Ksh 364.20 for large scale wheat farms. The small-scale wheat farms had relatively lower yields compared to large-scale farms. The average yield was 17 bags (90kg) or 1.53 tonnes per ha resulting to a gross margin of Ksh 6,259.80 per ha. The large-scale farms on the other hand had yields of over 25 bags (90kg) per ha leading to a gross margin of KShs 16,482.50. Several reasons can be suggested for this disparity. These are:

i) Nutrient status of the soils over time.

Wheat crop has a high nutrient requirement and hence continuous cultivation of the crop on a piece of land will worsen the soils nutrient status unless appropriate remedial measures are taken. Small-scale producers tended to continuously cultivate the fields because of lack of alternative space to cultivate. More nitrogen (less phosphorus) is required as the land gets older in terms of years under production (NPBRC, 1990). However, Hassan *et al*

(1992) found lower levels of fertilizer use to be associated with smaller size farms. This worsening nutrient status of the soils on small-scale wheat farms reduce the yield.

ii) Inability for smallholder farmers to acquire inputs such as agrochemicals, certified seeds and machinery services on time. None of the small wheat producer was observed to have good access to credit and thus used less chemical fertilizers, quality seeds, herbicides and pesticides compared to large wheat producers. The same thing applied to access to machinery services leading to delays in farm operations.

iii) Poor standards of wheat husbandry on small wheat farms. Late planting of the wheat crop, failure to weed it adequately and on time and failure to control pests and diseases can cause its yields to decline significantly. Small-scale farmers produced wheat under poor standards of husbandry as opposed to large-scale farmers as observed by Hassan *et al* (1992).

iv) Large size allows greater flexibility in the combination of resources and greater efficiency in their use. Large farms suffer less from under-utilization of machinery and equipment and this tends to give them lower cost per unit of output. Large-scale wheat farming has been reported to be more profitable on average than small-scale wheat production (Hassan *et al*, 1992).

Despite the high production costs of wheat farming on small-scale farms, quite a number of wheat producers were observed to be operating on such units (less than 5.0 ha) possibly because the government's pricing policy had made wheat crop more competitive over maize and other farm enterprises.

4.2 The Average Production Cost Model of Wheat Production

Multiple regression was used to analyze the effect of wheat enterprise size, degree of specialization in wheat production, level of managerial skills of the producer and the level of use of machinery owned by the producer on average production cost of wheat in Nakuru District. The wheat enterprise size (Z) was measured as volume of wheat output in tonnes. In the course of this study, seeded acreage as an alternative measure of size was examined and tested. However, the model using volume of output gave better results in terms of a higher $\bar{R}^2$ value and consistence in the signs of the coefficients with those in the economic theory. In addition, output as a measure came nearer to meeting the requirements of an ideal measure of the agricultural inputs applied to the crop. The quantity of inputs applied varied greatly among the wheat producers and this was reflected in the volume of output attained. Those who applied recommended amounts of inputs on average achieved higher output levels per unit area compared to those who applied lower input amounts. The results of the analysis are shown in Table 4.2.

The regression results in Table 4.2 indicate that wheat enterprise size significantly affected average production cost of wheat production. The enterprise size variable (1/Z) was statistically significant at one percent level and the sign of its coefficient was positive.

Table 4.2: Estimated Parameters for the Average Production Cost Model per Unit of Output

Dependent Variable = AC	in '000 ' Kshs
Regressors	Regression coefficient
1. Constat	9.278 (17.575)***
2. 1/Z	6.098 (24.145)***
3. DP	1.118 (6.216)***
4. CEI	-3.863 (-10.001)***
5. MU	-0.041 (-0.646)*
F	198.365
$\bar{R}^2$	0.929
N	69

The t - statistics are given in parentheses and the ones marked with asterisks are significant at the following levels:
* - significant at 10% significant level,
** - significant at 5% significant level,
and *** - significant at 1% significant level.

The abbreviations refer to the following:

Z = The size of wheat enterprise as value of wheat output in tonnes (t). The initial analysis indicated an inverse relationship between Z and AC. So Z was fitted in the AC model as 1/Z.

DP = The degree of specialization in wheat production (DP) measured as the percentage of total income from wheat as opposed to income from other farm enterprises.

CEI = Cost Effective Index defined as the predicted average cost per tonne of wheat output divided by the actual average cost per tonne of wheat output

MU = the level of use of machinery owned by the producer measured by the ratio of the total machinery expenses to the fixed expenses of the farm.

AC = Average cost of wheat production in "000" KShs.

These results demonstrate that, *ceteris paribus*, enterprise size is inversely related to the average production cost per tonne of wheat. This confirms the belief that wheat is a decreasing cost industry with size of enterprise. One possible reason for this state of the industry accrues from the technology package used in wheat production. Wheat in Kenya is largely produced under a highly mechanized mode of production. Wheat production requires heavy machinery and equipment use (tractors, ploughs, planters, boom sprayers and combine harvesters) for cultivation, planting, weed, pest and disease control, and harvesting. The reduction in costs as size increase could possibly be attributed to the better utilization of these fixed factors.

A priori, as size increase, fixed costs are evenly spread out to the output resulting in reduction of unit costs. In addition, increase in size makes labour specialization possible. This results in acquisition of skills and permits employment of people of special aptitudes and abilities. Most of the large-scale wheat producers had a trained farm manager with skilled manpower such as a marketing specialist, an accountant, or a crops officer who could be able to make appropriate farming decisions that can optimize production logistics resulting in minimized production costs.

The degree of specialization in wheat production (DP) significantly and positively influenced the average cost per tonne of wheat. The variable was statistically significant at one percent level. The results indicate a positive relation between average cost per tonne of wheat and degree of specialization in wheat production. This means that the higher the level of specialization in wheat farming, the higher the average production cost, all other things being equal. In other words, diversification on wheat farms leads to production of wheat at a lower cost. This could be due to complementary and supplementary relationships between wheat and other farm enterprises. An increase in these enterprises on wheat farms results in an increase in wheat output and reduction in cost of production due to production of some wheat inputs and diversion of surplus resources from wheat to them.

The cost effective index (CEI) variable was significant at one percent level and the sign of its coefficient was negative. These results indicate a negative relationship of managerial skills of the entrepreneur with the average cost of production. This means that the better manager would have lower production costs for a given volume of wheat output, all other things being equal.

The level of machinery use (MU) was significant at ten percent level and the sign of the coefficient was negative. This indicates an inverse relationship between own machinery usage and the average cost of production. Farmers using their machinery for wheat farm operations operate at a lower cost compared to those using rented services. In addition, those who depend on hired machinery services face the problem of acquiring machinery to carry out farm operations on time. Timeliness of farm operations which is directly associated with ownership of machinery complements the usage of inputs thus saving costs.

In conclusion, the variation of the average cost of production (AC) of wheat is largely explained by enterprise size (Z), degree of specialization in wheat production (DP), managerial skills of the entrepreneur (CEI) and to a smaller extent, the usage of own machinery (MU).

4.3 The Estimated Short-run Cost Model of Wheat Production

The short-run period is defined as period during which economic factors have limited flexibility in their actions (Nicholson, 1989). In the short-run, the use of variable inputs like seed and agro-chemicals are altered while scale of operation and art of technology remain constant. To meet these conditions, costs of farms with scale of operation limited to 2.30 ha or less were adopted for estimating short-run cost function. These farm sizes were used because they formed the largest proportion (about 50 percent) of the sample.

The method of ordinary least squares, employing the quadratic formula:

$$TC=\alpha+\beta_1 Q+\beta_2 Q^2$$

and hyperbolic formula;

$$AC=\alpha+\frac{\beta}{Q}$$

where

TC = total cost;

AC = average cost in thousand shillings; and

Q = wheat output in tonnes

were used to compute the short-run cost curves. The quadratic and hyperbolic functional forms were used because they gave the best fit and higher $\bar{R}^2$ values, consistent signs of the coefficients with those in the economic theory and significant independent variables as indicated by the "t" test (Figures 4.1 and 4.2; and Table 4.3)

Figures 4.1 and 4.2 present the fitted relationship for total cost (TC) and average cost (AC), respectively. Each point presents the costs for each farm sampled. The quadratic and the hyperbolic forms fitted the observed values of costs and output indicating a quadratic short-run total cost function with a concave curve and a hyperbolic average cost function with a convex (rectangular hyperbolic) curve. The graph demonstrates that the shape of TC curve is determined solely by the shape of the short run variable costs. The short-run fixed costs give the intercept of the curve.

The results of regression analysis indicated in Table 4.3 show that $\bar{R}^2$ value for total cost and average cost were 0.97 and 0.81 respectively. The $\bar{R}^2$ value for total cost indicated that over 90 percent of the variability in costs was explained by the variability of the volume of wheat output. However, the high $\bar{R}^2$ value could have also been due to moderate correlation (0.56) between Q and Q^2 due to relatively short ranges of the Q (output) and TC (total cost) values. For average cost, the $\bar{R}^2$ value indicates that over 80 percent of the variability in costs was explained by the variability in the volume of wheat output.

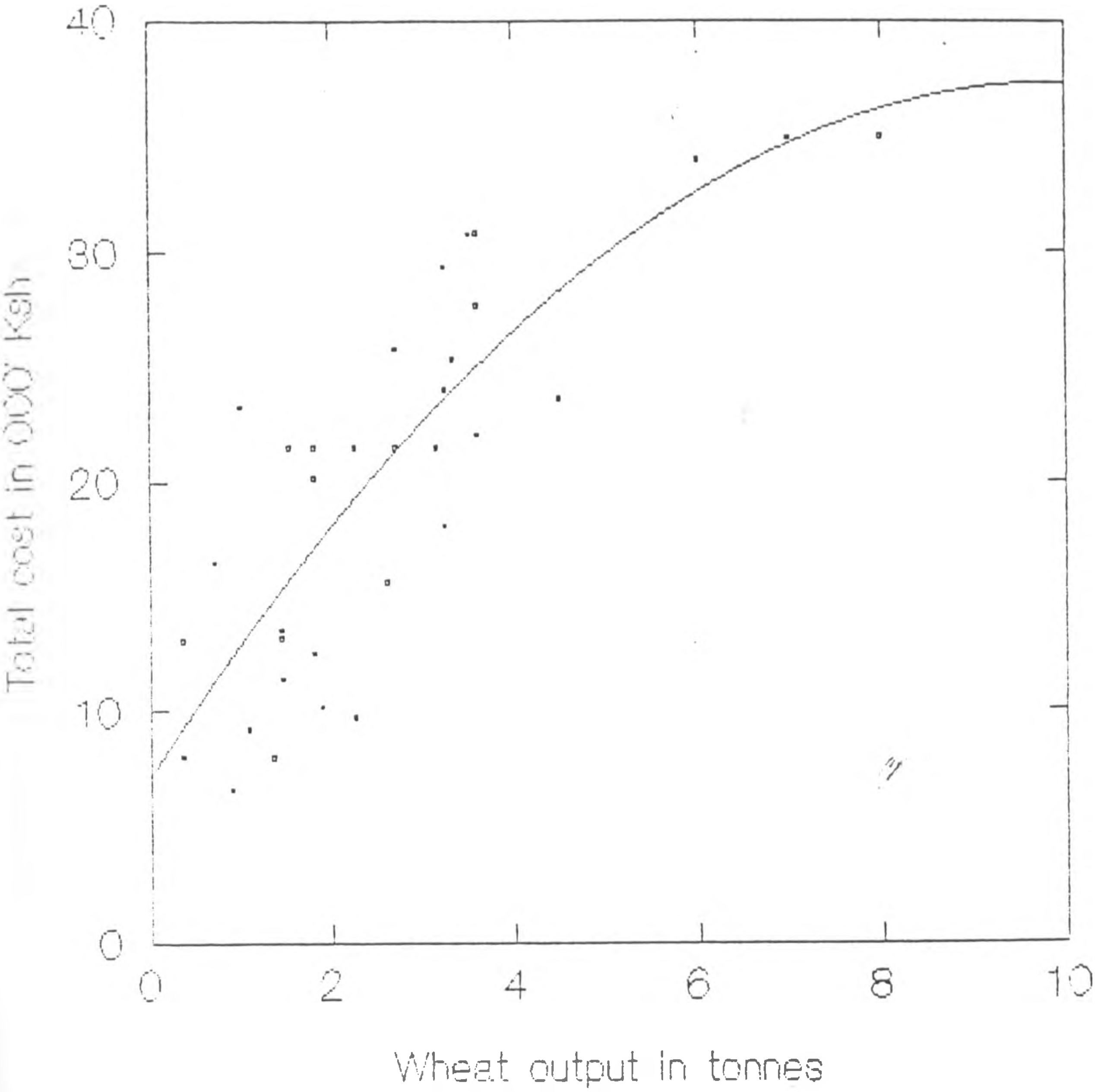


Fig 4.1: Fitted quadratic relationship of short-run total cost and wheat output

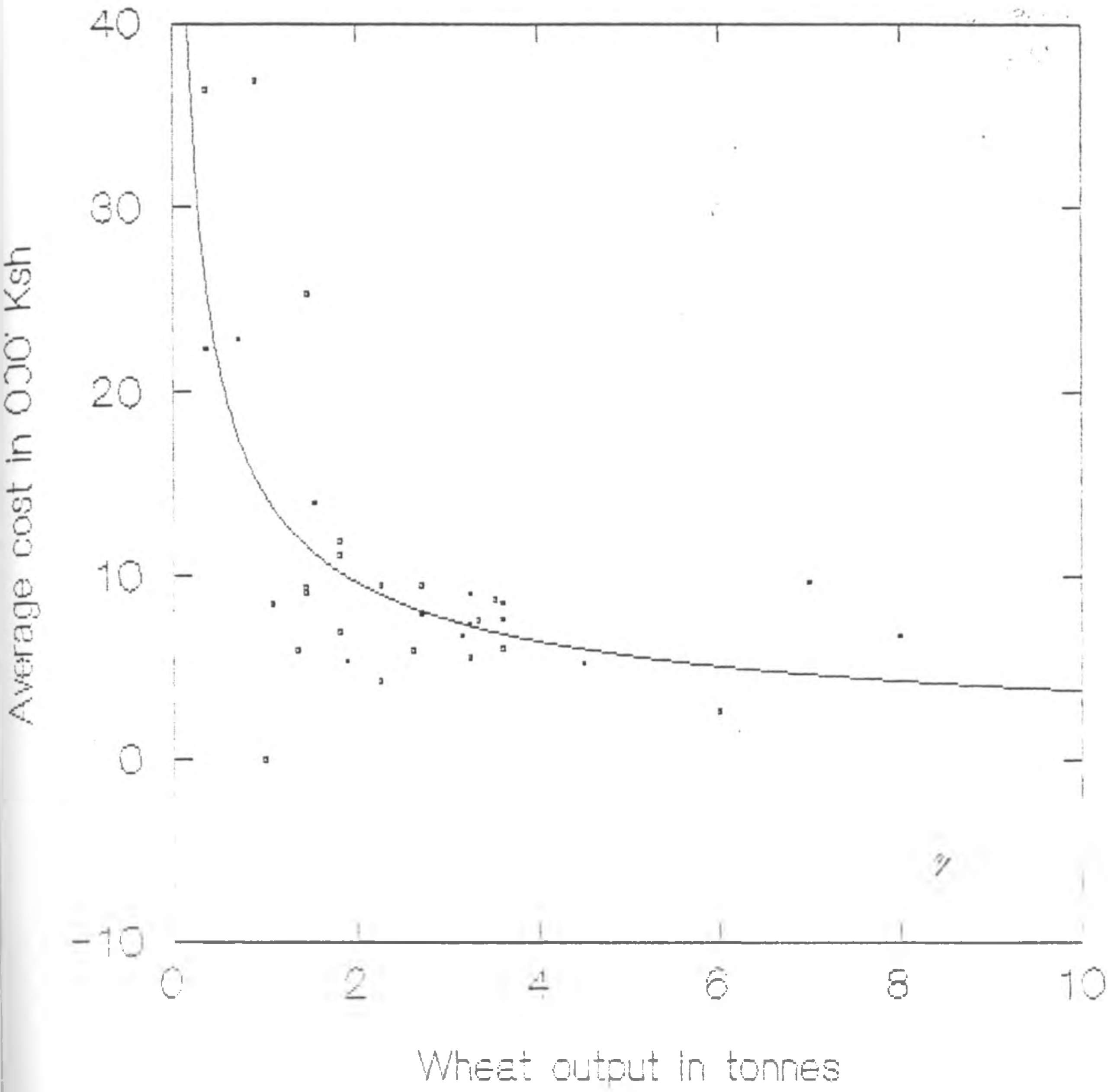


Fig 4.2: Fitted hyperbolic relationship of short-run average cost and wheat output

4.3: Estimated Parameters for the Total and Average Cost Functions

Independent Variables	Dependent Variables	
	Total Cost (TC)	Average Cost (AC)
Constant	16.16 (11.5)***	5.66 (7.11)***
Output (Q)	1.09 (4.29)***	
Q^2	0.036 (21.82)***	
I/Q		6.87 (11.56)***
$\bar{R}^2$	0.97	0.81
N	34	34

The t-statistics are given in parentheses and the ones marked with asterisks are significant at the following levels:

* - significant at 10% significant level
** - significant at 5% significant level
and *** - significant at 1% significant level.

The output variables were significant at one present level in both cases, and the signs of the estimated coefficients were positive. This indicates, a positive relationship between total cost and volume of output and, an inverse relationship between average cost and volume of wheat output. These findings are in line with economic theory where the total cost function is mostly parabolic of either one degree (quadratic) or second degree (cubic) and the average cost function that is either quadratic or hyperbolic (Koutsoyianis, 1988).

4.4 Volume of wheat output and main cost components

Using the Ordinary Least Squares (OLS) estimation method, the hyperbolic functional relationship was fitted onto the data to analyze how the main components of costs are related to variations in wheat output. The main cost components were working capital, labour and machinery operation expenses. Working capital was computed as the sum of the variable capital input costs per tonne of wheat produced. The variable capital inputs included the seed, fertilizers and pesticides. Machinery operations involved the cost of land preparation, planting, spraying, harvesting and depreciation cost of machinery per tonne of wheat produced.

Results of the regression analysis in Table 4.4 indicate important cost components in wheat production to be machinery operations, labour and the purchase of variable capital inputs e.g seeds and agrochemicals.

The machinery operations involved the use of medium to large tractors (75-125 horse power range) and compatible cultivation, planting and spraying equipment and combine harvesters. All the sampled farmers indicated one ploughing (two on virgin lands) by one-way disc ploughs followed by one or two disc harrowing before planting wheat with a seed drill. All medium to large-scale farmers used tractor-pulled boom sprays to control weeds, diseases and pests. About 90 percent of small-scale wheat farmers used the same method while, the rest used hand operated knapsack sprayers. In the case of harvesting, all large-scale and over 90 percent small-scalefarmers used self-propelled combine harvesters while, the rest

Table 4.4: Estimated Parameters for the short-run cost components

Independent Variables	Dependent Variables		
	Mechanical Operations	Labour Cost	Variable Capital Inputs
Constant	1.6149 (5.27)***	1.759 (4.05)***	3.467 (6.41)***
Output	1.6645 (7.38)***	1.942 (5.98)***	3.416 (8.46)***
$\bar{R}^2$	0.63	0.52	0.69
N	34	34	34

The t-statistics are given in parentheses and the ones marked with asterisks are significant at the following significant levels:

*** - significant at 1% significant level,
** - significant at 5% significant level,
and * - significant at 10% significant level

harvested the crop by hand. The output variable was statistically significant at one percent level when regressed with cost of machinery operations. These results indicate that cost of machinery operations is a very important cost component in wheat production.

The output variable was statistically significant at one percent level with labour cost item. The sign of the coefficient was positive. These results indicate that labour is one of the most important cost item in wheat production and decrease with increasing volumes of output. Labour costs involved the family labour (case where family members were involved in production of wheat) and hired labour costs.

Variable capital inputs involved seed and agrochemicals. The output variable was statistically significant at 1% level with variable capital. Procurement costs of these inputs varied depending on source.

Regression analysis of individual machinery operation items with output gave various levels of significance (Table 4.5). The

Table 4.5: Regression results of machinery operation cost items with output

Independent Variables	Dependent Variables			
	Land preparation Cost	**Planting Cost**	**Spraying Cost**	**Harvesting Cost**
Constant	0.842 (4.20)***	0.291 (4.24)***	0.231 (7.51)***	0.830 (1.61)***
Output	0.750 (5.08)***	0.233 (0.462)**	-0.006 (-0.96)	0.241 (9.88)***
$\bar{R}^2$	0.74	0.42	0.04	0.86
N	34	34	34	34

The t-statistics are given in the parentheses and the ones marked with asterisks are significant at the following significant levels:-

*** - significant at 1% significant level
** - significant at 5% significant level
and * - significant at 10% significant level

output variable was significant at one percent when regressed with land preparation, planting and harvesting cost items. However, the significance level was over 10% (significant at 50%) when output was regressed with spraying cost item. This indicates that land preparation, planting and harvesting are the most important machinery operation cost items on wheat farms. Regression analysis of output variable with individual variable capital input costs (costs of seed, fertilizers and pesticide) gave different levels of significance of output variable (Table 4.6). The output variable was statistically significant at one percent level with seed cost.

Table 4.6: Regression results of variable capital cost items with output

Independent variables	Dependent Variables		
	Seed Cost	Fertilizer Cost	Pesticide Cost
Constant	91.50 (0.73)	2.128 (1.63)*	0.485 (3.96)***
Output	1.401 (15.42)***	-0.930 (-0.70)	0.054 (0.43)
$\bar{R}^2$	0.89	0.02	0.03
N	34	34	34

The t statistics are given in the parentheses and the ones marked with asterisks are significant at the following significant levels:

*** - significant at 1% significant level,
** - significant at 5% significant level, and
* - significant at 10% significant level

However, the output valuable was not significant with fertilizer cost and pesticide cost. These results indicate seed cost as the main variable capital cost on wheat farms. The insignificance of fertilizer and pesticide costs could be attributed to their low level of usage especially by the small-scale producers.

4.5 Resource Use Relationships in Wheat Production and Other Farm Enterprises

Regression analysis was used to determine the relationship that exist between wheat enterprise and other farm enterprises in usage of farm resources. The results for this analysis are presented in Table 4.7. The table presents the estimated

Table 4.7: Estimated Parameters for the Effect of Degree of Specialization in wheat on cost of wheat production

Dependent Variable =	Average Cost
Regressors	Regression coefficient
Constant	6.66 (12.98)**
Livestock operation as opposed to wheat (LW)	-7.053 (-0.327)**
Other crops as opposed to wheat (OC)	0.010 (1.20)*
$\bar{R}^2$	0.53
N	69

The t-statistics are given in parentheses and the ones with asterisks as superscripts are significant at the following significant levels:

*** - significant at 1% significant level,
** - significant at 5% significant level,
and * - significant at 10% significant level.

parameters of increasing livestock and increasing crops variables with average cost (cost per tonne of wheat). The LW variable reflecting livestock (dairy) activities as opposed to wheat was statistically significant at 5 percent level and the sign was negative. This indicates an inverse relationship between livestock (dairy) activities on wheat farms and average cost of wheat production. This means that the greater the dairy activities on wheat farms, the lower the average cost of wheat production, all other things being equal. The OC variable reflecting other crop activities as opposed to wheat, was statistically significant at 10 percent level and the sign was positive. This indicates that increase in crop enterprises on wheat farms leads to increased average cost of wheat production and vice versa. This could be possibly be due to competition that exist between wheat and other crops in resource use. The low $\bar{R}^2$ value could be due to the reason that this is a cross-section analysis.

Regression results of linear average cost models of various cost components (machinery use cost, land, labour cost, and variable capital cost) indicated that the livestock (LW) variable was statistically significant at 5 percent level with variable capital inputs and factor labour and the sign of the coefficients in both cases was negative (Table 4.8). However, for factor land and machinery, the livestock variable was significant at 10 percent with a positive sign of the coefficients. These results indicate a direct relationship between livestock variable and machinery usage and the factor land and an inverse relationship between livestock and labour and variable capital inputs. Livestock activities especially dairy lead to reduced unit cost of resource usage especially factor labour and variable capital inputs. This might be because livestock (dairy) keeps these resources (labour

Table 4.8: Regression results of resource use costs in wheat production and other crop enterprises on a wheat farm

Independent variable	Machinery Cost	Land use Cost	Labour Cost	Variable capital cost
Constant	2.01 (12.76)***	0.807 (15.49)***	1.47 (5.147)***	1.82 (12.23)***
Dairy activities as opposed to wheat (LW)	2.91 (0.45)*	-4.510 (-2.06)**	2.65 (2.21)**	-8.87 (-1.42)**
Other crops as opposed to wheat (OC)	-3.874 (-0.33)**	2.546 (0.65)*	-4.21 (-0.20)*	0.020 (1.795)*
$\bar{R}^2$	0.47	0.55	0.62	0.47
N	69	69	69	69

The t-statistics are given in parentheses and the ones marked with asterisks as superscripts are significant at the following levels:

*** - significant at 1% significant level,
** - significant at 5% significant level,
and * - significant at 10% significant level.

and capital) employed much more and therefore leads to reduced production cost of wheat crop.

The estimated coefficient for the crops variable was significant at 5 percent level with machinery costs and the sign was negative. However, for land, labour and variable capital costs, the other crops variable coefficient was statistically significant at 10 percent level. The signs of the coefficients for land and variable inputs were positive and negative for labour.

These results indicate complementarity and competition relationships in resource use in wheat production with livestock (dairy) and other crops enterprises, respectively. In the case of complementarity, the wheat crop furnish the raw-materials (barn etc) which are used in milk production, and the livestock enterprise contributes farmyard manure to the crop, which help maintain yields. Some farmers especially the small-scale ones indicated using farmyard manure on their wheat fields.

The results indicate that livestock (dairy)- wheat systems operate at lower costs and are much more self-sustaining than the crops-wheat systems. Dairy farming returns more plant nutrients to the soil in the form of manure than does crops. Wheat in Kenya is commonly grown for three or more years in succession and then might be rotated with pasture or other crops to break the cycle of diseases and weeds and to improve soil structure (Longmire and Lugogo, 1989). About 7 percent of the small-scale farmers (average area under wheat of 2.3 ha) rotate wheat with grazing land while 6 percent of large-scale farmers (average area under wheat of 55.1 ha) have been estimated to do the same (Hassan et al, 1992). During the survey it was observed that smallholders grew maize and vegetable crops and maintained a small dairy herd. Dairying sometimes complements crops in resource use on these smallholdings. Labour required for dairying are evenly distributed throughout the year because farmers rotate land from crops to pastures and because dairy cattle can consume crop residues, roadside pasture and other readily available feed that might otherwise be underused.

4.6 The Estimated Long-run Cost Function and Economies of Size in Wheat Production

In deriving the long-run cost functions, all factors of production e.g scale of operation, labour, machinery etc were assumed to be variable. The OLS method was used to estimate long run quadratic total cost and long run hyperbolic average cost functions. The estimated coefficients of these functions are shown in Table 4.9. The fitted functional forms are also shown in figures 4.3 and 4.4.

Table 4.9: The Estimated Parameters of Long-run Cost Function

Independent Variables	**Dependent Variables**	
	Total cost	**Average Cost**
Constant	60.71 (1.36)*	5.23 (13.39)***
X_4	1.923 (6.74)***	
X_4^2	7.96 (-4.10)***	6.23 (13.11)***
H_4		0.72
$\bar{R}^2$	0.85	69
N	69	

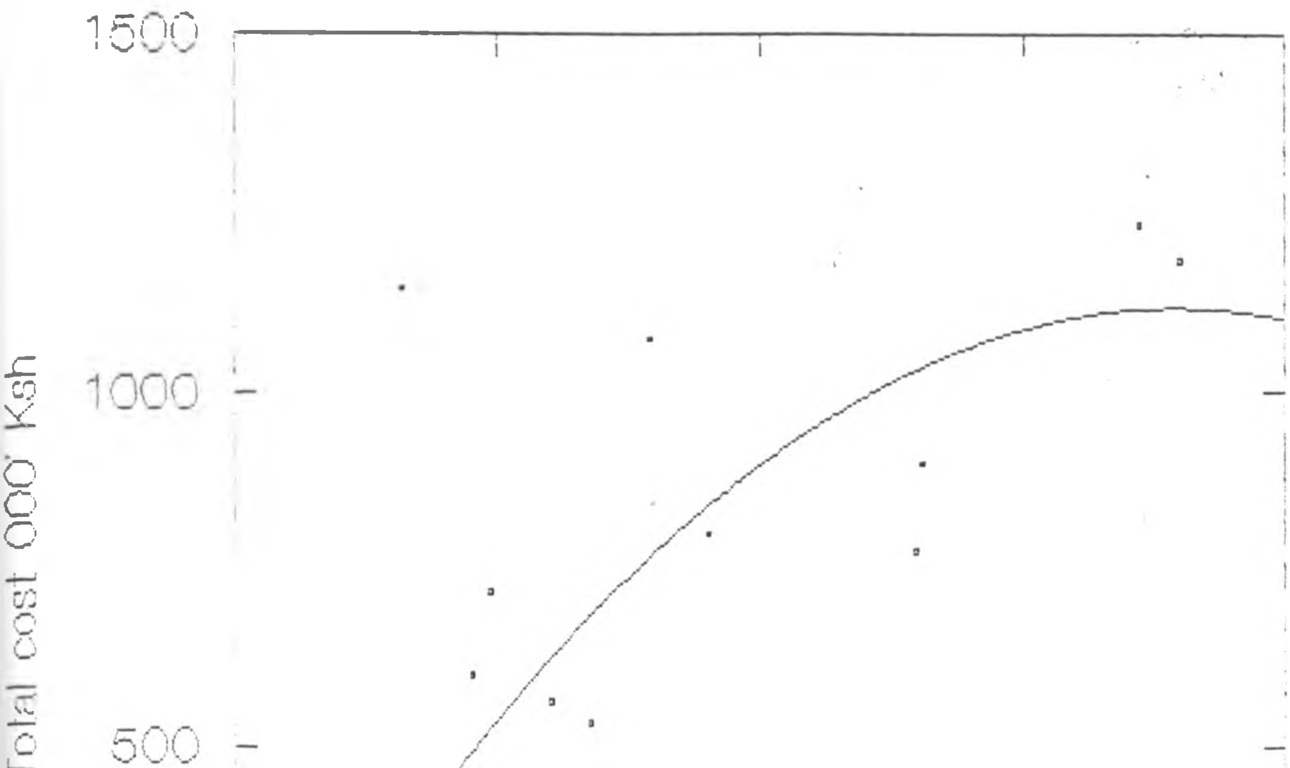
The t - statistics are given in parentheses and the ones marked with asterisks are significant at the following levels:-

xxx - significant at 1% significant level
xx - significant at 5% significant level and
x - significant at 10% significant level

The variables in the table are abbreviated as below:

X_4 = total wheat output in tonnes.

and H_4 = the inverse of wheat output


1500
1000
500
Total cost 000' Ksh

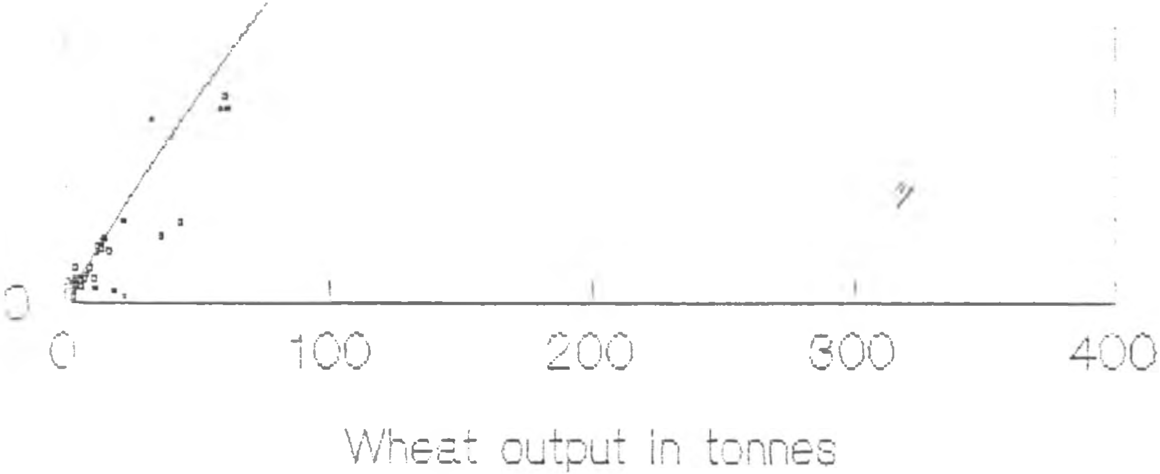
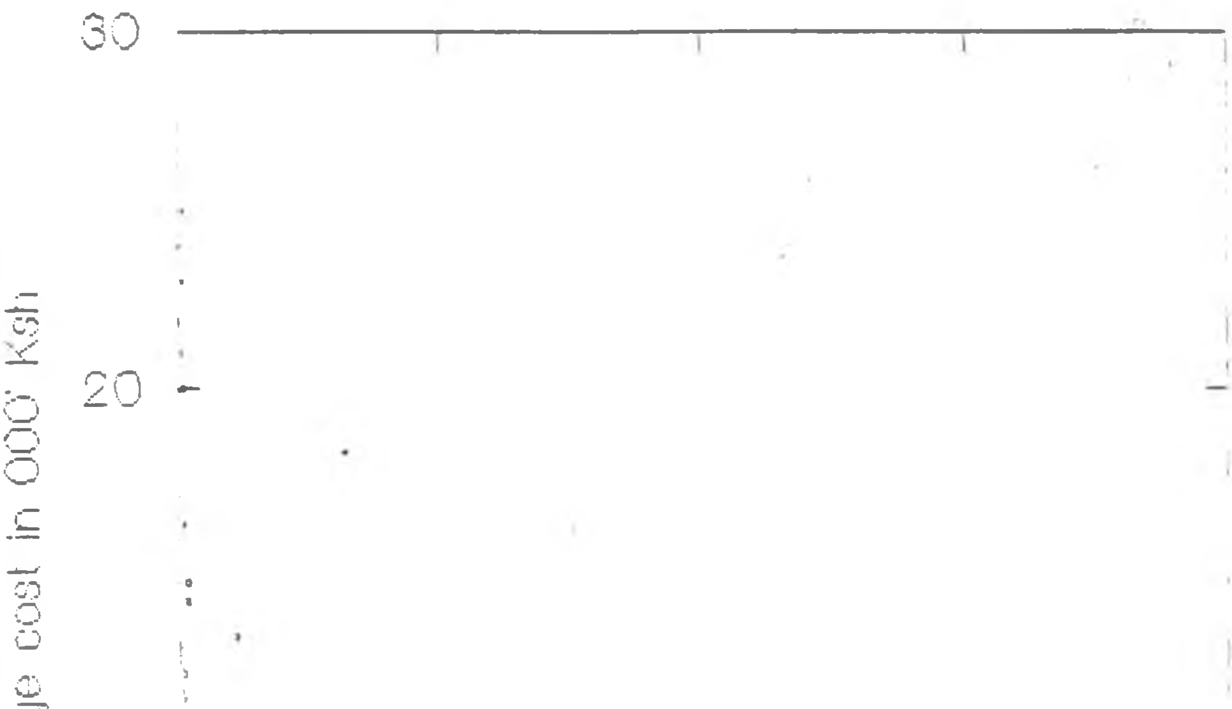


Fig 4.3: Fitted quadratic relationship of long-run total cost and wheat output as size of wheat enterprise


30
20
ge cost in 000' Ksh

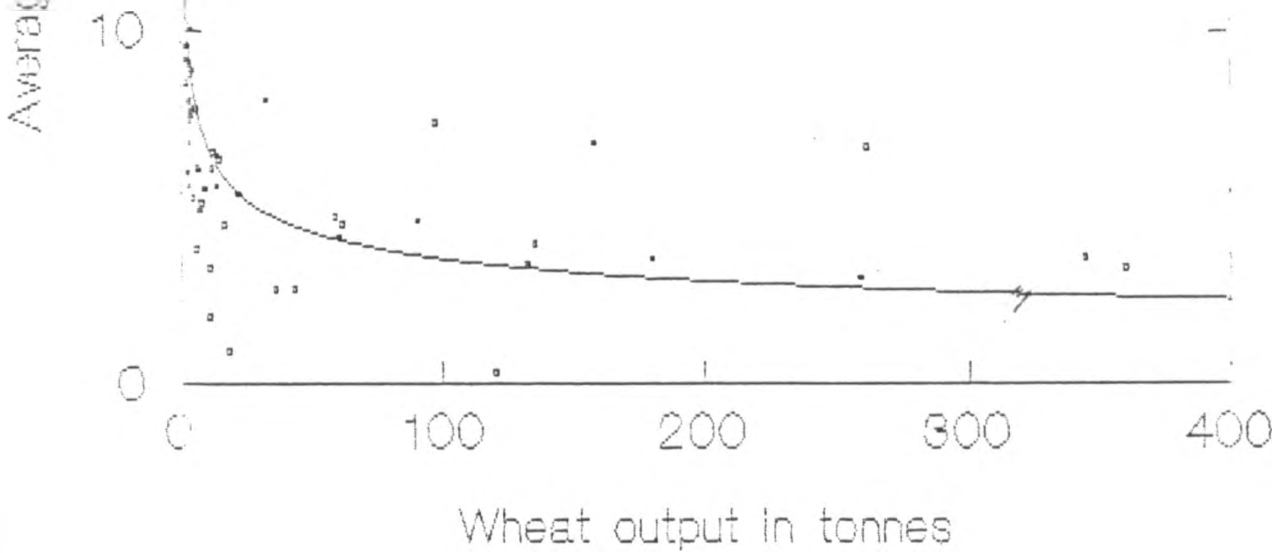


Fig 4.3: Fitted hyperbolic relationship of long-run average cost and wheat output as size of wheat enterprise

The $\bar{R}^2$ value for the estimated total cost function was 0.85 indicating that over 80 percent of the variability in costs was explained by the variability of volume of wheat output. All coefficients were statistically significant at the one percent level and the signs were positive. The relationship therefore between total cost and output is quadratic.

For average cost (AC) the $\bar{R}^2$ value was 0.72 and the coefficients were significant at the one percent level. The sign of the coefficient was positive indicating an inverse relationship between average cost and size of wheat enterprise. The fact that size variable, measured by volume of wheat output in tonnes explained the variation in the average cost significantly giving an inverse relationship of average cost with wheat enterprise size indicates that economies of size exist for wheat farms in Nakuru District. Since the available sample data does not extend to very large farms (equivalent to 18,000 tonnes or over) no observations of either continued decreasing or increasing average production costs are available to support or reject the usual theoretical concept of increasing costs (i.e diseconomies of size) for these farms. Neither can conclusive inferences about optimum farm size be made. Given the data obtained, all that can be said is that production costs decline rapidly with initial increases in size and then decline slowly as size continues to increase. Average cost per tonne of wheat declined throughout the farm sizes from Kshs 22,905.60 per tonne for the farm with 0.4 ha seeded with wheat reaching a level of Kshs 297.0 per tonne for the farm with 700 ha seeded with wheat.

Regression analysis was applied on costs of factors of wheat production to identify sources of economies of size in the wheat production sector. These costs were land cost for land use, machinery cost for the use of machinery, labour cost for the use of labour and management and variable capital cost for the use of variable capital inputs like fertilisers. The results of the regression analysis using a hyperbolic functional relationship are indicated in Table 4.10 below.

Table 4.10: Estimated Parameters for the effect of the wheat enterprise size on the costs of factors of wheat production.

Independent Variables	Dependent Variables			
	Land rents	**Machinery**	**Labour cost**	**Variable capital input cost**
Constant	0.480 (9.94)***	1.426 (9.95)***	0.833 (2.934)***	0.828 (0.69)
Size of wheat enterprise (Z)	1.13 (9.53)***	2.165 (7.73)***	2.998 (5.40)***	2.110 (3.44)**
R^2	0.79	0.72	0.59	0.20
$\bar{R}^2$	0.62	0.51	0.35	0.10
N	69	69	69	69

The t-statistics are given in parentheses and the ones with asterisks as superscripts are significant at the following significant levels:

*** - significant at 1% significant level,
** - significant at 5% significant level,
and * - significant at 10% significant level.

From table 4.10, the wheat enterprise size variable was significant at one percent with the average costs of labour usage, land use and machinery. However the size variable was significant at 5 percent level with the average cost for variable capital inputs like fertilizers. The signs of the coefficients in all cases were positive indicating an inverse relationship between enterprise size and the cost of each of the above factors used in producing a tonne of wheat. Economies in the use of labour and management arise from specialization involving the use of people with skills, aptitude and abilities such as a crops officer, or a marketing specialist.

Large-scale production allows division of labour and specialization of labour force with the result of an improvement of the skills and hence the increased productivity of various types of labour. It was observed that the proportion of workers who could be described as specialized was much higher on large farms. Most of the large-scale farms had employed people with specialized skills such as a crops officer or a marketing specialist. However, the proportion of employed specialist workers on small-scale farms was small. This is because on such small-scale farms, the farmer and members of his/her family constitute a significant proportion of the total management and labour force on the farm.

Economies associated with machinery operations arise mainly from specialization and indivisibilities of the machine, set-up costs, initial fixed costs and technical volume/input relations. It was observed during the survey that production methods become more mechanized (capital intensive) as the size of enterprise increases.

More specialized capital equipment as well as more investment was evident on large scale farms, a factor that makes the large-scale methods of production have high overhead costs.

The survey indicated that costs of operating machinery were generally higher on a per-tonne basis on smaller fields than on larger ones. These higher costs on smaller fields resulted possibly from the increasing amount of time lost, as average field size declines, through headland overlap, turning, moving from field to field, and "setting up" the machinery in each field before starting the job (Longmire and Lugogo, 1989).

Economies of size in land use might arise if an increase in enterprise size require a less- than- proportional increase in land rental rates per tonne of wheat. The survey indicated that land rental rates were uniform throughout all categories of farm sizes thus implying that the observed economies of size in land use could have principally been due to an increase in output per unit area as size of farm increase. Yields on large scale farms were higher than those on small scale farms (Table 4.1).

The economies associated with variable capital inputs arise from marketing through lower purchase costs and or operating costs per unit of capacity. It was observed that large-scale farms purchased their variable capital inputs like fertilisers in large quantities mainly from dealers where they were offered discounts. The small-scale farms on the other hand purchased their inputs mainly from retailers in small quantities where discounts were rare.

4.7 Hypothesis Testing

4.7.1 Rate of wheat output and cost

The null hypothesis, that rate of wheat output has no significant effect on cost (B=0) was tested against the alternative hypothesis, that rate of wheat output does affect cost (B#0) by regressing total cost against rate of wheat output.

The calculated t-ratio for the estimated coefficient exceeded the critical value at 5% level of significance, thus null hypothesis B=0 was rejected in favour of the alternative hypothesis B#0 that the rate of wheat output does affect cost. The sign of the coefficient B was positive indicating a direct relation with total cost. It is therefore concluded that the rate of wheat output has a significant effect on the costs of wheat production.

4.7.2 Economies of size

The null hypothesis that size of wheat enterprise does not significantly affect average cost i.e. there are no economies of size (B=0) was tested against the alternative hypothesis that size of wheat enterprise has a significant effect on average cost i.e. economies of size exist (B#0) by regressing average cost against size of wheat enterprise.

The calculated t-ratio for the estimated coefficient exceeded the critical value at 5% level of significance. Thus the null hypothesis B=0 was rejected in favour of the alternative hypothesis B#0 that size of wheat enterprise has a significant effect on average cost. This confirms the assertion that economies of size exist in wheat production industry in Kenya.

4.7.3 Cost and degree of wheat specialization

The null hypothesis that the degree of specialization in wheat does not significantly affect average cost (B=0) was tested against the alternative hypothesis that degree of specialization in wheat does affect average cost (B#0) by regressing the average cost against the ratio of the wheat income as opposed to incomes from other incomes.

The calculated t-ratio for the estimated coefficient exceeded the critical value at 5% level of significance. Thus the null hypothesis B=0 was rejected in favour of the alternative hypothesis B#0 that degree of specialization in wheat does affect the average cost. Since the sign of the coefficient was positive, it indicates a significant direct relation with average cost, all other things being equal. This demonstrates that diversification on wheat farms leads to reduction in unit costs of wheat production possibly due to complementary and supplementary relationships that exist between wheat and other farm enterprises.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary of Results and Conclusions

During the last two to three decades, the Kenyan wheat industry has witnessed a sluggish growth in annual output characterized by erratic trends over the years. This has been attributed to escalating input costs and land subdivision leading to reductions in quantity of resources allocated to wheat crop. The costs particularly those of agro-chemicals and machinery usage, increased considerably following the liberalization of the prices of inputs and the devaluation of the Kenyan shilling. The broad objective of this study was therefore to examine the cost structure of wheat production industry in Kenya with special reference to Nakuru District. The method of Ordinary Least Squares (OLS) was used to compute the cost structure of wheat production. Multiple regression analysis was applied to the data to determine the factors that affect cost behaviour. The quadratic and hyperbolic functional forms were used to estimate the short-run and long-run cost curves. In all cases, the coefficients of determination or $\bar{R}^2$, the t-ratios and the coefficients of wheat output, specialization, managerial skills, use of own machinery and wheat enterprise size were calculated. The data on the wheat production costs was obtained from a farm survey of wheat producers in Nakuru District using multi-stage stratified random sampling procedure. The data included farm investments, volume of wheat output and costs, as well as other farm enterprises and their incomes. A sample of 80 wheat farmers were interviewed of which 69 gave adequate information which was used for analysis for this study.

The results of this study indicate that cost of wheat production is influenced by many factors. Cost of wheat production was observed to depend on the size of wheat enterprise, level of managerial skills of the entrepreneurs, other farm enterprises and level of usage of own machinery. Average cost per tonne of wheat declined significantly with the rising size of wheat enterprise. Small-scale wheat farms incurred higher wheat production costs than large-scale wheat farms. A small-scale farm with 1.6 ha seeded under wheat incurred a total cost of KShs 12 660.40 (and variable cost of KShs 5 045.20) while a large-scale farm with 700 ha seeded under wheat incurred a total cost of KShs 416.60 (with variable cost of KShs 204.60) to produce a tonne of wheat.

The disparities in the costs of wheat production on small-scale and large-scale wheat farms were largely due to poor standards of wheat husbandry on small-scale wheat farms and existence of economies of size in the wheat production industry. The poor standards of wheat husbandry practices were positively associated with poor levels of managerial skills of the small-scale producers and poor access to machinery. This was demonstrated by the fact that average cost decreased significantly with rising level of managerial skills of the entrepreneur and usage of own machinery.

Large-scale wheat farms were found to be able to exploit economies of size that exist in the wheat production industry. The wheat industry achieved both pecuniary economies and real economies. Pecuniary economies were demonstrated by paying lower prices for the factors used in wheat production due to bulk-buying by the farmers as the size of wheat enterprise increased. More important, however, were the real economies realised from the spreading out of the cost of fixed factors (permanent labour, fixed capital and land) as size of wheat enterprise increased.

The wheat enterprise exhibited strong relationships with other farm enterprises in the usage of farm resources. Wheat and dairy (livestock) enterprises exhibited complementary and supplementary relationships. This was demonstrated by the relationship that under increasing level of dairy activities on a farm, the cost of usage of resources by wheat is reduced. The benefits to wheat enterprise may have been the farmyard manure furnished and good rotation programme that ensured good level of plant nutrients. On the other hand, competition was exhibited between wheat and other crop enterprises. This was demonstrated by the relationship that under increasing level of other crops on a farm, the cost of wheat production increased.

5.2 Implications and Recommendations

This section highlights the policy implications and recommendations that are relevant to decisions in resource and enterprise mix to achieve production efficiency on wheat farms.

The high production costs incurred by small-scale wheat producers demonstrates great inefficiency of wheat production under small-scale conditions in Kenya. This is due to use of low yielding wheat variety seeds (use previous seasons produce) and poor standards of wheat husbandry practices. For wheat production to continue on small-scale conditions, there is need to develop and support measures that can reduce the production costs. These measures include: first to keep prices of inputs low, cooperatives, farmers' companies and farmers' groups should be strengthened and encouraged to buy agricultural inputs for their members in bulk. Such groups should be furnished with the information such as sources and prices of given agricultural inputs. There is also need to improve supply and access of credit to small-scale wheat farmers through appropriate policy reforms and institutional arrangements for credit.

Second, the fact that costs of land preparation and harvesting are the significant cost components on a wheat farm indicates the need of designing appropriate technology suited for small-scale conditions to ensure timeliness of such operations. Farmers' cooperatives, farmers companies and farmers' groups should also be encouraged to purchase machinery for their members use. In the view of escalating fuel prices, the use of animal draught should be promoted among the small-scale wheat farmers.

Third, the existence of complementary and supplementary relationships between wheat and dairy enterprises indicates that there is some scope for reducing wheat production costs through diversification with enterprise mix of wheat and dairy enterprise.

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Appendices

APPENDIX B

Calculation of time required to perform various farm operations on farms of various sizes

Time required to perform various farm operations was drawn from Longmire and Lugogo (1989) and information in farm management bulletins in Kenya. Further to this, farmers and extension officers provided more information required to do particular tasks with wheat in Nakuru district. Longmire and Lugogo (1989) calculated the time required to complete one hectare for particular operations and the amount of machinery time lost per day for different average field sizes using spreadsheet analysis and assumptions obtained from machinery contractors. The calculations were made using average working speed, average working width, average road speed, average time to set up in each new field, average time per day for servicing machinery and average daily work hours. The results are shown in Table B.1.

Table B.1. Estimated time required to complete one hectare for different machinery operations by average field size

	Average field size (ha)					
	0.4	1	4	10	40	400
	(h/ha)	(h/ha)	(h/ha)	(h/ha)	(h/ha)	(h/ha)
75 HP tractor with						
3-disc plough	3.2	2.8	2.6	2.5	2.5	2.5
2-way disc harrows	1.6	1.2	0.9	0.9	0.8	0.8
seed drill	1.5	1.0	0.7	0.7	0.6	0.6
boom spray	1.2	0.7	0.4	0.3	0.3	0.2
Combine harvester	1.3	0.9	0.6	0.6	0.5	0.5
Knapsack spraying	3.7	3.2	2.8	2.7	2.6	2.6

APPENDIX C

Calculation of costs of machinery costs

The six cost components for machinery were singled out: depreciation, capital (financing and investment), fuel and oils, repairs and maintenance, operator labour, contractors overheads and housing and insurance. The main methods for costing were follows:

Depreciation

Costed using a straight-line rate of depreciation. The hourly depreciation is calculated by taking the difference between the new purchasing price and the second-hand value (assumed to be 33 percent of new value), and dividing this by the total working hours of the machine (hours per year multiplied by number of years work).

Capital

Calculated by taking an average of the new purchase price and the second-hand value, multiplying this by the commercial interest rate (less the rate of inflation) and dividing by total hours worked per year by the machine.

Fuels and oils

Calculated by using the assumption of a fuel consumption rate of 125 g/h/HP, where 1 kg diesel = 1.18 L (Ministry of Agriculture and Livestock Development 1986). Oil, grease, and other lubricants were costed as an extra 5 percent of total diesel fuel cost.

Repairs and maintenance

Calculated by using the ratio of expected repairs and maintenance costs to new price, as documented in the Ministry of Agriculture (1986). These ratios included a 40 percent loading for tax, most of which is for import duty (Kenya, 1985). These ratios are probably considerably inflated by the long lead time farm machinery dealers have in importing spare parts and by the limited competition in supplying spare parts. Dealers informed us that they had to order spare parts form overseas and obtain foreign currency allocation well ahead of receiving the parts. For example, the equivalent ratios for Mexico were estimated to be between 80-90 percent of new value, compared with 170-440 percent in Kenya.

Operator wages

Estimated at the wage levels contractors pay skilled operators. The relative operator wage factor is taken as the ratio of machinery operator hourly wage to the hourly wage for rural workers.

Contractors' overheads

Estimated at 10 percent of total machinery costs per hour. An additional loading on costs at 1 percent of new value is for housing and insurance (Ministry of Agriculture and Livestock Development, 1986).